A REPORT ON RESEARCH INTO THE INTEGRATION OF SAFETY PLANNING AND THE COMMUNICATION OF RISK INFORMATION WITHIN EXISTING CONSTRUCTION PROJECT STRUCTURES

Cameron, Iain Department of Building & Surveying, Glasgow Caledonian University, U.K.
Duff, Roy Department of Building and Civil Engineering,University of Manchester Institute of Science and Technology (UMIST), U.K.

Introduction – Health & Safety Management in Construction

The performance standards traditionally associated with the delivery of construction projects are time, cost and quality. However, in recent think-tanks such as The Construction Task Force (www.construction.detr.gov.uk/cis/rethink/index.htm), The Construction Best Practice Programme (www.cbpp.org.uk), The Key Performance Indicators Zone (www.kpizone.com), and The Movement for Innovation (www.m4i.org.uk) have set additional targets, challenging construction to plan more thoroughly and improve performance in many areas, including a greatly increased attention to health and safety.

Today's thinking seriously challenges the old model of time/cost/quality trade-off, which suggested that an improvement in one must lead to deterioration in at least one of the others. It now extends the total quality management philosophy that 'quality is free' and embraces the premise that delivery in one area, safety, can actually lead to benefits in other areas, time and cost. The importance of effective construction planning and control in the communication and avoidance of health and safety risks cannot be overstated but the fundamental premise which underlies this research, is that this need not and should not be a separate exercise aimed solely at health and safety. Effective management will embrace all production objectives, as an integrated process, and deliver construction, which satisfies all these objectives, not one at the expense of the others.

Health and Safety Targets

The UK Government has recently set ambitious targets to reduce workplace accidents and ill health across all industries in *"Re-vitalising Health and Safety"*. However, construction's safety performance is worse than most industries, currently deteriorating and a major component of society's accident and ill health experience. Because of this the Health & Safety Commission and the Deputy Prime Minister hosted a Construction Summit entitled *"Turning Concern into Action"* on 27 February 2001. The summit communicated key 'Action Plans' to improve performance and meet new ambitious targets, set by CONIAC (Construction Industry Advisory Committee in the UK), for the construction industry. The Deputy Prime Minister has made it clear that he wants decisive action. This proposed research will, inter alia, develop key performance indicators which will assist HSE and industry to *"Work Well Together"* to realise some of these improvements. The targets currently being pursued can be summarised below.

"Re-vitalising Health and Safety" targets to be reached by the year 2010 for all industries include:
1- To reduce work days lost (per 100 000) by 30% due to accidents
2- To reduce the incidence rate of fatal and major injury accidents by 10%
3- To reduce cases of ill health by 20%

"Turning Concern into Action" targets to be achieved by 2005 and 2010 by construction industries are:
1-To reduce the incidence rate of fatalities and major injuries by 40% (2005) and 66% (2010)
2-To reduce the incidence rate of cases of work-related ill-health by 20% (2005) and 50% (2010)
3-To reduce the number of working days lost per 100,000 workers from work-related injury and ill-health by 20% (2005) and by 50% by (2010).

Communication and Information Flow

Effective health and safety planning to improve risk information, communication and control are fundamental parts of the UK's Health and Safety Executive (HSE) current construction focus – *"Working Well Together"* (wwt.uk.com). The flow of appropriate risk management information is also fundamental to much of UK health and safety legislation:

The Health and Safety at Work Act 1974
The Management of Health and Safety at Work Regulations 1999
The Construction (Design and Management) Regulations 1994
The Construction (Health, Safety, Welfare) Regulations 1996
The Health and Safety (Consultation with Employees) Regulations 1996

However, the Construction (Design and Management) ACoP Consultative Document acknowledges that CDM compliance documents, written specifically for the purpose, are sometimes cumbersome and add little value to management processes generally. Because of this, the ACoP document indicates that stakeholders should treat CDM information provisions as part of the construction planning process. The ethos is: *"minimise bureaucracy and maximise performance"*.

To comply with all this legislation, and to establish effective health and safety planning and control, a large number of management procedures are required. The authors believe that health & safety is best managed within a contracting organisation's **existing** production management structure and procedures, as any attempt to overlay a safety specific structure is likely to meet resistance and organisational constraints.

Industrial Problem to be Investigated by the Research

Effective planning for health and safety is essential if projects are to be delivered on time, without cost overrun, and without accidents or damaging the health of site personnel. These are not easy objectives as construction sites are busy places where time pressures are always present and the work environment constantly changing.

The construction industry tends to be under resourced and under planned in relation to other industries and this promotes a crisis management approach to all kinds of production risk, a feature of construction culture which can impact on health and safety management. However, the industry frequently demonstrates that it can plan proactively, to manage production risk, if it is required to do so. Consider highly planned works, such as those requiring a temporary rail possession, which almost invariably run smoothly. This type of work is managed in a highly focused way and planned in great detail. This contrasts with routine work where recent collaborative EPSRC(IMI) research by Dundee University and UMIST (Dr Duff) has demonstrated that productivity increases of at least 20% are readily available from a combination of more rigorous short-term planning, clear communication of goals, performance measurement and a participative approach to obtaining commitment at all levels. This approach is clearly cost-effective. There is no reason why health and safety performance should not benefit from the same approach and achieve at least as much improvement. Indeed, research for HSE (Duff *et al.,* 1993), adopting only the performance measurement and goal-setting principles, has shown that well over 20% reduction in unsafe operative behaviour is achievable (HSE Contract Research Report, CRR 229/1999); and more recent work has demonstrated comparable improvements in site management behaviour related to its health and safety responsibilities (Cameron, 1999).

The problem investigated by the programme of research outlined in this paper is how best to promote the effective integration of health and safety management into project planning and control in all construction activity – complex **and** routine – and thus achieve similar improvements. This will involve the development of methods that will ensure that health & safety management truly permeates construction sites by *'building-in'* safety planning and control as a core aspect of normal time and resource management, rather than attempting to run separate safety procedures as *'bolt-on'* extras.
In order to achieve a holistic approach to the management of construction, it is important to view health and safety planning as an integral aspect of production planning **from the beginning**. This should involve, for example, including safety risk assessment as part of the general management of

construction risk; and including specific safety activities and milestones on the master construction programme. This allows safety activity to be monitored in the same way as production and embraces the *'what gets measured, gets done'* philosophy of management. For example, the authors' chose a 'Linear Responsibility Chart', detailing **who** does **what, when** and **where** (CIOB, 1991). This monitors health and safety responsibilities, along with other responsibilities, to avoid safety management being overlooked as a result of unclear priorities. Safety arrangements and effort then becomes controlled and visible as a central objective of production management.

This thinking demonstrates that strategic planning for Health and Safety begins at the very start of the project and a commitment to proactive safety planning can be evidenced by a review of the allocation of responsibilities for safety (Health and Safety Plan). This should be clear from a review of the project organisational structure chart which ought to detail **who** has responsibility for **what** (safety roles).

The following is an example of the extent of a comprehensive set of safety roles which form the foundation of the more advanced 'Linear Safety Responsibility Chart':

Site Manager
- Holds subcontractor pre start meetings
- Updates risk assessment control chart for all work activities
- Delivers safety induction talks
- Chairs safety committee
- Maintains records of statutory records
- Conducts safety audits with safety manager

Sub agent
- Fire Inspection and fire marshal and first aid
- Conducts Tool Box Talks
- Conducts works risk assessments
- Inspects and audits subcontractors and site for safety
- Deputy for safety induction talks
- Crane and lifting operations 'appointed person'
- Conducts works risk assessments
- Inspects and audits subcontractors and site for safety

Project Engineer
- Conducts excavation inspections
- Conducts RA for temporary works
- Temporary works co-ordinator who oversees safe installation and removal

General Foreman
- Conducts scaffold inspections
- Communicates visible commitment to safety
- Crane co-ordinator

Works Foreman
- Inputs in to risk assessment
- Procures safety plant and PPE and inspects same
- Deputises for Site Manager and Sub Agent for safety acts
- Builds safety consideration in to daily part of work instructions

Chargehands
- Inputs in to risk assessment
- Procures safety plant and PPE
- Inspects work equipment and PPE
- Identifies extra safety training needs of his squad

Tradesmen and Labourers
- Report unsafe acts and conditions
- Maintain their own PPE
- Co-operate with the main contractor

Research Objectives

1. To produce a theoretical model of construction management, planning and control, and practices for the integrated management of health and safety risks.

2. To improve the effectiveness and practicality of this model through consultation with experienced practitioners.
3. To investigate current construction planning, control, and supervisory methods and tools, and evaluate contractors' methods for the management of health & safety risk.
4. To identify gaps between current health and safety management practice and the model, and revise the model to benefit from any improvements suggested by this investigation.
5. To field test the revised model in order to further improve the validity of the safety planning model by taking account of these practical experiences.
6. To produce a guide to best planning and control practice in integrated construction management of health and safety risk, including a set of 'Key Integrated Safety Management Planning Procedures' and 'Key Safety Performance Indicators'.

Research Method Employed

Objective 1: The first objective will be achieved by investigating available literature on good practice in construction management, in general, and legislation and other literature on health and safety management, in particular. This will cover site investigation, site set-up and mobilisation, site layout planning, contractor design (including temporary works), method statements, risk assessment, programming and allocation of resources, short-term planning and control, construction site supervision, the management of design variations throughout construction, and commissioning and client handover. A draft, theoretical model of 'best-practice' procedures, information flows and planning tools will be produced, showing source, destination, content, timing and frequency of communications and the roles and responsibilities of typical participants in the construction management process. This will show the integration of health and safety management with the general planning and site management processes.

Objective 2: The draft model will be tested for completeness, perceived value, practicality and the potential for integration into real construction sites, by consultation with a range of experienced practitioners; and modified accordingly. This interaction will use a selection of interview, Delphi and focus group techniques, as appropriate and depending on opportunity and availability of participants.

Objective 3: The next objective is to investigate how far actual practice diverges from the modified model. This will involve the collection and mapping of data on a variety of live case-study construction sites by: interviews with key project actors; passive observation of site induction meetings, planning meetings, tool-box talks etc.; and, review of site management documentation, such as site investigations, risk assessments, construction programmes, method statements etc. A gap analysis of health and safety content and quality will then be carried out, against criteria derived from the model. Instances of deviation from the model, particularly instances of failure to comply with accepted good practice or legal requirements, or instances of dealing with health and safety as a peripheral issue, will be recorded and reasons sought. Instances of alternative or better ways of achieving the model objectives will be recorded for inclusion in the model.

Objective 4: This will involve developing strategies for the introduction of any previously untried health and safety management procedures in the model (effective 'best-practice' procedures discovered during observation of current practice may not require any further field testing). This will be done with the assistance of industrial collaborators, and recording practitioner feedback. Strategies will focus particularly on ways of integrating health and safety management, such as health and safety plans and risk assessments, into equivalent mainstream construction management procedures. The drivers for change will include improved overall communication flows, methods of reducing the duplication of safety effort and ways of promoting teamwork and consultation etc., to the benefit of the whole construction management process. The model mechanisms are clearly not yet determined but current thinking suggests that they will include: structured meeting agendas; safety management performance indicators; goal setting and 360° feedback; risk assessment workshops; integration of accident/ dangerous occurrence reporting with other feedback into short-term planning procedures; collection and feedback of employee contributions into the whole short-term planning process, including health and safety; assessment of employee experience and competence across all factors of performance, including health and safety; re-engineering site management supervisory practices, such as induction and tool-box training, to integrate risk awareness with production related information.

Objective 5: This will involve the production of a set of documented Key Integrated Safety Management Procedures which can be used by HSE and industry to support a strategy for integrating health & safety management within existing construction management systems. These aids will also be used as the basis for a set of Key Performance Indicators which can help monitor health & safety activity within construction planning and control.

Conclusion

This paper has presented a planned programme of study which is currently being negotiated with the UK's Health and Safety Executive (HSE). The initial findings of the study and early collaborator consultation has suggested that health and safety is not seen as an integral aspect of work planning. Instead, risk information and avoidance strategies are conducted at a later date and risk assessments and control plans are viewed as separate activities - sometimes 'the domain of the specialist'. For example, construction barcharts seldom make reference to key safety items (e.g. completion of risk assessment, approval of method statements, training events etc). This suggests that safety planning is being conducted too late in the process in order to truly permeate site planning and supervisory practices. This paper recommends that more research is required to find effective and efficient ways of (easily) embedding safety planning and risk communication within the day-to-day planning tasks of the construction site management team.

References

Cameron I., 1999, *A Goal Setting Approach to the Practice of Safety Management in the Construction Industry: Three Case Studies*. PhD Thesis. University of Manchester Institute of Science and Technology (UMIST). Department of Building Engineering.

Cameron, I. & Duff, A.R.,1999, "Constructing a construction safety culture: a human approach" *Construction Paper 105, Construction Information Quarterly, Vol 1, Issue 2* The Chartered Institute of Building. P.22-27.

CIOB, 1991, *Planning and programming in construction – a guide to good practice.* Chartered Institute of Building Publications, Englemere, Ascot.

CIRIA, 1997, *Experiences of CDM: Report No. 171.* Construction Industry Research and Information Association. London SW1.

Duff, A.R., Robertson, I.T., Cooper, M.D. & Phillips, R.A. (1993) "*Improving safety on construction sites by changing personnel behaviour*" Contract Research Report 51/1993, Health & Safety Executive, ISBN 011 882 1482.

Egan, J., 1998, *Re thinking construction.* The report of the Construction Task Force on the scope for improving the quality of UK Construction, DETR London.

HSE, 1997, *Evaluation of the CDM Regulations 94*. The Consultancy Company. HSE Contract Research Report 158. HSE Books.

HSC, 2000, *Re-vitalising Health & Safety: strategy statement*. June 2000, HSE/DETR.

HSC, 2000, *Proposals for revising the Approved Code of Practice on 'Managing construction for Health and Safety'*. CDM Consultative Document. Aug 2000, HSE.

HSC, 2000, *Securing Health Together*. MISC225. August 2000, HSC/DETR.

HSE, 2000, *Health and Safety Benchmarking: improving together*. HSE Books.

HSE, 2000, *Re-vitalising Health and Safety in the Construction Industry: developing an agenda for action*. Working Well Together Conference. London, June 2000.

HSE, 2000, *Tackling Health Risks in Construction: developing an agenda for action.* Working Well Together Conference. London, October 2000.

Robertson, I.T., Duff, A.R., Marsh, T.W., Phillips, R.A. Weyman, A.K. & Cooper, M.D. (1999) "*Improving safety on construction sites by changing personnel behaviour – Phase Two*" Contract Research Report 229/1999, Health & Safety Executive, ISBN 0 7176 2467 6.

Internet References

HSE's 'Working Well Together' campaign. *wwt.uk.com.*

Egan's Report. *www.construction.detr.gov.uk/cis/rethink/index.htm.*

Key Performance Indicators Zone. *www.kpizone.com*.

Movement for Innovation (M4I). *www.m4i.org.uk.*

Construction Best Practice Group (KPI's). *www.cgpp.org.uk.*

A REPORT ON RESEARCH INVESTIGATING PRESUMPTIVE ASBESTOS SURVEYING STANDARDS IN PUBLIC BUILDINGS IN SCOTLAND

Cameron, Iain School of the Built and Natural Environment, Glasgow Caledonian University, U.K.
Graham, Ian M. School of the Built and Natural Environment, Glasgow Caledonian University, U.K.

Introduction

Forthcoming changes to the Control of Asbestos at Work Regulations 1987 will place specific duties on persons in control of premises to **manage** Asbestos Containing Materials (ACMs) in their buildings. A comprehensive and accurate building survey is the foundation of any successful asbestos management strategy. Therefore, it is necessary under the proposed Asbestos Regulations 2002 to assess how the following may be successfully implemented:

- Identify the location of ACMs - Survey.
- Keep a record of its location - Register.
- Assess how hazardous it is - Risk assessment.
- Instigate an inspection programme - Monitoring procedures.
- Adopt structured documentation practices – Asbestos Management system.
- Implement procedures in case of a fibre release - Emergency plan.

HSE have proposed a draft document, MDHS 100, which contains advice on surveying techniques. However, this documents advice will not be directly enforceable as the only surveying technique available to surveyors. Therefore, this creates a ‘grey-area’ in terms of standardising asbestos surveying techniques throughout the UK. This in turn may create difficulty in establishing a UK-wide register for accessing the necessary information concerning the location of ACMs in UK Public Buildings.

CURRENT AND PROPOSED REGULATIONS (HSE)

The UK currently has a three stage legislative strategy for the Control of Asbestos as shown below:

- **The Control of Asbestos at Work (CAW) Regs. 2002 (Proposed Asbestos Regulation)** – it is proposed that this regulation will be consolidated with the Control of Asbestos at Work Regulation 1987 (which largely deals with safe removal techniques), coupled with the present proposed amendments for identification and surveying. It is thought the new Regulations will become law by June 2002.
- **The Asbestos (Prohibitions) Regulations 1985 and 98** – this prohibits the use of asbestos in a variety of applications including **all** construction projects these days.
- **The Asbestos (Licensing) Regulations 1983** – this aims to ensure that only competent employers will undertake the more hazardous work involving asbestos (e.g. lagging, sprayed coating, and boards).

The draft Asbestos 2002 Regulations mirror existing duties in the UK’s Management of Health and Safety at Work Regulations 1999, but they also extend these regulations by an explicit duty on the controller of the premise to identify and manage ACMs.

OVERVIEW OF HSE’s OBJECTIVES

HSE propose to publish an Approved Code of Practice (ACoP) within the proposed Asbestos 2002 Regulations. The document will give employers guidance on the preferred means of compliance with their duties to manage the risk from asbestos. The guidance covers the following:

- Identifying asbestos.
- Maintaining a register of asbestos.
- Assessing the risk of fibre release.
- Preparing an action plan to monitor the state of asbestos in building.
- Setting up an administrative systems to control any future disturbance of suspected ACMs.

A publication from the Method for Determining Hazardous Substances series (MDHS 100) supports the previously described changes. HSE have issued this *"Method for Determining Hazardous Substances for Surveying, Sampling and Assessment of Asbestos Containing Materials in Premises for Management Plans"*. The guidance seeks to establish and standardise current good practice, so that asbestos containing materials (ACMs) in premises are accurately surveyed, recorded and assessed, in order that an effective management plan is produced. The main objective is to **manage** ACMs in premises to prevent or reduce airborne fibre exposure to maintenance workers who may unknowingly disturb ACMs.

An appropriate log to record the survey information is an area that is still open to discussion. A register is at present is the most likely solution, however, annotated drawings are also a possible choice. The potential for these plans being displayed over the Internet is a real possibility. HSE are keen to ensure that competent surveyors with suitable qualifications are the only persons who carry out asbestos survey work. An HSE asbestos working group has agreed that the minimum qualification for asbestos survey work should be the British Institute of Occupational Hygienists (BIOH) P402 proficiency course: 'Building surveys and bulk sampling for asbestos'. The BIOH higher qualification S301 is preferable (Asbestos Competency Certificate). A pilot accreditation scheme (the 'UKAS' scheme) for asbestos surveying practices or companies is also proposed to be in place during the summer of 2002.

Research Objectives

1. Assess asbestos surveying training standards in Scotland.
2. Assess the effectiveness of quantitative asbestos risk assessments.
3. Investigate possible provisions for asbestos survey information.
4. Assess asbestos surveying standards in Scotland

Research Methodology

Three Local Government Authority case studies were carried out to evaluate how they intend to implement the requirements for asbestos surveys, risk assessments, and asbestos registers. A day of observations and informal interviews was conducted for each case study. The cases were chosen because of their different geographic locations within Scotland / United Kingdom and data were collected by interviews, observation, and document review.

- Glasgow City Council (GCC) – Many buildings (population 800 000).
- Highland Town Council (HTC) – Prosperous areas – Inverness (population 80 000).
- Comhairle Nan Eilean Siar (CNES) – Western Islands (population 5000).

Findings From the Three Case Studies

Training Standards

Both Glasgow City Council (GCC) and Highland Town Council (HTC) are striving in the right direction in terms of gaining a good standard of qualification through completing the BIOH Modules (British Institute of Occupational Hygiene). Unfortunately, Comhairle Nan Eilean Siar (CNES) are lagging behind in terms of qualifications gained, their surveyors have only an appreciation of the dangers of asbestos due to the fact that they have only undertaken brief awareness seminars. These only aid the surveyors in taking their level of competency to the next level (=BIOH Modules).

A new training scheme is being run by the Royal Institute of Chartered Surveyors (RICS). However, this is of little help in setting standards throughout Local Authorities. It merely focuses on Building Surveyors who are *'chartered' (MRICS)* - this would result in very few surveyors of the Local Authorities interviewed gaining accreditation qualification.

[1] The Royal Institute of Chartered Surveyors (RICS) and the Surveyors And Valuers Accreditation (SAVA) scheme have collaborated in implementing an accreditation scheme for certifying individuals as competent to conduct asbestos surveys. This is known as 'SAVA' accreditation.

Surveying Standards

The actual methodology of surveying proved to be a grey area to investigate. CNES had no set method; HTC did not carry out their own surveys; and GCC were in the process of implementing a new system. CNES have an advantage over the other Councils because the vast majority of their properties are small. Although, HTC are not carrying out their own surveys, they do have a very efficient computer system planned for the future by using hand-held software to note down the information. But, GCC, due to the implementation of a new register, have new survey sheets drawn up in line with the asbestos register guidelines which will create a system that will give out accurate survey information for the end user.

Risk Assessments

Risk Assessments appeared to be an area of an asbestos project management that was largely controlled by financial constraints and internal politics. In an ideal world, each property would be given equal attention. However, in the real world, property prioritisation occurs, and this has meant focusing on 'schools' because of the sensitive and political importance of this kind of property.

A worrying area to emerge from the research is about the risk assessment methods employed. The 'risk rating' factors that Councils use in determining what is a *priority* seems inconsistent. None of the case studies could clearly define the levels to which the risk assessment scores were rated. CNES used a similar method to that proposed by the MDHS100 document. The information laid out in the assessment did not clearly define a risk level and it did not appear that they had any method of coming to a conclusion apart from pure experience as a surveyor. HTC carried out initial visual risk assessments in order to produce a brief for tendering to consultants. To their credit they drew up a framework that provided each area of an asbestos project a *zone* that dictated **who** was to be made aware, **how** they were to be alerted and **when**, **who** would carry out the risk assessment, and an action zone that dictated the **asbestos contractor's duties**.

GCC have implemented an integrated risk assessment and survey sheet. The structure of the assessment is clear and concise and gives an accurate 'risk rating' score. Unfortunately, the risk ratings provided by the software designers, have been altered by GCC to suit their own version of the risk ratings. This clearly shows that financial implications are going to affect the actual level of risk scored !.

Asbestos Register

Across all three case studies, an asbestos register was probably seen to be the most important part of implementing a successful asbestos surveying strategy. The main reason being that in trying to protect the public and construction operatives, it is necessary to produce the asbestos survey information in a clear form for all Local Council staff; especially construction operatives carrying out the work.

The standard of information provided by both HTC and GCC was of a good standard. GCC's information being very detailed. However, it is apparent that government inspectors would not be satisfied with CNES's asbestos register. The main worrying factor being that all the survey information was not provided. It is possible that they rely more on the paper copies of the information, however, this information <u>would not be easily accessible</u> for all other Council staff.

Interestingly, all the case studies mentioned that they had either implemented, or were in the process of implementing, an 'Intranet system'. This is a necessity within any Local Authority as it provides freedom of information for all staff at the time they require the information.

Auditing

None of the three case studies mentioned auditing in any degree of detail. It is probably an area that has been largely overlooked. This area now requires serious attention. Many of the asbestos registers installed are fairly new and require the training of staff to use them, therefore, it is necessary to have a process of internal and independent external audits. This will ensure that everything is being used in the correct manner. There is also the added pressure that government (HSE) may, at any time, cross-examine the information and decision making process in relation to the Asbestos Register.

CONCLUSIONS

1. The MDHS 100 document does not clearly state the training standards required for asbestos surveying. This is surprising considering that they have agreed (with UKAS) on a qualification that would set a standard.
2. The advice given for surveying standards is vague. Although information is given on asbestos materials and location, it is unclear as to the exact methodology to adopt. A single method is needed.
3. The required structure of an asbestos survey is clearly defined by HSE, however, a suitable format has not been drawn up. For example, the Internet is not being exploited.
4. The MDHS 100 risk assessment algorithm is very cumbersome to use due to its two-part structure. The first section is accurate in assessing the material risk. The second section on building usage seems very subjective. Conclusions drawn do not seem to be valid. An adequate one-step risk assessment will provide the necessary information for a 'risk rating' and this is needed urgently.
5. The implementation of an asbestos register is seen to be one of the weakest areas of the document. They do not dictate strongly enough the standard of register required, they simply state: *'a computer database of suitable form is extremely useful'*. This comes across in a very unassertive way. A stronger case should be put forward for a computer database systems.
6. The standard of Local Authorities databases vary from simple spreadsheets to hi-tech computer databases. In general, a simple spreadsheet will not cover the required information because it is limited in scope. HSE need to devise a prescriptive format that all organisations should adopt (or enhance), to avoid sub-standard asbestos registers.
7. All Local Authorities see the implementation of an intranet system as being paramount in ensuring that all Council employees have access to the asbestos register.
8. The cost implications of training surveyors and operatives through BIOH Modules are reasonable and affordable for Local Authorities and should therefore be compulsory.
9. In larger Councils such as GCC and HTC, the financial impact of wide scale asbestos surveying of their building stock will prove to be very onerous.

Recommendations

1. The three important areas of the proposed changes to the Asbestos Regulations appear to require further tightening. The guidance relating to training, survey methodologies, risk assessments and asbestos registers are not specific enough for Local Authorities to effectively implement.
2. The UK government (HSE) need to align themselves more strongly with UKAS (an accreditation body) to enforce acceptable methods of surveying.
3. It is essential that HSE devise an accepted assessment criterion for asbestos risk assessments. There is too much variation available. A simple set method is desirable and this should include contingency plans for when things go wrong.
4. HSE should put out to tender the 'design of an appropriate asbestos method with a set survey format, risk assessment procedure, and asbestos register'. This could take the form of an HSE Contract Research Report.
5. The budget allocated to asbestos works for Local Authorities needs to be increased. This should come from central government. The asbestos problem that will not diminish without extra funding.

References

DETR (1999). *Asbestos and man-made fibres in buildings: Practical Guidance* HMSO. 0-7277-2835-0.

Doll R & Peto J. (1996). *The effects on health of exposure to asbestos*. *The Lancet.* ISBN 0-7176-1075-6.

HSE (1999). *Controlled asbestos stripping techniques for work requiring a licence*. ISBN 0-7176-1666-5

HSE (1999). *Working with asbestos cement*. ISBN 0-7176-1667-3.

HSE (1999). *A guide to the asbestos (licensing) regulations 1983 as amended: Second edition. (L11)* ISBN 0-7176-2435-8.

HSE (1999). *The control of asbestos at work: Third edition (L27)*. ISBN 0-7176-1673-8.

HSE (1999). *Working with asbestos insulation, asbestos coating and asbestos insulating board. (L28)*. ISBN 0-7176-1674-6.

HSE (1999). *Asbestos alert for building maintenance, repair and refurbishment workers.* 0-7176-1209-0.

HSE (1999). *Managing asbestos in workplace buildings.* ISBN 0-7176-1179-5.

HSE (1999). Asbestos dust kills. ISBN 0-7176-1696-7.

HSE (1999). *Working with asbestos dust in buildings.* ISBN 0-7176-1697-5.

HSE (1999). *Proposals for amendments to The Control of Asbestos at Work Regulations 1987; a new Approved Code of Practice; and a minor amendment to the Health and Safety (Enforcing Authority) Regulations 1998*. CD 159.

www sites

RICS/SAVA (2000). http://www.ricsonline.org/government/press.html

UKAS (2000). http://www.ukas.com/new-docs/accredit.htm

UK DETR (2001). http://www.environment.detr.gov.uk/asbestos/guide

A REPORT ON RESEARCH INVESTIGATING THE PRACTICAL USEFULNESS OF CURRENT FALL PREVENTION AND PROTECTION METHODS WHEN WORKING AT HEIGHTS

Cameron, Iain Department of Building & Surveying, Glasgow Caledonian University, U.K.
Duff, Roy Department of Building and Civil Engineering, University of Manchester Institute of Science and Technology (UMIST), U.K.

Introduction

The UK Construction Industry suffered 84 fatal accidents during the year 2000. Almost half of these fatalities were due to 'falls from heights' and around half of these were due to 'falls from roof edge' and 'falls through roof'. The statistics also suggest that new build (e.g. profiled aluminium roofs) are just as dangerous as refurbishment (e.g. asbestos cement roofs). These figures demonstrate that falling accounts for the majority of fatal accidents in the UK Construction Industry.

There are numerous pieces of statute which aim to plan roofwork and introduce technical measures to prevent falls in the UK. Section 2 of the Health and Safety at Work Act 1974 requires contractors to provide a safe place of work and this includes roofwork. Regulation 3 of The Management of Health and Safety at Work Regulations 1999 require the risks associated with working at heights to be assessed and controls introduced to reduce this risk to as low a level as is reasonably practicable. Regulation 4 of these regulations places an emphasis on measures which protect the whole workforce and thus yield the greatest benefit. This means that collective protection (e.g. safety net) is favoured over individual protection (e.g. safety harness) and general preference is given to methods of fall protection which take advantage of technological progress.

Further, Regulation 6 of The Construction (Health, Safety, Welfare) Regulations 96 place an absolute duty to prevent falls when working at a height of over 2 metres. This is achieved by a requirement for guardrails and toeboards and where this is not possible by the introduction of methods which will arrest a fall as a last line of defence. Also, the planing of a safe system of work and risk controls will form an important section of a Principal Contractor's Health and Safety Plan issued under the Construction (Design and Management) Regulations 94.

In accordance with the principles of risk prevention and protection hierarchy, there are five key areas which this research programme intends to evaluate because they represent the current state of 'best-practice' when working at heights in construction:

1. The benefits and limitations of safety nets during roofwork
2. The benefits and limitations purlin trolley systems during industrial roofwork
3. The benefits and limitations of air inflated safety bag systems when working at heights and/or near a leading edge
4. The benefits and limitations of cable based fall arrest systems as a means of protection when working at heights and/or near a leading edge
5. The benefits and limitations of the use of currently specified fall arrest systems when erecting and dismantling scaffold (SG4)

The practical usefulness of these methods of fall protection are currently being investigated through a combination of expert opinion and experiences drawn from live field trials on case study sites.

Research Objectives

This research will investigate the following objectives:

1. To evaluate the benefits and limitations of safety nets during roofwork
2. To evaluate the benefits and limitations trolley systems during industrial roofwork
3. To evaluate the benefits and limitations of air inflated safety bag systems when working at heights and/or near leading edges

4. To evaluate the benefits and limitations of cable based fall arrest systems as a means protection when working at heights and/or near a leading edge.
5. To evaluate the benefits and limitations of the use of currently specified fall arrest systems when erecting and dismantling scaffold (SG4).

Objectives – Background Information

(1) The benefits and limitations of safety nets during roofwork

These systems are growing in popularity within the UK Construction Industry as a direct result of Regulation 6 of the Construction Regulations 96. The systems are becoming easier to use and install as new suppliers and rigging companies enter the marketplace. Further, the systems have been widely championed in the UK through HSE'. The use of safety nets during industrial roofwork is a published 'HSE Enforcement Priority for the Year 2001'. It is also possible that safety nets can be used on some refurbishment work for example, to protect falls through fragile rooflights in circumstances where the primary protection (the solid roof light cover) is carelessly removed.

It is the writers' belief that there are some problems with the use of safety nets which prevent there use on all occasions, and although they are an excellent method of fall protection, they have limitations and these need to be investigated.

For instance,
a. How feasible are nets during refurbishment work with highly serviced roof spaces ?
b. How feasible are nets to install if the site encounters poor ground conditions ?
c. How feasible are nets to erect during mezzanine or swimming pools construction ?
d. How feasible are nets during the construction of tall buildings beyond the reach of normal access equipment ?
e. What changes do designers need to make to allow easier installation of nets and their border ropes and how can this be done so as not to impede contraction for example, gutters ?

Furthermore, are some contractors negating the purpose of safety nets by the systems of work they design. For instance, some contractors are insisting on the use of safety harnesses in addition to the use of nets. They argue that nets gives people a false sense of security and this encourages workers to take risks. These harnesses place a massive shock load on the body and this introduces other problems ('suspension trauma' and rescue practicalities and damage to internal organs etc). This introduces another research question in relation to nets:

f. How prevalent is this practice and how can contractors be persuaded to abandon this practice and let the net serve its purpose ?

(2) The benefits and limitations purlin trolley systems during industrial roofwork

These systems have been around for a long time and are usually used in conjunction with safety harnesses. This is because, traditionally, the purlin trolley has a double handrail on the 'Leading Edge' (the opposite side to that being worked on) which provides protection. But, has an open 'Working Edge' (the side where the sheets will be progressively installed) and thus requires a harnesses attached to the trolley to prevent falls at the working edge.

However, a number of technological advantages have been made in this area in recent year. For instance, patented systems (e.g. Rossway) now mange to protect the 'Working Edge' by means of a trolley which limits the open area by the provision of a horizontal barrier (attached to the trolley) which rests about six inches below the location where the roof sheet will be fixed to. This means that if someone accidentally stands on the unfixed sheet, the sheet will be caught (and therefore the worker) by the horizontal barrier. The system eliminates the need for harnesses etc and has been endorsed by HSE as a safe system of roof work which provides an alternative to the use of nets and/or harnesses (www.rosswaydowd.co.uk)

This system may well be an alternative to nets, for use on occasions where nets are limited, in order to an alternative to nets and possibly limit the risk from net installation. The system is suitable for simple roof designs that do not feature curved surfaces or intricate plan shapes and cost effective systems for industrial warehouses.

This programme of research reported in this paper will investigate the kinds of building designs where this system can be used and the kind of design changes that will require to be made to allow this systems to function effectively. This may include the specification of roof panels of the same modular width and the location of anti sag bars etc.

(3) The benefits and limitations of air inflated safety bag systems when working at heights and/or near a leading edge

There are situations in construction where nets are impractical and the alternative means of fall protection has normally been a harnesses and line. These include the installation of precast slabs where there is always a leading edge at each floor of the building. The concept of air inflated safety bags in growing in recognition within the industry. These systems are being trialed by the Precast Flooring Federation (PFF) at present. Also, it is possible that these systems could augment traditional scaffold 'crash decks' by overlaying the air bags on the scaffold deck and thus provide a softer landing during atrium construction etc.

Also, perhaps the greatest opportunity for these systems is in domestic housing, this sector of the industry has always struggled with the concept of safety nets and it is probably fair to say that nets have their limitations when used during low level construction. Further, harnesses are also problematic during this type of work because it is difficult to find attachment points and workers have to attach / detach frequently. Therefore, safety air bags may have much to offer the housing sector.

The opportunities for this systems of work will be investigated by this research. Further, problems of perception will also be viewed which may inhibit the industry's acceptance of these methods, for example, air bags being viewed as a child's amusement park toy etc.

(4) The benefits and limitations of cable based fall arrest systems as a means of protection when working at heights and/or near a leading edge.

These systems can be installed as either a last line of defence during new construction work or as a permanent maintenance systems installed during new building. Also, the systems is useful during refurbishment work. The facts are that there are some occasions when it is possible that safety nets could be impractical. This could be the case during unusual new build structures – parabolic and ellipse type roofs. These roof shapes also render purlin trolley systems useless.

Therefore it is possible that steel cable systems which operate with a harness and inertia reel attached to the running line may offer practical and cost advantages over nets. Also, even if cable based systems prove to be of only limited value during new build, it is conceivable that occasions will exist during refurbishment work where cable systems are preferred over nets.

This is particularly the case during the renovation of historic buildings with dome roofs and other unusual features. These buildings may make nets difficult and dangerous to install and may mean that the net is well over 2m below the apex of the roof. Also, it is conceivable that cable systems may need to be specified as part of the maintenance system because they are unobtrusive and thus sympathetic to the architectural needs of historic buildings.

The programme of research reported in this paper will evaluate the types of projects where cable systems should be considered on the grounds of practical usefulness.

(5) The benefits and limitations of the use of currently specified fall arrest systems when erecting and dismantling scaffold (SG4)

The National Federation of Scaffold Contractors (NFSC) published Guidance Note: SG 4 – *'The Use of Fall Arrest Equipment when Erecting, Altering and Dismantling Scaffold'* during 2000. The guide is endorsed by the Construction Confederation, HSE, several major contractors, NFSC member companies. The guide is in direct response to Regulation 6 of the Construction Regulations 96.

The system appears to be well presented but on close inspection there are a number of limitations that the researchers believe require to be addressed. It is well documented that the guide does not comply with Regulation 6 of CHSWR 96 and is in fact a compromise. The guide only applies when working at a height of over 4m. The reason for this is that if someone wears a 2m lanyard attached at foot level (=worst case position), then they will fall a minimum of 2 metres with a shock load to the body of 12KN (circa 12000Kg). This is unacceptable and has to be reduced to half this load under EU Standards. This requires the introduction of a 1.75m shock absorbing lanyard. This lanyard will 'tear' for a distance of 2m when worn as part of a fall prevention strategy. This means that the scaffolder (if clipped on at the worst case foot position) would fall 1.75m plus the 2.0m of the lanyard tear – a total of approximately 4m with the shock load to the body being reduced to 6KN.

It is clear that this does not fully comply with Reg 6 of the Construction Regulations 96 and the possibility of secondary injuries during this 4m fall need to be considered. This point has been forcefully demonstrated by the UK Construction Industry Training Board (CITB) who found that the skull of a mannequin was literally smashed due to striking a scaffold transom during a 4m fall whilst wearing the shock absorbing lanyard. The CITB's spokesperson believed that the strength of the mannequin's skulls was at least equal to that of a human skull.

A safer systems would be to introduce an inertia reel as part of the installation. These reels are very lightweight and compact and are similar in construction, operation, and looks to a car seat belt. And, if used as part of the fall prevention installation, would drastically reduce the free fall distance of the scaffolder – to around 2m if attached at the worst (foot height) case, and about 0.5m if attached at the best (head height) case. This amended system would comply with the Construction Regulations 96 (Reg 6) and would reduce the risk from secondary injuries. Alternatively, a fixed anchorage point attached to scaffold uprights (standards) would reduce falls to only a short length. For example, 'The Jordan Clamp', which ensures that all scaffold lanyard hooks are always attached at above head height.

This programme of research reported in this paper will evaluate the feasibility of this systems and the views of the key stakeholders, and some major contractors, on the worth of this revised methodology.

Related Issues of Concern – Training of Roof workers

The training of roof workers and the equipment they hold has always been an issue of concern. Roofwork is much more dangerous, at least statistically that steel erection. It is fair to say that the modern day steel erector is better trained, older, and more psychologically aware of the danger than a roof worker. The steel worker operates along open steel and is spatially aware. The roof worker on the other hand walks across a platform that appears to be solid and is thus subject to a false sense of security and therefore less aware of the dangers. The roof worker is tends to be younger, had little previous training, and works for a small company with limited access and safety equipment.

The Roofing Industry Alliance Hallmark Scheme in the United Kingdom – a kind of 'Quality Mark' or 'Kite Mark' – hopes to overcome some of these problems by ensuring the necessary training of experienced construction workers and assessing the quality of companies via a rating scheme. The scheme intends to weed out the 'cowboys' and restore credibility to the roofing industry.

The research reported may well investigate the merits of this scheme and the ways in which Principal Contractors can be persuaded to endorse the scheme and therefore reduce the opportunities for non-skilled roof workers to operate in the construction industry. Presently, however, this 'competency' objective is less certain because it seems HSE have allocated this research to others.

Research Methodology

The research reported here will be delivered through a combination of a desk top review of the suitability of current technical guidance and standards for fall prevention when working at heights. This will be followed by a series 'focus group' meetings of experts and vested interest groups. This group will identify a series of live case study sites of each different method of fall protection which the research team will visit and observe. Also, a research 'steering group' maintains the direction of the research. Finally, interviews with experienced site managers, suppliers, and operatives are to be conducted. These interviews will determine the experiences of site managers and operatives in relation to the identified fall prevention methods.

The 'focus group' of interested parties may well include The National Federation of Roofing Contractors (NFRC), The National Federation of Scaffold Contractors (NFSC), The Scottish Building Employers Federation (SBEF) and/or The Construction Confederation (CC), The Health and Safety Executive (HSE), The Major Contractors Group (MCG), and other interested stakeholders e.g. designers, suppliers, trade unions, trade contractors.

The focus group will identify case study sites and industrial partners who will provide access for the research team to observe the use of safety nets, purlin trolleys, safety air bags, cable base systems, harnesses during scaffold operations etc. This will allow the research team to evaluate the practical usefulness of the different methods of fall prevention methods for working at heights and the ways in which each of these methods can be improved. This may well involve interviews with construction mangers, construction workers, and construction suppliers in order to investigate the optimum arrangements required for the implementation of these methods of fall prevention.

The research will culminate in a 'best-practice' publication which will be derived from the desk top literature review, the focus group findings, and the live case study sites identified from the steering group and interviews.

Conclusion

This paper has presented a planned programme of study which is currently being negotiated with the UK's Health and Safety Executive (HSE). The initial findings of the study and early collaborator consultation has suggested that there are a range of potential fall prevention and protection methods available for use when working at heights, each system with benefits and limitations. For example, some are suited to new build, others to refurbishment, and some are dependent on other circumstances such as plan shape of the building. It is clear that all methods can add value to the construction process, however, a Technical Guide is required in order to outline to designers and contractors the optimum circumstances of specification and/or use for each respective system. This technical guide is currently lacking but this research hopes to deliver this technical standard and further details will be reported at the conference.

References

CITB 2000, *If you should fall.* Construction Industry Training Board. CITB Video 9VID066), CITB, Bircham Newton, Norfolk, PE31 6RH.

HSE, 2000, *Health and Safety in Roofwork.* HSG33, Health and Safety Executive, HSE Books.

NASC 2000, *The use of fall arrest equipment whilst erecting, altering and dismantling scaffold.* Guidance Note SG4 by The National Association of Scaffold Contractors in the UK.

THE EXPOSURE OF BRITISH CONSTRUCTION MANAGEMENT DEGREES STUDENTS TO HEALTH & SAFETY LEARNING AND ASSESSMENT: ARE WE FULFILLING OUR DUTY OF CARE?

Cameron, Iain Department of Building & Surveying, Glasgow Caledonian University, U.K.
Fairlie, Norman Department of Building & Surveying, Glasgow Caledonian University, U.K.

Introduction

The CIOB sets the standard by which the 'chartered builder' is qualified. Further, the CIOB details the experience required to achieve corporate membership. In January 1995, the CIOB ran a higher education project, under contract from the Department of Employment, which provided a basis for establishing a Higher Education Discipline Network for Building Management (CIOB 1995). The project had three objectives:

(i) to identify excellence in the delivery of building management education, with a particular focus on innovative practices and vocational learning;
(ii) to improve the standard of education by bringing teaching staff together to share information and learn from the experiences of others; and
(iii) to disseminate examples of good practice through publications and seminars.

This project culminated in the generation of the Education Framework (CIOB 1996a). The Framework is designed to provide best practice for the delivery of construction management degrees in the UK.

Research Objective

The objective of this paper therefore is to evaluate a single important question -
'To what extent does health and safety feature in this model of best practice ?'.

CIOB Regulations

Those who aspire to become a chartered builder in the UK generally require a CIOB-accredited honours degree in construction management in addition to at least three years' experience at an appropriate level. This results in the achievement of corporate member grade (MCIOB). Section 6 (regulation 40) of the CIOB's 'Membership regulations' (CIOB 1994a): *"An applicant must have had a minimum of three years' experience at professional level in a firm, consultant practice, department or other organisation engaged in the construction, alteration, maintenance, repair, provision, design, inspection or management of buildings, other construction work or in building education."*

It lists the following acceptable activities: *"Building control; building asset management; building surveying; estimating; construction management; cost and production control; design; inspection and maintenance management; project management; purchasing; quantity surveying; site engineering; teaching; planning; quality; facilities management; and any other function acceptable to the Institute."* However, safety is not explicitly noted. At the very least, this seems to contradict the CIOB's own 'Regulations of professional competence and conduct' (CIOB 1994b), which detail the standard of competence that corporate members must achieve.

These Regulations, unlike the Education Framework, place a strong emphasis on health and safety. Rule 15 specifically targets health and safety:

"15 Members shall at all times have due regard for the safety, health and welfare of themselves, colleagues and any others likely to be affected:

15.1 a knowledge of health and safety risks in the industry and the main principles and strategies for control;

15.2 an understanding of the responsibilities for the safety, health and welfare placed on all parties involved in the building process;

15.3 a working knowledge of the current legislation and advisory information;

15.4 a recognition of the importance of keeping themselves up to date."

The Safety, Health & Welfare Committee

The requirements of Rule 15 are supported by the work of the CIOB's Safety and Health Committee (CIOB 1998a). The Committee consists of 10 members whose objectives are to act as a focus for health and safety within the CIOB. In particular, the Committee:

(i) provides advice on health and safety training, including revising and reviewing the Institute's syllabus for corporate membership examinations;
(ii) liaises on health and safety matters with other professional institutions and similar bodies, government departments and other committees and groups within the CIOB;
(iii) examines, consults on and responds to consultative documents received by the Institute from government departments, the Health and Safety Executive (HSE), the Health and Safety Commission (HSC) and other organisations;
(iv) produces articles for inclusion in the Institute's monthly journal and other national construction media;
(v) reports regularly to the Institute's Professional Services Board and receives its guidance on matters to be investigated and reported on.

In a Safety, Health and Welfare Committee report (CIOB 1998a), the chairman commented on a pilot study the Committee had undertaken in relation to the health & safety content of university construction degrees:

> *"For several years the Committee has been looking at the Education Framework with regard to the health, safety and welfare content. ... It is apparent that there is a lack of direction and standards, with some universities and colleges taking the subject of health & safety more seriously than others."*

The Committee concluded that there was a lack of guidelines in relation to health and safety from the CIOB towards universities. In particular, the Committee recommended that the CIOB should issue, as a matter of urgency, firm directives to the universities in order to make health and safety a significant component of a student's education, preferably via a specific health and safety module, hence ensuring that basic health and safety practices are taught to every student undertaking a CIOB-accredited construction degree.

Overview of Ciob's Objectives

A CIOB-accredited course is designed to equip those undertaking it with a formal education that provides this initial preparation. This core knowledge can then be developed by industry (Riggs, 1988). The CIOB's Professional Development Programme for graduate members (CIOB 1998b) attempts to structure this training in order that graduates will possess the level of competence required by the Institute's regulations to become a corporate member. If the CIOB expects prospective members to comply with health and safety legislation (as laid down in its 'Regulations of professional competence and conduct') then it is reasonable to suppose that its Education Framework should provide this initial preparation by ensuring that accredited degree programmes adequately address health and safety issues.

Rule 15 gives an indication of the importance that the CIOB places on health and safety for corporate membership and yet the Education Framework's (CIOB 1996a) module descriptors make no specific demands on universities to include health and safety (Fig. 1).

There are currently 30 higher education institutions in the UK offering CIOB-accredited construction management degrees. The left hand side of Fig. 1 shows a lack of specific reference to health and safety within the structure of undergraduate programmes, although the subject receives treatment within some modules. The detailed syllabuses of taught modules reveal that health and safety receives little attention within levels 1 and 2. For example, 'Design and technology 1' (at level 1) has a passing reference to "safety precautions" in relation to excavations, and 'Management' (at level 2) has a reference to "health, safety and welfare policies" and "audit procedures". In total, fewer than two lines of a two-page module descriptor are devoted to safety for any module within the CIOB's Education Framework. The only module that makes any notable reference to safety is one within the 'Construction management' option at level 3. Indeed, none of the modules within the Education Framework makes detailed reference to risk assessment, arguably an essential process.

Figure 1 therefore demonstrates an anomaly between CIOB education and CIOB training.

Education Framework		**Professional Development Training**
Level 1 Modules (formation studies): Design and Technology 1 Science for Building Materials Site Surveying Business Environment 1 Information and Decision Making Structures Other CIOB Certificates & Diplomas Assessed Experiential Learning		**Twelve Competencies** (attained over 3 years): Decision Making Communication Managing Information Planning Quality Managing Resources Costs and Valuations Personal Management Health and Safety (see below)
Level 2 Modules (core studies): Design and Technology 2 Business Environment 2 Legal Studies Management Management of Building Production Building Services Pre-contract Services Other CIOB Certificates & Diplomas Assessed Experiential Learning	>	**Health and Safety:** This unit is designed to asses overall knowledge and understanding of safe working practices and principle hazards in construction activities and to asses competence in risk assessment in your own working environment following satisfactory assessment of the required knowledge and understanding. Element 1: Identify, describe, explain principle hazards and appropriate health and safety working practices Element 2: Identify hazards, and asses risk from work
Level 3 Modules (professional studies): Four Option Modules Project Evaluation & Development Assessed Experiential Learning/Thesis		Element 3: Identify and describe implementation of risk control measures.
"UNIVERSITY"		**"INDUSTRY"**

Figure 1 The elements of the CIOB's Education Framework (University Education) and its Professional Development Programme (Industry Training)

Education

There is a comprehensive body of literature that attempts to define education. The Department of Employment (1971) describes education as activities which aim at developing the knowledge, moral values and understanding required in all walks of life rather than knowledge and skill relating to only a limited field of activity. However, Peters (1972) claimed that education was too complicated to define. He regarded being educated as a state that individuals achieve, with education being a set of processes that lead to this state. This indicates a broad learning base during the initial stages of education with the field narrowing and becoming more specialised during the final stages of learning. With regard to construction health and safety, the importance of formal education was recognised by Davies and Tomasin (1996):

> *"It is recommended that time is devoted on the relevant courses at universities or to the subject of health and safety in the construction industry. This should cover an outline of safety legislation and the duties of employers and employees. It should describe the hazards that professional staff face in their work and outline the problems facing designers in ensuring that their work is safe to build, operate and maintain."*

Garavan (1997) suggested that educational achievements are viewed as a prerequisite for a job. Indeed, health and safety is now beginning to be recognised as an important part of business management education (see, for example, Confederation of British Industry 1990).

Training

Training of recent graduates in construction management is required in order that they might effectively put theory into practice. Training then becomes an integral part of continuing professional development. The educational foundation on which such training builds should be able to support both the needs of the organisations employing the graduates and the professional needs of the individuals concerned in terms of their career development. The CIOB has, through its Professional Development Programme (CIOB 1998b), emphasised the importance of continuing professional development for graduate construction managers. Gilley & Eggland (1989) elaborate on career development by describing it as "an organised, planned effort comprising structured activities that result in a mutual career plotting effort between employees and organisations".

It must be borne in mind that company directors are answerable to their shareholders, who are looking for a return on their investment. A positive corporate image will help to achieve this. In addition, an organisation with a poor health and safety record is unlikely to be a desirable option for potential clients. Therefore, it is in a company's interests to view health and safety training as a long term investment rather than an immediate cost. However, employers and graduates should not be expected to rely on training to fill gaps in basic knowledge that have been left by inadequate provision on degree programmes.

Research Methodology

The second authors' study is similar in nature to one undertaken previously by the CIOB's Safety and Health Committee in 1996 (CIOB 1996c). This earlier study generated a low response. The authors' follow-up study therefore attempted to enhance the validity of its findings. The CIOB's earlier study was based on a questionnaire ('Health and safety – academic courses'), which was sent to all higher education institutions running CIOB-accredited construction management degree courses. A response rate of only 30 per cent was achieved. The authors considered that a semi-structured telephone interview format would be a better method of data collection.

A list of British CIOB-accredited university honours degree programmes in construction management was obtained from the CIOB's 'Directory of Construction Courses 1996/97' (CIOB 1996b). It was considered that to obtain satisfactory answers, the programme manager should be interviewed. Thereafter, the programme managers were contacted and interviewed during March 1999. The length of each interview varied between 10 and 30 minutes, depending on each respondent's interest in the subject, their level of involvement with the CIOB and the time available. Out of a total of 30 CIOB-accredited universities, the second author secured 25 telephone interviews representing an 83% response.

Results - Responses to Questions

Q1: How many students are currently in their honours year of the course?

Table 1 shows that the size of courses varies considerably. Indeed, there are certain CIOB-accredited universities that are major suppliers of managers to the construction industry. In Scotland, with 23 students in their final year, Glasgow Caledonian University represents the major provider. In England and Wales, major providers are Leeds Metropolitan University, the University of Glamorgan, Oxford Brookes University and Northumbria University. The module content and teaching methods of these programmes are therefore particularly important in judging the standard of graduates.

University	No. Students	University	No. Students
Paisley	12	Coventry	23
Luton	12	Loughborough	23
Heriot-Watt	13	Sheffield Hallam	25
Reading	15	Southampton Institute	30
De Montfort	16	Brighton	30
Napier	20	UMIST	32
Wolverhampton	20	Ulster	33
Bolton Institute of HE	21	West of England	34
Liverpool John Moores	22	Leeds Metropolitan	50
Salford	22	Glamorgan	70
Central Lancashire	22	Oxford Brookes	80
Glasgow Caledonian	22	Northumbria	87
Anglia Polytechnic	23		

Table 1 Number of students in the final year of each CIOB-accredited BSc(Hons) construction management degree (March 1999)

Q2: How many honours dissertations per year address health and safety issues?

Table 2 indicates the wide variations that exist between universities in the number of health and safety dissertations, ranging from Sheffield Hallam University with 6 from 26 (23%), to Leeds Metropolitan University with only 1 from 50 (2%). The latter has a large number of students (50 in the final year), and it was recognised by the interviewee that the two per cent figure should be higher. The syllabus is now being reviewed to increase safety.

University	No. Students	University	No. Students
Paisley	1 from 12	Coventry	2 from 25
Luton	2 from 12	Loughborough	3 from 25
Heriot-Watt	1 from 13	Sheffield Hallam	6 from 26
Reading	1 from 15	Southampton Institute	1 from 30
De Montfort	1 from 16	Brighton	1 from 30
Napier	1 from 20	UMIST	2 from 32
Wolverhampton	1 from 20	Ulster	1 from 33
Bolton Institute of HE	2 from 20	West of England	3 from 35
Liverpool John Moores	1 from 21	Leeds Metropolitan	1 from 50
Salford	1 from 23	Glamorgan	5 from 70
Central Lancashire	4 from 23	Oxford Brookes	2 from 80
Glasgow Caledonian	5 from 23	Northumbria	7 from 87
Anglia Polytechnic	1 from 25		

Table 2 Number of students within each university selecting a dissertation topic relating to health and safety (March 1999)

Q3: What is the safety input as a percentage of the total hourly input per year?

Table 3 shows the programme managers' estimate of current safety input. Universities teaching safety solely on an ad hoc basis within modules found it difficult to quantify a response. Programme managers seemed unable to identify prescribed hours per module dedicated solely safety. Accurate figures could be given only where safety was taught as a dedicated series of lectures within a general module, or as a stand-alone module.

University	Percentage	University	Percentage
Paisley	10%	Coventry	10%
Luton	12%	Loughborough	12%
Heriot-Watt	10%	Sheffield Hallam	12%
Reading	3%	Southampton Institute	10%
De Montfort	15%	Brighton	5%
Napier	10%	UMIST	2%
Wolverhampton	5%	Ulster	5%
Bolton Institute of HE	5%	West of England	5%
Liverpool John Moores	10%	Leeds Metropolitan	1%
Salford	10%	Glamorgan	5%
Central Lancashire	10%	Oxford Brookes	2%
Glasgow Caledonian	10%	Northumbria	8%
Anglia Polytechnic	12%		

Table 3 Estimates of safety input as a percentage of total course input (March 99)

Q4: Which of the following forms does the health and safety input take?
(i) a completely separate health and safety module;
(ii) separate and identifiable lectures within another module; or
(iii) discussed ad hoc as safety measures and procedures.

Responses showed that the majority (48 per cent) provide health and safety input by separate lectures within modules. Forty-four per cent of universities, on the other hand, teach health and safety if and when it is deemed necessary, whereas only eight per cent (two universities) deliver a specific health and safety module. A sizeable number therefore cover health and safety topics, presumably to varying extents, within lectures on different subjects. Southampton Institute of Higher Education confirmed this by stating that health and safety is integrated at all times where appropriate within lectures. The University of Brighton considered that separate health and safety input was not necessary as continuous ad hoc input achieved the same results. This is, of course, a good argument, providing universities are sure that staff actually do this.

Q5: Is there identifiable safety coursework that the students must undertake?

Seventeen of the 25 universities contacted (68 per cent) do not set separate, identifiable health and safety coursework. Southampton Institute of Higher Education pointed out that, while its coursework is not specifically health and safety-oriented, students must address the relevant regulations, where required, in all coursework. This is an opinion that was echoed by most of the programme managers, regardless of whether specific health and safety coursework was set. However, most were unable to exemplify the point and the few who did mentioned site-based technical issues (for example, scaffolding, earthwork supports and use of plant). No interviewee offered responses that included, for example, developing a safety management system, or promoting a positive safety culture.

Q6: Are there specific health and safety examination questions?

Of the 25 universities questioned, 13 (52 per cent) acknowledged that they had set a separate, identifiable health and safety question in at least one examination, with the other 12 relying on health and safety being addressed where appropriate in other questions.

Q7: Is it possible to sit final exams without answering a health and safety question?

Eleven of the 13 universities responding 'yes' to question 7 also answered 'yes' to this question. Only two (Loughborough University and Glasgow Caledonian University) structure their examinations so that health and safety questions must be answered.

This means that students attending the other 23 universities do not have to answer a question specifically designed to test their knowledge of health and safety legislation or practice. Comments from the other universities resembled those in replies to question 6 (ie that health and safety should be addressed at all times where appropriate). Again, this point was not illustrated when prompted by the interviewer. The fact that programme managers could not, in the main, outline safety legislation covered (aside from the CDM Regs) or elaborate on taught safe systems of work, suggests a less than desirable safety content.

Q8: Should health & safety be compulsory within the CIOB Education Framework?

Only one programme manager believed that health and safety should not be a compulsory discrete subject within the CIOB's Education Framework. Views were mixed on the impact that making health and safety compulsory would have on students' learning and the level of guidance that would have to be issued to programme organisers. However, the consensus was that inclusion of safety within the Framework would give standards in the form of prescription that would provide a consistent level of health and safety education.

Q9: If the CIOB included safety in its Education Framework, would this:
(i) raise students' overall awareness of health and safety issues; or
(ii) make no difference as the current input is sufficient?

Although 96 per cent of programme organisers stated in response to question 8 that they thought that the CIOB should include health and safety in its Education Framework, only 32 per cent considered that it would raise their students' awareness of health and safety. The remainder suggested that their current input is sufficient, regardless of the absence of formal obligations. The conclusion from responses to questions 8 and 9 is that nearly all programme managers want safety course requirements to be prescribed, in order to ensure consistency and to raise standards in other institutions, but two-thirds of those interviewed believed that such prescription would make little difference to their own students.

Q10: Are you aware of the specific health and safety module within the CIOB's Professional Development Programme for graduate training?

The obligations placed on the graduate construction manager with regard to health and safety are extensive (as outlined in the Professional Development Programme – see Fig. 1). However, four programme managers (16 per cent) were unaware of the Programme's existence. Despite this, once the Programme had been explained, respondents believed that students were suitably prepared to tackle the training framework, even though the survey tends to suggest that undergraduates do not receive sufficient safety education.

Q11: Are you aware of Rule 15 [safety] of the CIOB's 'Regulations of professional competence and conduct'?

Twelve programme managers (48 per cent) were not aware of Rule 15.

Discussion

There is mounting pressure on the CIOB to include health and safety in its Education Framework. Two key issues extracted from the survey are outlined below:

(i) Legislation: The CDM Regulations have forced the construction industry to face health and safety issues. Health and safety must now be considered at all stages of the building process. It is argued that recent legislation has raised the profile and importance of health and safety to such an extent that universities must address these changing needs now.

(ii) Safety culture: Egan (1998) has criticised the culture of the industry and, in particular, its poor safety culture. It is necessary for the industry to embrace a culture whereby safe working practices are the norm.

Conclusions

The following conclusions have been drawn from the survey results:

1. CIOB-accredited construction degree programmes in the UK play an important role in the initial preparation of construction managers. However, in general, a lack of direction exists within CIOB-accredited construction degree programmes in the UK regarding the depth of health and safety education that undergraduates receive. The survey suggests that around half of the British universities recognise its importance and devote appropriate time to it, while others view it as an area of study that should be broached only when necessary.
2. Opinions vary considerably on the role that universities should play in undergraduate health and safety education. Respondents implied, with only a couple of exceptions, that industry has a much greater role to play than universities in the development of an individual's safety expertise. As a result, the health and safety requirements that the CDM Regulations have placed on the industry, for instance, are not being taught uniformly across British CIOB-accredited construction degree programmes.
3. The level of knowledge of health and safety legislation and practices among students is not assessed adequately. In all but two of the accredited universities, candidates can sit examinations and achieve a pass mark without having to answer a single question on health and safety. Eight of the 25 British universities set health and safety coursework. Some respondents suggested that health and safety was part of production coursework but, when asked to exemplify, no persuasive responses were offered.
4. Forty-eight per cent of CIOB programme managers were unaware of the CIOB's Rule 15 (outlining competence in health and safety). This is not acceptable.

5. The CIOB's interpretation of adequate health and safety input within its Education Framework differs from that of its Safety and Health Committee. This is compounded by the unreconciled relationship between the Education Framework and the Professional Development Programme with regard to safety.
6. The lack of primary reference to health and safety in the CIOB's Education Framework has led to a situation where health and safety education is at the discretion of programme managers or even individual lecturers.
7. This paper had one objective: 'To what extent does the CIOB's Education Framework include safety?'. Evidence from the survey of programme managers of British CIOB-accredited construction degrees suggests that the Education Framework does not totally exclude safety, as passing references can be found to the term "safety considerations". However, the survey does indicate that sufficient attention is not currently being paid to health and safety within degree programmes. Although production lectures occasionally include health and safety issues, the form that this takes is less than transparent. The CIOB must place health and safety education in a more central role if the health and safety improvements envisaged by the Construction Task Force (Egan 1998) are to be achieved.

Recommendation

Similar types of study should be conducted within other countries represnted at this conference. For instance, studies within Hong Kong educational institutions who offer qualifications in construction, and in particular those Hong Kong Universities who offer CIOB accredited Construction Management degrees, would offer an indicator of the educational importance of safety. This type of replication research will assess students' Health and Safety education experience (extent and depth of safety learning). This will give a good indicator of the status of safety within each respective copuntries Higher Education system.

Postcsript

This research was completed over one year ago and since the completion of this study, several high profile safety culture initiatives have been launched. Ambitious targets have been set to reduce accidents across all industries ('Revitalizing Health and Safety') and in construction in particular ('Turning Concern into Action'). These initiatives have specifically targeted *"increased education levels within safety-critical professions"* and this would include Construction Management. It is understood that the CIOB intend to responded to this demand by putting together an action-plan to address the shortfall in safety content within their Education Framework. At August 2001, the details of this are not publicly known. However, it is encouraging to see that CIOB and therefore accredited degree are at last beginning to 'see the light' after years of indifference.

References

Chartered Institute of Building, 1994a, *Membership regulations and graduate notes on the professional interview*, CIOB, Ascot, Berkshire.

Chartered Institute of Building, 1994b, *Regulations of professional competence and conduct*, CIOB, Ascot, Berkshire.

Chartered Institute of Building, 1995, *Higher education discipline network in building management*, CIOB, Ascot, Berkshire.

Chartered Institute of Building, 1996a, *Education Framework*, CIOB, Ascot, Berkshire.

Chartered Institute of Building, 1996b, *Directory of construction courses 1996/97*, CIOB, Ascot, Berkshire.

Chartered Institute of Building, 1996c, *Health & Safety academic course questionnaire and analysis of results*, CIOB, Ascot, Berkshire.

Chartered Institute of Building, 1998a, *Chairman's report from the members of the Safety, Health and Welfare Committee to the members of the Professional Services Board*, CIOB, Ascot, Berkshire.

Chartered Institute of Building, 1998b, *Professional development programme*, CIOB, Ascot, Berkshire.

Confederation of British Industry, 1990, *Developing a safety culture,* CBI, London.

Davies V. J. and Tomasin K., 1996, *Construction safety handbook*, Telford, London.

Department of Employment, 1971, *Glossary of training terms*, HMSO, London.

Egan J., 1998, *Rethinking construction.* Report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality of UK construction, DETR, London.

Garavan T.N., 1997, Training, development, education and learning: different or the same?, *Journal of European Industrial Training,* 21, 2, 39–50.

Gilley J.W. and Eggland S A, 1989, *Principles of human resource development*, Addison-Wesley Publishing, Reading.

Lester-Smith W.O., 1966, *Education: an introductory survey*, Penguin, Harmondsworth.

Lewin K., 1951, *Field theory in social sciences*, Harper, New York.

Peters R.S., 1972, *Education and the educated man*, Routledge and Kogan Page, London.

Riggs L.S., 1988, Educating the construction manager, *Journal of Construction Engineering and Management*, 114, 2, 279–285.

ANALYSIS OF CONSTRUCTION SITE INJURIES IN PALESTINE

Enshassi, Adnan School of Civil Engineering, Islamic University of Gaza, Gaza Strip, Palestine
Mayer, Peter E. Institut fuer Geotechnik und Baubetrieb, TUM, Muenchen, Germany

KEYWORDS

Construction, site injuries, safety, codes, Palestine

Introduction

Construction fields are considered dangerous places. A large number of people die on them every year. Many site injuries result from people falling from structures like roofs and scaffolds, or being hit by falling objects. Many others are caused by the misuse of mechanical plant and site transport, including hoists (Frayer, 1995). There is nearly always keen competition for new contracts and site personnel are often under pressure to work to tight time and cost constraints. It is hardly surprising that safety is often neglected.

In spite of the low attention often given to construction sites injuries in many countries, the statistics continue to be alarming. For instance, fatal accidental injury rates in the United Kingdom and Japan are reported to be four times higher in the construction industry, when compared to the manufacturing industry (Bentil, 1990). Construction is often classified as a high-risk industry because it has historically been plagued with much higher and unacceptable injury rates when compared to other industries. In the United States, the incidence rate of accidents in the construction industry is reported to be twice that of the industrial average. According to the National Safety Council, there are an estimated 2,200 deaths and 220,000 disabling injuries each year (National, 1987).

Over the years, construction has been a major contributor to the national economy. Presently, however, its share of the GNP is about 5-7 percent. In the 1970's this percentage was roughly 7 - 10 percent (Koehn, 1996). In Palestine, construction share of the GDP in 1994 is about 16.8, in 1992 the percentage was about 13.0 (Table 1). Therefore, it is crucial to take safety factor into consideration in the construction industry in Palestine in order to minimize the number of injuries on construction fields. This paper presents an analysis of statistical date on construction site injury between 1999 to 2000 published by the Ministry of Labor.

Safety Management

The attitudes and behavior of construction workers and managers towards safety is undoubtedly a major factor in the poor accident record of the industry in Palestine. Many workers and managers see construction as a rough job for tough, self-reliant people. It is widely believed that building to tight deadlines at low cost is incompatible with high safety standards (Adb. Ghani, 1996).

Construction workers accept that their work is demanding and risky, although they usually underestimate the risk. Group norms may cause individuals to ignore safety measures for fear of appearing cowardly to their workmates (Laney, 1982). Many managers and workers resent outside pressures on them to comply with safety regulations and sometimes make collusive arrangements to avoid them. Unfortunately, in Palestine safety regulations do not exist till now (Enshassi, 1998).

If construction site is to become safer, the major task is to change people's attitudes. This may mean changing contractors and clients' attitudes too. They may have to accept that there is a safety premium to pay on the cost of construction; that if getting a rock-bottom price means that people will be killed or seriously injured, then the price is too low.

The management of labor safety and health at a construction site is the responsibility of the employer. The implementation of a specific safety plan is the responsibility of various sections and departments of a company. Depending upon the scope and nature of the organization, the employer should direct the labor safety and health management committee to perform the following duties (Labor safety, 1991):

- Prepare a thorough occupational accident prevention plan and direct implementation on sites.
- Plan and monitor labor safety and health management in all divisions.
- Plan and check regularly the labor safety and health installations.
- Direct and supervise safety personnel in conduction inspection tours, periodic inspections, and priority inspections of the work environment.
- Plan and conduct labor safety and health education and training.
- Respond to and supervise occupational accident investigations and compile occupational accident statistics.
- Provide the employer with data and suggestions related to labor safety and health management.

Industry Category	**Year 1992**	**Year 1993**	**Year 1994**
Construction	13.0	16.4	16.8
Agriculture	35.5	29.0	33.3
Industry	7.4	8.4	8.2
Government	10.5	11.8	11.2
Other GDP	33.6	34.4	30.5
Employment in West Bank and Gaza	204.0	232.0	249.0
Employment in Israel	116.0	83.0	68.0

Source: IMP and PRCDAR

Table 1 Economic Structure Percentage of GDP

Year	**Total Industrial Injury (A)**	**Construction Injury (B)**	**(B/A) X 100% (%)**
1994	22	1	4.5%
1995	32	1	3.1%
1996	23	1	4.3%
1997	48	6	12.5%
1998	35	9	25.7%
1999	75	31	41.3%
2000	247	89	36%
Average Percentage Construction in Injury from the Total Industrial Injury			18.2%

Source: Ministry of Lobour, PNA, Annual Reports

Table 2 Construction Injury As Compared To Total Industrial Injury

The construction industry should be interested in safety regulations and implementation for humanitarian and economic reasons. In humanitarian terms, if accidents occur, a construction firm and/or its employees may suffer pain and/or loss of life due to an accident. In addition, its safety record will be lower and there may be a loss of the firm's reputation. In economic terms, an effective safety management program may be profitable for a construction firm. This is because accidents have high direct (medical, worker's compensation) and indirect (reduction of productivity, job schedule delays, rework) costs.

Analysis of the Construction Site Injuries

The analysis was based on the statistical data published by the Ministry of Labor in Palestine between 1994 and 2000. Table (2) shows that from 1994 to 2000 the total industrial injuries increased from (22) cases to (247) cases. In addition, the number of reported construction site injuries increased from (1) case to (89) cases. The site injuries account for an average of (18.2%) of the annual total industrial injuries. However, it has been found that the majority of contractors in Palestine did not report site injuries to the Ministry of Labor (Enshassi, 1997). Two main reasons were found behind that. Firstly, the employees have no insurance, and, secondly, the employers are concerned to loose their reputation if they report the site injuries. Therefore, it is uncertain whether the number of injuries which was published by the Ministry of Labor was correct or not.

It can be seen from table (3) that construction site injuries (28.6%) are the highest among other major industrial injuries. It can be observed from tables (2) and (3) that construction site injuries have dramatically increased in 1999 (41.3%) and in 2000 (36%) compared to 1994 (4.5%). This can be traced to the increase of building and construction activities aiming at the reconstruction of newly developing Palestine after the peace accord. The International and Arab communities have contributed to the Palestinian National Authority in 1994 US$511,738M and in 1995 US$429,995M and in 1996 US$516,276M in order to reconstruct Palestine (PECDAR, 1997).

Due to the urgent need for improving the infrastructure in Palestine, an emergency program was established to reconstruct and build as much as possible in a short duration. This situation puts a lot of pressure on clients and contractors as well, in order to complete a number of projects (e.g. housing, schools, roads, water and sewage) in a short time. There is still an absence of safety codes and regulations in Palestine. This has led to an increase in construction site injuries. It should be noticed that the figures presented in tables (2) and (3) which were published by the Ministry of Labor might not be realistic.

According to a survey conducted by the author (Enshassi, 1997), the number of construction site injuries is far more than what was published by the Ministry of Labor. It has been observed that when an accident happens on a construction site, the employer does not report to the concerned department. He tries to solve the problem internally according to the culture and attitudes of people involved. This unhealthy system has contributed negatively to the safety requirements on the site. In addition, no body can learn what the cause of the accident is and how it can be avoided in the future. Moreover, no reliable statistical data is available regarding the real number of injuries on construction projects.

Year	All Industries	Manufacturing & Processing	Wood Workshops	Tiles & Blocks Factories	Services	Construction	Plastic Factories	Electricity	Sanitary Services	Others
1994	22	7	2	3	1	1	1	--	--	7
1995	32	11	6	2	1	1	1	--	--	10
1996	23	10	1	1	1	1	--	--	--	9
1997	48	6	8	5	7	6	1	3	8	4
1998	35	6	5	6	--	9	--	2	2	5
1999	75	8	6	12	1	31	2	5	4	6
2000	247	32	15	19	12	89	15	16	15	34
Total	482	80	43	48	23	138	20	26	29	75
%	100	16.6	8.9	10	4.8	28.6	4.1	5.4	6	15.6

Source: Ministry of Lobour, PNA, Annual Reports

Table 3 Total Major Industrial Injury According to Type & Industry

Most construction site injuries in Palestine were subjected to the production-related workers and equipment operators. The type of accidents mainly are the result of construction workers, include being struck by falling objects and stepping on, striking against or being struck by objects. The statistics show that the reasons for accidents were falling (18%), equipment and plant (7%), material dropped from a height (9%), misuse of manual equipment (3%), steel works (6%), nails (49%) and other miscellaneous (8%). The nature of the injuries mainly consists of fractures, wounds, cuts, sprains and pains, confusions, crushings and superficial injuries. Most frequent site injuries occur as a result of poor usage of safety belts, safety helmets and boots, and over exertion of construction workers on site.

Degree of Injury

Construction site injuries consist of minor injury, disablement and fatality. Table (4) shows the degree of total industrial injuries. In 1994, it has been found that (7) cases were minor injuries, (13) cases were disablement and (2) cases were fatality. In 2000, it can be seen that (42) cases were minor injuries, (198) cases were disablement and (7) cases were fatality. This indicates that safety regulations and measures were not considered by employees.

Table (5) shows the percentage of construction injuries over the total industrial injuries. In 1994, one minor injury case was found, and no single disablement or fatality was found. In 2000, (51) minor injury cases were found, (34) disablement cases were observed and (4) fatal cases were found. This indicates that the rate of injury has increased for all degree of injuries. It means that safety procedures were not a priority for most employees in Palestine.

By comparing the degree of construction injuries to the total industrial injuries (see tables 4, 5) the percentage of minor injury, disablement and fatality of the construction over all the industries was gradually increasing from 1994 to 2000. The percentage of minor injuries increased from (4.5%) to (20.7%) and disablement rose from (0%) to (13.7%), and it also similarly occurred to the fatality which rose from (0%) to (1.6%) of the total industrial fatality. Unfortunately, the Ministry of Labor has no data regarding the financial implication of construction injuries. However, insurance, claims, delay in construction works and compensation paid to the affected workers or families have financial implications as a result of construction site injuries.

Year	**Total Industrial Injury**	**Minor Injury**		**Disablement**		**Fatality**	
		No.	**%**	**No.**	**%**	**No.**	**%**
1994	22	7	32%	13	59%	2	9%
1995	32	15	46%	16	50%	1	4%
1996	23	13	57%	10	43%	--	--
1997	48	23	48%	23	48%	1	4%
1998	35	20	57.2%	14	40%	1	2.8%
1999	75	37	49%	35	47%	3	4%
2000	247	42	17.2%	198	80%	7	2.8%

Source: Ministry of Lobour, PNA, Annual Reports

Table 4 Degree of Total Industrial Injury

Year	**Total Industrial Injury**	**Construction Injury**	**Minor Injury**		**Disablement**		**Fatality**	
			No.	**%**	**No.**	**%**	**No.**	**%**
1994	22	1	1	4.5%	--	--	--	--
1995	32	1	1	3.1%	--	--	--	--
1996	23	1	--	--	1	4.3%	--	--
1997	48	6	3	6.25%	3	6.25%	--	--
1998	35	9	3	8.6%	5	14.3%	1	2.8%
1999	75	31	16	21%	13	17.3%	2	3%
2000	247	89	51	20.7%	34	13.7%	4	1.6%

Source: Ministry of Lobour, PNA, Annual Reports

Table 5 Percentage of Construction Injury Over the Total Industrial Injury (According to The Degree of Injury)

Conclusions

The analysis of the data presented in this paper brings about the following findings:

- Construction site injuries account for an average of (18.2%) of the annual total industrial injuries, this is considered relatively high.
- The number of construction site injuries (28.6%) is the highest among other major industrial injuries. This is quite an alarming result.
- The majority of contractors in Palestine did not report construction site injuries to the Ministry of Labor. Contractors try to solve the workers injury problems internally according to the local culture.

- Safety codes and regulations still do not exist in Palestine. Therefore, there is an urgent need to establish and implement safety codes in Palestine.
- Most frequent construction site injuries occur as a result of poor usage of safety belts, safety helmets and boots and over exertion of construction workers on site.
- The common types of injury were fractures, wounds and cuts and sprains and strains.

The above mentioned findings are quite alarming to those concerned about site safety in Palestine. It is more so if we consider, the unreported injuries. It is important to eliminate the cause of accidents in order to minimize the number of injuries. Construction site safety precautions should be promoted in all construction sites.

Recommendations

The job safety plan must be based on analysis of project risks and a preventive program specifically modeled to combat the particular and peculiar hazards of that project. In addition, construction workers often tend to be unmindful of safety regulations. It is recommended that construction workers should be constantly reminded of the safety problems present through their supervisors. Clear instruction is required concerning how specific tasks should be carried out so as to minimize the chances of accidents and injuries. The success of a safety program is contingent upon the advance recognition of the hazards present and personal safety instruction to the tradesmen before hazardous work is initiated.

In Palestine, it is the responsibility of contractor to provide a safe and healthy work environment. This must be accomplished in conformity with established standards that are designed to prevent the risk of injury caused by tools, machinery, equipment, etc. It is recommended that safety codes and regulations should be created and updated frequently. The purpose of these codes is to prevent injuries, fatalities, and structural failures. They also indirectly reduce the expenses and assist in maintaining the reputation of construction firms.

The Ministry of Labor should put more emphasis on safety requirements and implementation. The Ministry must set up a safety committee, the main functions of this committee are:

- To monitor working arrangements on site with regard to health and safety.
- To develop site safety rules, safe systems of working and guidelines for hazardous operations.
- To study accident trends and safety reports.
- To investigate the causes of serious accidents.

Effective implementation programs should focus on both the physical and the behavioral sides of safety and health. An adequate safety program can assist minimizing construction site injuries which in return can reduce financial loss, increase productivity, enhance the potential profit, and above all save lives of work teams to help the industry and nation as a whole.

There is a pressing need to make students of civil engineering, architecture in Palestine more aware of the importance of health and safety. This can be accomplished by incorporating some courses on construction safety in the core curricula of such programs. In addition, there is a need to conduct training programs on a regular basis for construction engineers and workers about safety rules and regulations. Construction site safety should be seriously considered as one of the keys to successful construction industry.

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References

Abd. Ghani, K., Construction Site Injuries: The Case of Malaysia, Proceedings of the First International Conference of CIB Working Commission W99 - Lisbon - Portugal, 1996.

Bentil, K, The Impact of Construction Related Accidents on the Cost and Productivity of Building Construction Projects, Proceedings of the CIB 90, Vol. 6, Management of the Building Firm, Sydney, 1990.

Enshassi, A., Construction safety : issues in Gaza Strip, paper published in the International Journal of Building Research and Information, Vol. 25, No. 6, 1998.

Enshassi, A., Construction Site Injuries in Palestine: Causes and Effects, unpublished paper, 1997.

Frayer, B., The Practice of Construction Management, London, Collins, 1995.

Koehn, E. and Pan, C, S, Comparison of Construction Safety and Risk Between USA and Taiwan, Proceedings of CIB - W65, The Organization and Management of Construction, UK, 1996.

Laney, J. C., Site Safety, London and New York: Construction Press, 1982.

Labor Safety and Health Act, Council of Labor Affairs, Executive Yuan, Taiwan, Republic of China, 1991.

National Safety Council, OSHA Investigates Connecticut Apartment Project Collapse. OSHA Up to Date, Vol., XVI, No. 5, Chicago, Illinois.

PECDAR, Monthly Information Bulletin, Jerusalem, Vol. 1, No. 7, 1997.

COMPARATIVE STUDY ON SAFETY AND APPLICATION OF BAMBOO AND METAL SCAFFOLDING IN HONG KONG

Fang, Dongping Department of Construction Management, School of Civil Engineering., Tsinghua University, P.R. China
Wu, Shenghou Department of Construction Management, School of Civil Engineering., Tsinghua University, P.R. China
Hua, Bin Department of Construction Management, School of Civil Engineering., Tsinghua University, P.R. China
Wong, John Gammon Construction Co., Ltd.

Introduction

Finance, real estate, tourism and manufacturing are the four major industries in Hong Kong. Construction industry, which relate to the real estate industry, has been playing an important role in the economy of Hong Kong. Being an essential means and equipment for construction, scaffolding provides workers with working platform, safe access and protection.

It is because of its lightweight, skillful workers and especially its low price, the bamboo scaffolding has the advantages in construction bidding process. However, the disadvantage is its low strength, inflammableness, irregular shape, changeable nature and uncertain quality that badly influence the construction safety and quality as well as companies' image. The metal scaffolding overcomes those shortcomings of bamboo scaffolding, and it also has such advantages as easy for erection, safe and reliable, and meeting the demand of standardization and automation in construction industry. Now, more and more contractors are considering to use it, although the price is much more expensive than bamboo scaffolding. Therefore, metal scaffolding remains in inferior position to their competitor. Since bamboo and metal scaffolding have their own advantages and disadvantages, both have been argued as being better for Hong Kong construction industry.

It is recorded that three quarters of the construction fatal accidents occurred in Hong Kong are falls from height. D. Mak [1] pointed out that among 41 fatal accidents occurred on construction sites in 1997s, 20 were related to falls, in which 6 (30 %) were workers falling from bamboo scaffolding [2]. K.W. Wong [3] studied the management of bamboo scaffolding and provided relevant useful information for carrying out supervision and inspection of works associated with bamboo scaffolding and to improve the safety of bamboo scaffolding in Hong Kong. W. Y. Fu [4] indicated that bamboo scaffolding provides a flexible, practical and economical means of support. He also pointed out that there was no specific regulations concerning design, calculation and drawing of bamboo scaffolding in Hong Kong and that qualification of structural design and construction of bamboo scaffolding would be depended on the experience of scaffolding workers. However, in many aspects of the safety, it need to be improved. S.L. Chan [5] suggested a computerized method to design and analyze bamboo scaffolding. Y. Y. Wong [6] and J. Chow [7] discussed the requirements of laws and regulations for inspection and supervision of bamboo and metal scaffolding and they had suggested a method to improve the current situation. However, there are seldom research studies on comparing safety and future application of the two kinds of scaffoldings.

Objectives of this study are to synthetically and systematically evaluate the application of two kinds of scaffolding by investigating and comparing their safety performance, economical effectiveness and influences on other major factors, and to explore the development trend of scaffolding in Hong Kong and the countermeasures the government and contractors should consider.

Research Methodology

Figure 1 shows the research framework of this project. Safety performance and economical effectiveness are the emphasis in this research framework. As temporary structures, scaffolding is provided by suppliers, rented by contractors, and erected and dismantled by workers. Workers and the scaffolding form a human-environment system in which safety is the emphasis. Contractors and suppliers form a market system in which economic issues are the emphasis.

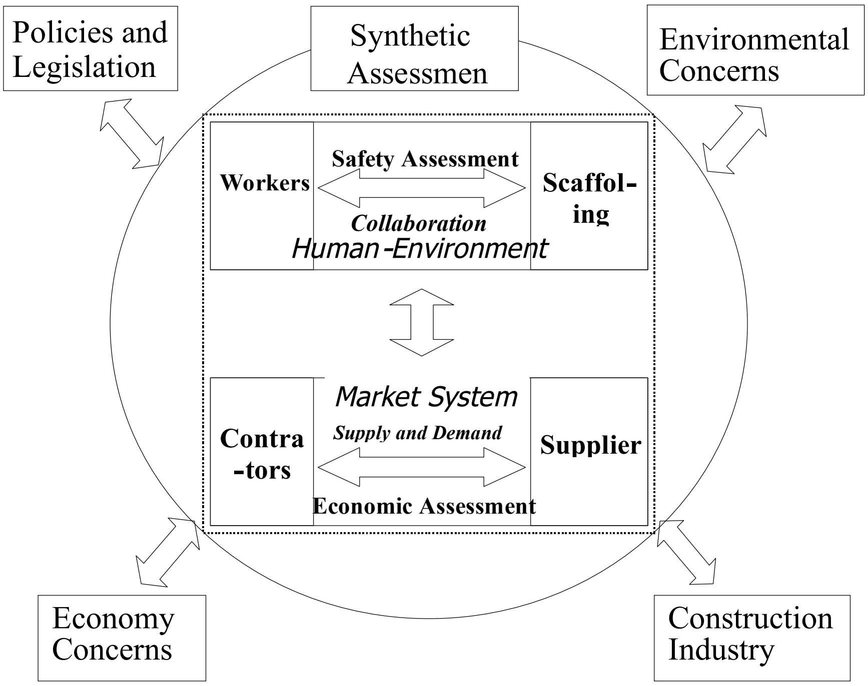


Figure 1 Research Frame

Comparison on safety performance

Scaffolding is erected by scaffolders and its quality is directly influenced by scaffolders' skills. Besides, scaffolding structure is the working platform for workers working on it and this working condition would influence the safety and quality of these workers' performance. The contractors are responsible for the management of erecting, dismantling and carrying out daily maintenance of scaffoldings. In this human-environment system, the safety of the two kinds of scaffolding will be assessed by hazard analysis, analysis hierarchy process and experimental psychology based method.

Hazard analysis [8] is originated from a method adopted by America Atomic Energy Commission. Its principle is to evaluate the risk of an event by comprehensively analyzing the probability of occurrence and the consequences of this event. The process is to decompounds a complex safety assessment problem into several sub-problems that can be evaluated independently, and then to assess these sub-problems independently, and finally to sum up results of sub-problems to an overall conclusion of the original problem. Thus, the risk index of an event can be obtained through following functions:

$H_i = L \times E \times C$

H_i — risk index of an factor

L — failure probability of an factor

E — accident probability of a failed factor

C — possible outcome of a failed factor

$$H = \sum_{i=1}^{n} H_i$$

N — number of factors

Analytic Hierarchy Process (AHP) [9] has been used to analyze complex decision-making problems in social, political, economical and technological field. Its solution process is as follows. 1) A complex problem is structured by decomposing it into a hierarchy with enough levels to include all factors to reflect the goals and concerns of the decision maker; 2) Elements are compared in a systematic manner using the same scale to measure their relative importance, and the overall priorities among the elements within the hierarchy are established; 3) The relative standing of each alternative with respect to each criterion element in the hierarchy is determined using the same scale and; 4) The overall score for each alternative can then be aggregated, and the sensitivity analysis can be performed to see the effect of change in the initial priority setting, while the consistency of comparison can be measured.

The experimental psychology[10] based test uses multi-channel physiology equipment to measure the influence of scaffolding conditions on human beings by measuring mental pressure and the level of nervousness caused by different working conditions (bamboo scaffolding and metal scaffolding). The authors developed this method to provide an objective tool for assessing working conditions' impact on workers' behaviors, especially on safety behaviors.

Comparison on economical effectiveness

Rents of scaffoldings are determined by its cost and market share, and directly influence the cost of a construction project as well as contractors' profit. The lifetime analysis of net present value and the payback period of the two kinds of scaffoldings is conducted from both suppliers' and contractors' point of view. After major economic indexes were defined based on the first survey in the summer of 2000, a questionnaire survey was conducted, and the static cost and dynamic cash flow are analyzed.

Synthetic comparison

Safety and economy are two correlated factors that determine contractor's choice of scaffoldings. The study takes the two major aspects and other factors such as construction quality and company's images into consideration to assess these two kinds of scaffoldings synthetically, so as to provide fundamental information for the government to enact relevant policies and for contractors to choose scaffoldings.

Questionnaire Survey and Analysis

Four sets of questionnaires and a survey on economical issues were developed. 20 pieces of questionnaire for expert were distributed, in which 17 pieces were replied effectively. 400 pieces of questionnaire for workers were distributed, in which 238 pieces were replied and 180 pieces were effective. 28 pieces of questionnaire for safety officers are distributed, all of which were replied effectively. 8 suppliers were surveyed, 10 construction sites were visited, and 30 project managers were inquired. Based on the outcome of these questionnaires and surveys, the safety performance and economic effectiveness of bamboo and metal scaffolding were studied, compared and analyzed by above mentioned methods.

Safety performance

By hazard analysis, the risk of accident in metal scaffolding is found to be 0.32 and that in bamboo scaffolding is found to be 0.68. By AHP, the risk of accident in metal scaffolding is found to be 0.39 and that in bamboo scaffolding is found to be 0.61. The safety assessment by the two methods results in consistent conclusions. Figure 2 shows the risk index of every factor by hazard analysis. The result of the experimental psychology based test indicates that the workers in bamboo scaffolding are easier to get nervous, tired, and to act erratically, all of which are easy to make accidents happen [10].

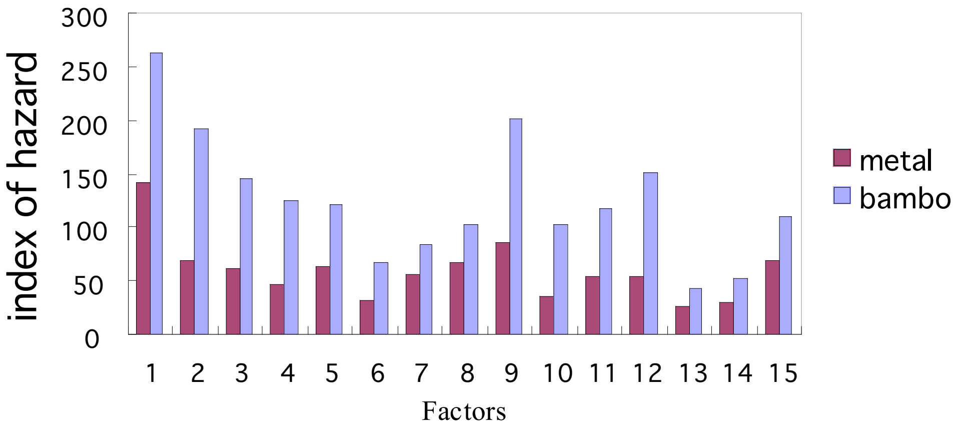


Figure 2 Hazard indexes of factors

1) broken putlog or lacking in putlog; 2) flabby or broken node; 3) rotten member of scaffolding; 4) broken member of scaffolding; 5) without or broken working platform; 6) without or broken toeboard; 7) without or broken guardrail; 8) broken bracing; 9) overload; 10) hit by downfallen object; 11) without safety belt; 12) without place the safety belt fasten; 13) without safety helmet; 14) tired and distracted; 15) violate operation regulation

Table 1 shows the safety risk ranking by AHP. The results of questionnaire survey also indicate that the safety knowledge is very important. The professional skill and safety knowledge provide workers with the capability to identify hazard and to decrease unsafe behaviors. It is also found that the safety training should pay more attention on the putlog, bracing, and so on to ensure workers to understand the consequences of destroying these parts of scaffolding. It is also very important to improve the working conditions of scaffolding because the spacious and neat working platform could decrease workers' nervous emotions and unsafe behaviors. Providing better working platform, safety belt and places for fastening safety belt could improve company's safety performance. Discovering and repairing destroyed parts in time will decrease the unsafe condition.

Economical effectiveness

The cost of bamboo scaffolding is low and the initial investment of metal scaffolding is relatively higher, the rent of metal scaffolding is generally 2~2.5 times of that of bamboo scaffolding. The payback period of bamboo scaffolding is shorter and the risk is low, while the payback period of metal scaffolding is longer and the risk is higher. For the metal scaffolding, the rent could be decreased if there is a stable market demand. The integral elevated scaffolding system, which has been widely used in China, has such advantages as short payback period, low risk and less material consumption.

Factors	Hierarchy	Factor and weight					Weight
	B	Human（B1）		Condition（B2）			
		0.656		0.344			
	C	Physic and mentality（C1）	Knowledge （C2）	Material （C3）	Erecting and dismantling （C4）	Destroyed by outside action （C5）	
		0.485	0.515	0.382	0.383	0.235	
	B*C	0.318	0.338	0.131	0.132	0.081	
Human	Degree of fatigue (D1)	0.601					0.19
	Working space（D2）	0.399					0.13
	Professional skill（D3）		0.498				0.17
	Safety knowledge（D4）		0.502				0.17
Condition	Selecting material（D5）			0.500			0.07
	Maintenance（D6）			0.500			0.07
	Design（D7）				0.594		0.08
	Experience （D8）				0.406		0.05
	Environment（D9）					0.455	0.04
	Human（D10）					0.545	0.04

Table 1 Safety risk ranking

Synthetic comparison

Metal scaffolding is better than bamboo scaffolding when synthetically comparing their safety performance, economic effectiveness, as well as quality, company's images and so forth. The synthetic assessment value is 0.87 for metal scaffolding and is 0.67 for bamboo scaffolding. Metal scaffolding is higher in price, and the cost difference between the two kinds of scaffolding will increase dramatically with the increase of the height of building. The rent of metal scaffolding wouldn't decrease largely on the basis of the information from suppliers. The integral elevated scaffolding system gains excellent synthetic assessment result and its cost is relatively lower. At the same time, the unit cost will decrease with the increase of the height of building. The assessment, synthetically considering safety, economy and other factors indicates that the metal scaffolding has advantages over bamboo scaffolding and that integral elevated scaffolding would have a bright prospect in Hong Kong because of its safety performance and reasonable cost.

CONCLUSION

This paper briefly introduced findings of a comparison study between metal and bamboo scaffolding on their safety performance and economical effectiveness. It is found that metal scaffolding is much safer than bamboo scaffolding, while bamboo scaffolding is much cheaper. To consider both safety and economic factors synthetically, it is found that contractors should be encouraged to use metal scaffolding for safer construction.

Acknowledgements

Appreciation is given to the Works Bureau of Hong Kong, Gammon Construction Ltd., Wei Loong Scaffolding Works Co. Ltd. and AES Scaffolding Engineering Ltd. etc. for their great support to this research. Professor Francis Wong, Professor Albert Kwok of Hong Kong Polytechnic University and Professor S.W. Poon of Hong Kong University contributed their knowledge and experience. This research was also supported by the National natural science foundation of China (Grant number 70172005) and the Beijing natural science foundation (Grant number 8002013).

References

[1] Dominic Mak Hung-kae Legislative Control Regime for Ensuring Safe Use of Scaffolding, Symposium on Bamboo and Metal Scaffolding 1998.

[2] Wong Che Keung, Identification of the Key Factors Involved in Bamboo-scaffolding-Related Accidents on Construction Sites in Hong Kong A report submitted as partial fulfillment of the requirements for master of applied science (safety management) 1998.

[3] Francis K.W. Wong, Bamboo Scaffolding-Safety Management for the Building Industry in Hong Kong, April 1998,Hong Kong Polytechnic University.

[4] Fu W.Y., Bamboo scaffolding in Hong Kong, The Structural Engineer 202-204, Volume 71, No11,1 June 1993.

[5] Siu-lai Chan and Francis K W Wong, etc., Empirical Design and Structural Performance of Bamboo Scaffolding, Symposium on Bamboo and Metal Scaffolding 1998.

[6] Wong Y.Y., Maintenance and Inspection of Bamboo and Metal Scaffolding, Symposium on Bamboo and Metal Scaffolding 1998.

[7] Joseph Chow Ming－kuen, Ng Hon-keung, Independent Checking and Control of the Design and Erection of Metal Scaffolding, Symposium on Bamboo and Metal Scaffolding 1998.

[8] Aimin Xiao, Safety system Engineering, China Labours Press,1982.

[9] Shubai Xu, Practical decision-making method—The theory of Analytic Hierarchy Process, Tianjin University Press, 1988.

[10] Fang Dongping, Rongxiang Lan, Wu Shenghou, Hua Bin, “Workplace Safety Evaluation Based on Experimental Psychology”, Proceedings of the 3rd International Conference on the Implementation of Safety and Health on Construction Sites, 2002, Hong Kong.

WORKPLACE SAFETY EVALUATION BASED ON EXPERIMENTAL PSYCHOLOGY

Fang, Dongping Department of Construction Management, School of Civil Engineering, Tsinghua University, Beijing, P.R. China

Lan, Rongxiang Department of Construction Management, School of Civil Engineering, Tsinghua University, Beijing, P.R. China

Hua, Bin Department of Construction Management, School of Civil Engineering, Tsinghua University, Beijing, P.R. China

Wu, Shenghou Department of Construction Management, School of Civil Engineering, Tsinghua University, Beijing, P.R. China

Li, Ning Department of Construction Management, School of Civil Engineering, Tsinghua University, Beijing, P.R. China

KEYWORDS

Experimental Psychology; Working Conditions; Safety Evaluation; Scaffoldings; Spectrum Estimation

Introduction

Industrial accidents and occupational diseases have negative influence on people, organizations, government and societies [1]. With the development of economy, the demand for workplace safety has been increasing. The employers come to take cognizance that improving workplace safety would reduce the loss of accidents and enhance the employees' loyalty and increase the employees' working efficiencies [1].

To promote the safety performance on construction sites, workplace safety evaluation plays a very important role. At present, there are different kinds of methods related to safety researches, such as safety checklist, preliminary hazard analysis, event tree analysis, fault tree analysis, index assessment etc [2]. However, these methods focus on identification and control of hazards, varied types of physical or chemical index and very simple biological inspection. They emphasize the physical environment aspects but neglect the human's reaction from the viewpoint of Ergonomics.

Bamboo scaffoldings are widely used in Hong Kong. Bamboo has anomalistic shape and significant variance in its properties. Recently, metal scaffoldings come to be used in Hong Kong because they are easy for erection and quality control. To compare the safety performance between bamboo scaffoldings and metal scaffoldings in Hong Kong, this paper conducts workplace safety evaluation based on experimental psychology by comparing human's physiological and psychological reaction (pulse, pectoral breath, ventral breath and electrodermal response) in different working conditions.

Description of the Experiment

Experiment preparation

Volunteers were randomly divided into 3 groups with around 10 examinees in each group. The first group is for the test in bamboo scaffoldings environment, while the second group in the metal scaffoldings environment and the third group in a normal in-service building for benchmarking. Three buildings, one using bamboo scaffolding, one using metal scaffolding, and one was in service, were chosen to conduct the experiments. In each group, the pulse, pectoral breath, ventral breath and electrodermal response were measured two times before (on the ground) and after the examinees walking through the scaffoldings or equivalent altitude in the benchmarking building to compare the differences.

It is required that the examinees are male and similar in basic conditions, such as age, height, weight, experience and so on. The experiments of the three groups were taken at almost same time of each day with similar external environment, such as weather, temperature and so on. The condition of the area of the examinees' movement, such as the height of scaffoldings, the length of movement, safeguard and so on, was similar except the style of the scaffoldings.

The experiment was made in the following sequence:
1. The preliminary remarks were made and measuring equipments were shown to the examinees;
2. Serial numbers were given to each examinee;
3. The physiological indexes of the examinees were recorded in quit, steady and isolated condition when they gathered under the buildings;
4. The examinees were asked to go upstairs and took a rest of half hour in the test area;
5. The examinees were asked to walk through the scaffoldings (test area) in prescribed speed (normal speed for a worker to pass it) one by one;
6. The physiological indices (pulse, pectoral breath, ventral breath and electrodermal response) of the examinees were recorded as soon as they walked through the scaffoldings.

Data Collection

Three experiments were conducted as shown in Table 1.

Group	Number of Examinees	Location	Time	Condition of External Environment
Benchmarking	14	Industrial Center of Hong Kong Polytechnic University	PM, January 15, 2001	The weather of three days was similar. It was quite ablare on site.
Bamboo Scaffoldings	11	Students' Dormitory of Hong Kong Polytechnic University	PM, January 16, 2001	
Metal Scaffoldings	8	The Elementary School in Jiang Jun Ao, Hong Kong	PM, January 17, 2001	

Table 1 Information of the experiments

The examinees' four physiological indices, pulse, pectoral breath, ventral breath and electrodermal response, were measured with polygraph. Each examinee got four curves of the four indexes lasting for 70~120 seconds on the ground, and other four curves on the scaffoldings or equivalent altitude in benchmarking building. The data was stored in a computer for further analysis.

There is a limitation that the polygraph used in this experiment can record only the relative magnitude of the signals, instead of the absolute magnitude. So from the collected signals, the absolute magnitude of the pulse, the peak value of the pectoral breath can't be identified.

Analysis and Discussions

Analysis of the Pulse

The method of AR model [3] is used to estimate the power spectrum function.

The use of ARMA is suggested by Sun Dongmei (1996) [3](3,2) to analogue the signals of the pulse. It is proved [3] that any ARMA or MA model can be replaced by high order AR model to estimate power spectrum. An 80-order AR model is used to conduct power spectrum estimation in this paper. And the Burg method [3] is used to calculate the power spectrum.

The statistical analysis of the first prime peak of the power spectrum shows,

- The inter-group independent T test showed that the difference of the pulse frequency of the samples from each group on the ground is not significant at the 95% level.
- The result of the intra-group paired T test of the pulse frequency is listed in Table 2. The difference between the pulse frequencies measured on the ground and that measured on the scaffoldings (or equivalent altitude on the benchmarking building) of the bamboo group is significant at the 70% level, but not significant at the same level for the metal group and the benchmarking group.

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	70% Confidence Interval of the Difference: Lower	Upper			
Pair 1[a]	5.68E-02	.15496	4.6724E-02	5.68E-03	.10783	1.215	10	.252
Pair 2[b]	-3.3E-03	9.1714E-02	3.0571E-02	-3.7E-02	3.06E-02	-.107	8	.917
Pair 3[c]	1.71E-02	5.2941E-02	1.5283E-02	4.94E-04	3.37E-02	1.120	11	.287

a. The pulse between on the ground and on the altitude in the bamboo scaffoldings group

b. The pulse between on the ground and on the altitude in the bamboo scaffoldings group

c. The pulse between on the ground and on the altitude in the benchmark group

Table 2 The Result of the Intra-Group Paired T Test of the Pulse

The result of the inter-group one way analysis of variance (ANOVA) [3] of the absolute value of the difference between the pulse frequencies measured on the ground and that measured on the scaffoldings (or equivalent altitude on the benchmarking building) is shown in the Figure 1, Table 3 and Table 4. Table 3 shows that variances are not homogeneous, so the result by Tamhane's T2 should be chosen in Table 4. Considering the absolute value of the difference between the pulse frequencies measured on the ground and that measured on the scaffoldings, Table 4 shows that the difference between the absolute value in the bamboo group and that in the benchmark group (or that in the metal group) is significant at the 90% level. But at the same the difference between the absolute value in the metal group and the absolute value in the benchmark group is not significant.

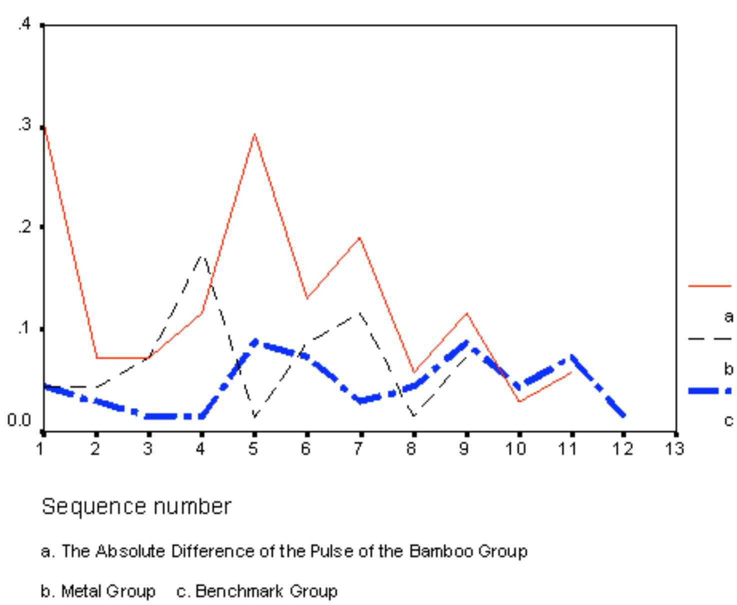


Figure 1 The Absolute Difference between the Pulse on the Ground and That on the Scaffoldings

Levene Statistic	df1	df2	Sig.
4.861	2	29	.015

Table 3 Test of Homogeneity of Variances by One Way ANOV

	(I) Type	(J) Type	Mean Difference (I-J)	Std. Error	Sig.	90% Confidence Interval[a]	
						Lower Bound	Upper Bound
LSD	Bamboo	Metal	5.9486E-02*	.028	.045	1.1134E-02	.10784
		Benchmark	8.4697E-02*	.026	.003	3.9792E-02	.12960
	Metal	Bamboo	-5.949E-02*	.028	.045	-.10784	-1.113E-02
		Benchmark	2.5211E-02	.028	.374	-2.223E-02	7.2648E-02
	Benchmark	Bamboo	-8.470E-02*	.026	.003	-.12960	-3.979E-02
		Metal	-2.521E-02	.028	.374	-7.265E-02	2.2226E-02
Tamhane	Bamboo	Metal	5.9486E-02	.028	.244	-1.646E-02	.13544
		Benchmark	8.4697E-02*	.026	.040	1.4881E-02	.15451
	Metal	Bamboo	-5.949E-02	.028	.244	-.13544	1.6463E-02
		Benchmark	2.5211E-02	.028	.506	-2.024E-02	7.0667E-02
	Benchmark	Bamboo	-8.470E-02*	.026	.040	-.15451	-1.488E-02
		Metal	-2.521E-02	.028	.506	-7.067E-02	2.0244E-02

*. The mean difference is significant at the .1 level.

a. Dependeng Variables. Absolute Difference

Table 4 Multiple Comparisons of the Absolute Difference between the Pulse on the Ground and That on the Scaffoldings, by LSD and Tamhane's T2 of One Way ANOV

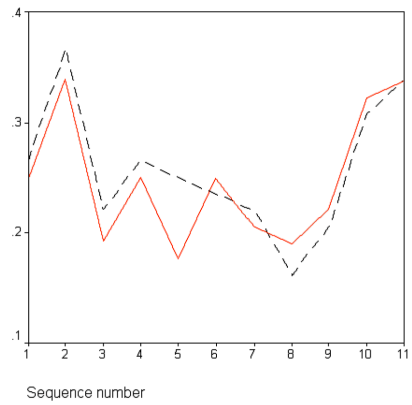
Analysis of the Breath

The signals of the breath were filtered by a Butterworth band-pass filter. A 20-order AR model and the Yule-Walker [3] method were used in the power spectrum estimation of the pectoral breath and the ventral breath.

The inter-group independent T test shows that the difference of the breath frequencies measured on the ground among groups is not significant at the 95% level.

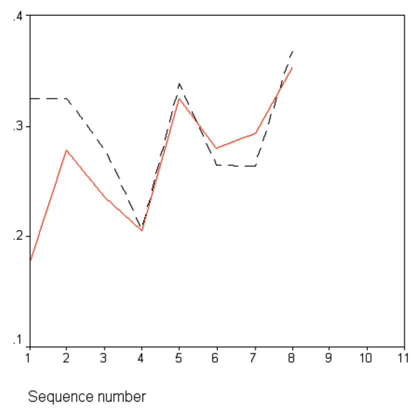
Figures. 2,. 3 and 4 show the differences of the pectoral breath frequencies measured on the ground with that measured on the scaffoldings (or equivalent altitude on benchmarking building). It can be concluded that the difference of each group is not significant, but the average value of the bamboo group is higher, while almost no change was found in the metal group or in the benchmark group.

The result of the analysis of the ventral breath is similar with that of the pectoral breath.



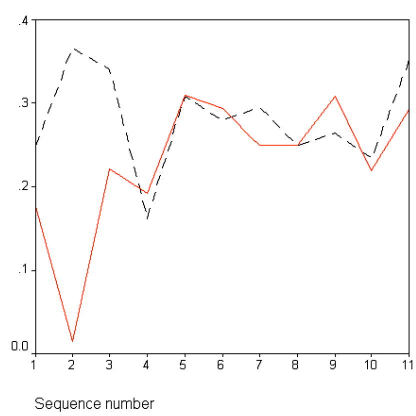
* Solid line. The Data on the Ground;
* Dashed line. The Data on the Scaffoldings

Figure 2 The Pectoral Breath of the Bamboo Group between on the Ground and on the Scaffoldings



* Solid line. The Data on the Ground;
* Dashed line. The Data on the Scaffoldings

Figure 3 The Pectoral Breath of the Metal Group between on the Ground and on the Scaffoldings



* Solid line. The Data on the Ground;
* Dashed line. The Data on the Altitude

Figure 4 The Pectoral Breath of the Benchmark Group between on the Ground and on the scaffoldings

Discussions

The following are some limitations of this experiment:

- The number of the samples is small. Because of the characteristic of human, the reaction to the change of the environment is quite different among different people. Even for the same people, his reaction to the same change of the environment in different time or in different condition could be quite different. So the conclusion of this paper should be verified by further studies.
- The equipments used in this experiment couldn't record the absolute value of the signals.
- There isn't any widely accepted model to relate the change of the frequency of the pulse and breath with the motion although some research has been undertaken.

Conclusions

- The frequencies of the pulse, pectoral breathe and ventral breath measured on the ground from three groups are pairwise compared. All the differences of pulse, pectoral breath and ventral breath are not significant at the 95% level, which means that the examinees of this experiment come from the same population.
- The difference between the pulse frequencies measured on the ground and that measured on the scaffoldings (or equivalent altitude in the benchmarking building) in the bamboo group is significant at the 70% level, but not at the same level in the metal group and in the benchmarking group. This result was also reinforced by the analysis of the pectoral breath and the ventral breath.
- The absolute value in the bamboo group is significant by comparing with that in the metal group (or in the benchmark group) at the 90% level. But analysis shows that, the absolute value in the metal group is not significant by comparing with that in the benchmark group at the same level. The pairwise comparison among groups using the pectoral breath and the ventral breath reinforced the result.

YANG Zhiliang (1990) [5] studied the change of the frequency of human's pulse under stimulation and approved that the pulse frequency would rise under tension. TIAN Xiuliang (1996) [6] presented that 3 times per minute is the critical value in judging the abnormal change of the frequency of the pulse under environment stimulation by summarizing more than 1,000 cases.

The value change of the pulse frequency in the benchmark group equals 0.046Hz (2.8 times per minute), which is in the scope of normal condition. The change in the metal group equals 0.072Hz (4.3 times per minute), a little higher than the change in the normal condition. And the change in the bamboo group equals 0.131Hz (7.9 times per minute), greatly beyond the scope of the change in the normal condition. So it can be concluded that the change in the pulse frequency in the bamboo group is significant, which implies a significant fluctuation of the examinees' emotion. The change in the metal group is a little beyond the scope under the normal condition, which implies little fluctuation of the examinees' emotion.

No report has been found up to now on the workplace safety evaluation by the method of experimental psychology, especially on construction safety evaluation. The finding is quite inspiring despite its limitations. Further research has to be conducted to verify and develop this experimental psychology method further.

Acknowledgments

Appreciation is given to the Works Bureau of Hong Kong, Gammon Construction Ltd., Tsinghua Tongfang Electronic Co. Ltd., Wei Loong Scaffolding Works Co. Ltd. and AES Scaffolding Engineering Ltd. etc. for their great support to this research. Professor Francis Wong, Professor Albert Kwok of Hong Kong Polytechnic University and Mr. S.W. Poon of Hong Kong University helped to organize examinees and contributed their knowledge and experience as advisors. This research was also supported by the National Natural Science Foundation of China (Grant number 70172005) and the Beijing Natural Science Foundation (Grant number 8002013).

References

[1] Xie Jinyu, Li Xinjian. Employee's Safety and Health. Beijing: Economy Management Publishing House, 1999.

[2] Wang Yuanhui. Safety System Engineering. Tianjin : Tianjin University Publishing House, 1999.

[3] Zhao Eryuan, Zhou Liqing. Fundamental Digital Signal Processing. Beijing : People's Posts and Telecommunications Publishing House, 1996.

[4] Sun Dongmei, Luo Zhichang. Parametric Modeling Method of Pulse Pressure Signal and Its Application in the Evaluation of Cardiovalcolar Function. Journal of Beijing Polytechnic University, P39-47, Vol. 22, No. 1, Mar. 1996.

[5] Yang Zhiliang. Experimental Psychology. Shanghai : East China Normal University Press, 1990.

[6] Tian Shixiu, Li Jinxi. The Effects of Infrasound on Blood Pressure and Pulse in Humans. ACTA Acustica, P254-258, Vol. 21, No. 3, May 1996.

STUDY ON THE OPTIMUM HOISTING PROJECT OF "DOUBLE-CRANE AND DOUBLE-ROPE SYSTEM" FOR LARGE-SCALE SLENDER R.C. COLUMNS

Fu, Bing	School of Structure Engineering, Zhejiang University, P.R. China
Chen, Longzhu	School of Civil Engineering & Mechanics, Shanghai Jiaotong University,
Chen, Xiangdu	Department of Civil Engineering, North-east China Institute of Electric Power

Introduction

In the construction of a Large or middle-scale plant or factory, slender R.C. columns are cut into pieces beforehand to prevent them being broken in the hoisting ,but it makes the process more complicated and destroys the integrity of the structure.

That problem can be resolved by applying double cranes, two rope systems and proper hoisting points. In Fig. 1, $\overline{R}_{n+1}$ and $\overline{R}_{n+2}$ denote two binding forces offered by two cranes. The left rope system can be represented by "$(n+1)-1-\bar{s}$", and "$(n+2)-(\bar{s}+1)-n$" represents the right one. The left and right rope systems have $\bar{s}$ and $n-\bar{s}$ fixed points respectively , n denotes the total number of hoisting points. m_{ri} (r = n+1, n+2 ; i = 1, 2, …, n) means the multiple of distance between each fixed and movable pulley that a rope passed by.

Presently, articles about this problem are few. Some authors' opinions are only applied to brief columns[2].Some authors didn't consider minus moments and the influence of the form of rope systems[3].

In this paper, the optimal hoisting points of rope systems are computed by optimization methods. All kinds of the rope systems drafted having one array of optimum hoisting points of their own, by comparing the inner forces a column hoisted with them receives in the process , the best rope systems can be determined to reduce the values of the inner forces further.

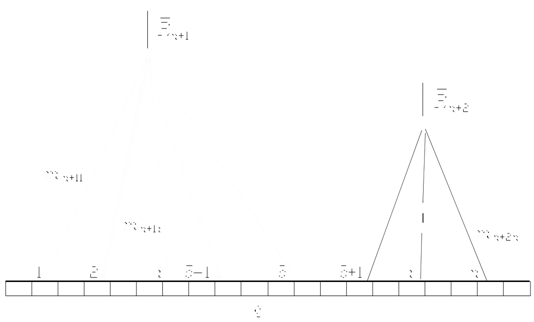


Figure 1 Double-crane and Double-rope system

Determination of Optimum Hoisting Points

The column receives maximal or minimal bending moment when there is some angle between its body and ground. Because the angle is changing, the restraint reacting forces that the ropes offer generate favorable or unfavorable change to the column. So every angle in the erecting should be consider.

The optimum hoisting points can be determined by optimization. In this method, the maximal bending moment in each span and minus bending moment at each hoisting point are called controlling moments. The target function is the maximal absolute value of the controlling moments from 0^0 to 90^0. The object of optimization is finding the minimum of the target function. Hoisting points' positions are elements of vectors to be optimized. The model of optimization can be

searching $[\, l_i \,]^{\mathrm{T}}$ $(\, i = 1, 2, \ldots, n \,)$

min $\max\left|M_k(\alpha, l_i)\right|$

s. t. $0 \prec l_i \prec l_{i+1} \prec l$

In the model, l_i , n and l denote the position of a hoisting point, its total number, and the length of the column respectively. M denotes one controlling moment. k denotes its no.. α denotes the angle.

By " Grid optimization ", the value of the target function is searched out. That is the maximum among the maximal absolute values of the controlling moments at all angles from 0^0 to 90^0 by each array of hoisting points. The minimum of the function is found by "Simplex optimization", and the elements of the corresponding vector are the optimum hoisting points' positions.

Analysis of Inner Forces for the Column Hoisted

For a uniform column to be hoisted, let l, q, G denote its length , uniform load , and gross weight. The calculation diagram is shown in Fig. 2 . In the diagram, n+1 and n+2 denote the two movable points, their loci are like ovum. The tangents of them lie in level when the directions of the two binding forces, $\overline{R}_{n+1}$, $\overline{R}_{n+2}$ are upright. These lead to

$$F(x_r, y_r) = m_{rs}\sqrt{(x_r - l_s\cos\alpha)^2 + (y_r - l_s\sin\alpha)^2} - L_r = 0 \quad (1)$$

and

$$f(x_r, y_r) = m_{rs}\cos\theta_{rs} = 0 \quad (2)$$

where

$$\theta_{rs} = c\tan^{-1}\left[\frac{x_r - l_s\cos\alpha}{y_r - l_s\sin\alpha}\right] \quad (3)$$

In the equations, r, s denote the no. of a movable and fixed point resp.. m_{rs} denotes a multiple. L_r denotes a rope's length. When $r = n+1$, s = 1, 2,..., $\bar{s}$; when $r = n+2$, $s = \bar{s}+1$, $\bar{s}+2$, ..., n. The meanings of $\bar{s}$ and n are the same as the ones in Fig.1. .If s appears two times in a product, it implies sum of the products owning tabs that s denotes. The following equations obey those rules.

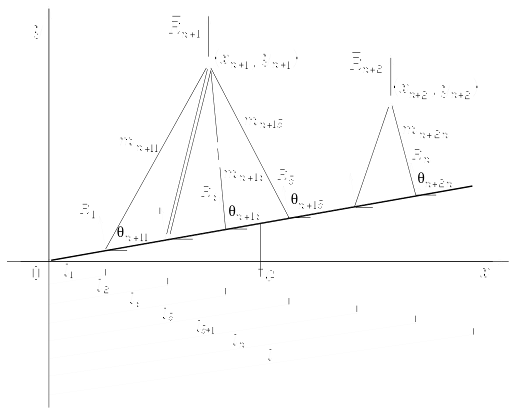


Figure 2 Calculation diagram

The binding forces are

$$\overline{R}_r = \frac{G(x_r - 0.5l\cos\alpha)}{x_r - x_t} \qquad (4)$$

where

$t = n+1,\ n+2,\ t \neq r$.

The constraint reacting forces at static points are

$$R_s = \frac{\sin(\theta_{rs} - \alpha)\overline{R}_r}{m_{rs}\sin\theta_{rs}} \qquad (5)$$

Let e denotes the no. of spans, the positions where shearing force is zero in each span are

$$l_0^e = \frac{\sum_{j=1}^{i} R_j}{q \cdot \cos\alpha} \qquad (6)$$

where

$i = 1, 2, \ldots, n$; $e = i+1$, $e \neq n+1$.

Let k denotes one controlling moment's no. ,
when $k = e$,

$$M_k(\alpha, l_i) = \sum_{j=1}^{i} R_j(l_0^e - l_j) - 0.5q \cdot \cos\alpha \cdot (l_0^e)^2$$

when $k = i$,

$$M_k(\alpha, l_i) = \sum_{j=1}^{i} R_j(l_i - l_j) - 0.5q \cdot \cos\alpha \cdot (l_i)^2 \qquad (7)$$

After analysis of inner forces, the results can be programmed and applied to the optimization of hoisting points. The flow chart of calculation is shown in appendix.

Study on the Optimum Hoisting Project of " Four -Hoisting- Point "

To be convenient and save material, four hoisting points are needed. As application examples of the above mentioned method, the project of Four-hoisting point is computed. The parameters for the column are $l = 32\ m$, $q = 9\ kN/m$; for the rope systems, $n = 4$, $r = 5, 6$, $\overline{s} = 2$, because the multiples' change of the right rope has little influence to the project, $m_{63} = m_{64} = 1, m_{51} \succ m_{52}$, but the difference between them can't be large, $L_5 = 30m$. The optimum rope systems are determined by comparison among the computation results of several rope systems drafted. They are shown in Tables 1-5.

The absolute value of every controlling moment reaches its maximum at some degree, and tend to be zero when the angle approaches to 90^0. This is shown in the tables.

α	$l_1 = 3.295$ $l_2 = 12.315$ $l_3 = 19.338$ $l_4 = 28.789$						
	sections in spans and at hoisting points						
	1	1—2	2	2—3	3	3—4	4
0	-48. 853	48. 040	-38. 274	18. 615	-35. 501	59. 598	-46. 407
10	-48. 111	39. 542	-53. 112	20. 122	-18. 659	67. 233	-45. 702
20	-45. 907	29. 932	-66. 882	20. 784	-5. 017	71. 091	-43. 608
30	-42. 308	20. 527	-77. 074	20. 436	4. 515	70. 615	-40. 190
40	-37. 424	12. 419	-81. 416	19. 020	9. 911	65. 829	-35. 550
50	-31. 403	6. 283	-78.386	16. 585	11. 746	57. 217	-29. 830
60	-24. 427	2. 321	-67. 535	13. 261	10. 870	45. 517	-23. 204

Table 1 The controlling moments by optimum hoisting points from $0^0 \rightarrow 60^0$ when $m_{51}= m_{52}=1$, l_5 =30m

α	$l_1 = 3.980$ $l_2 = 12.241$ $l_3 = 18.681$ $l_4 = 28.132$						
	sections in spans and at hoisting points						
	1	1—2	2	2—3	3	3—4	4
0	-71. 289	70. 206	38. 522	54. 633	-38. 420	48. 148	-67. 320
10	-70. 206	68. 111	36. 419	60. 519	-14. 251	60. 408	-66. 297
20	-66. 990	61. 873	30. 113	62. 509	5. 503	68. 691	-63. 260
30	-61. 738	52. 361	20. 707	60. 268	19. 019	71. 686	-50. 301
40	-54. 611	41. 071	10. 202	54. 201	25. 869	69. 004	-51. 570
50	-45. 824	29. 695	0. 971	45. 268	26. 810	61. 120	-43. 272
60	-34. 645	19. 604	-4. 983	34. 609	23. 272	49. 087	-33. 660

Table 2 The controlling moments by optimum hoisting points from $0^0 \rightarrow 60^0$ when $m_{51}=2$, $m_{52}=1$, l_5 =45m

α	$l_1 =44.262$ $l_2 = 12.063$ $l_3 = 18.666$ $l_4 = 27.589$						
	sections in spans and at hoisting points						
	1	1—2	2	2—3	3	3—4	4
0	-81. 744	78. 175	62. 941	71. 042	-53. 483	19. 856	-87. 573
10	-80. 503	79. 485	65. 240	78. 133	-28. 120	33. 425	-86. 243
20	-76. 815	76. 136	62. 631	80. 714	-6. 225	44. 210	-82. 292
30	-70. 793	68. 366	55. 377	78. 179	9. 980	50. 578	-75. 841
40	-62. 620	57. 226	44. 716	20. 758	19. 556	51. 698	-67. 085
50	-52. 544	44. 334	32. 601	59. 432	22. 844	47. 651	-56. 291
60	-40. 872	31. 382	21. 131	45. 592	21. 106	39. 261	-43. 787

Table 3 The controlling moments by optimum hoisting points from $0^0 \rightarrow 60^0$ when $m_{51}=3$, $m_{52}=1$, l_5 =60m

α	$l_1 = 3.802$ $l_2 = 12.513$ $l_3 = 18.961$ $l_4 = 28.337$						
	sections in spans and at hoisting points						
	1	1—2	2	2—3	3	3—4	4
0	-65. 034	59. 552	5. 991	34. 400	-43. 186	47. 303	-60. 389
10	-64. 046	53. 998	-1. 872	34. 235	-22. 978	57. 031	-59. 471
20	-61. 112	45. 451	-12. 179	34. 604	-6. 592	62. 959	-56. 747
30	-56. 321	35. 224	-22. 992	32. 536	4. 698	64. 220	-52. 298
40	-49. 819	24. 889	-31. 832	28. 506	10. 842	60. 742	-46. 260
50	-41. 803	15. 836	-36. 355	23. 225	12. 684	53. 113	-38. 817
60	-32. 517	8. 923	-35. 037	17. 379	11. 468	42. 280	-30. 194

Table 4 The controlling moments by optimum hoisting points from $0^0 \rightarrow 60^0$ when $m_{51}=3$, $m_{52}=2$, L_5 =75m

<table>
<tr><td>m_{51} m_{52}</td><td>L_6</td><td rowspan="2">l_1 l_2 l_3 l_4</td><td rowspan="3">maximum</td><td rowspan="3">percentage of decrease</td></tr>
<tr><td>1 1</td><td>30</td></tr>
<tr><td>m_{63} m_{64}</td><td>L_5</td><td>inatial positions</td></tr>
<tr><td rowspan="3">1 1</td><td rowspan="3">30</td><td>3. 380 12. 618 19. 380 28. 620</td><td>95. 481</td><td>——</td></tr>
<tr><td>positions after optimization</td><td rowspan="2">81. 462</td><td rowspan="2">15 %</td></tr>
<tr><td>3. 295 12. 315 19. 338 28. 789</td></tr>
<tr><td>2 1</td><td>45</td><td>3. 980 12. 241 18. 681 28. 132</td><td>71. 687</td><td>25 %</td></tr>
<tr><td>3 1</td><td>60</td><td>4. 262 12. 063 18. 666 27. 589</td><td>87. 573</td><td>8 %</td></tr>
<tr><td>3 2</td><td>75</td><td>3. 802 12. 513 18. 961 28. 337</td><td>65. 034</td><td>32 %</td></tr>
</table>

Table 5 Comparison of the projects drafted

Figure 5 shows that the parameters of the optimum project for this column are $m_{51} = 3, m_{52} = 2, m_{63} = m_{64} = 1$, $L_5 = 75m, L_6 = 30m$, $[\, l_i \,]^T = [\, 3.802 \;\; 12.513 \;\; 18.916 \;\; 28.377 \,]^T$, $i = 1 \sim 4$.

There is linear relation between inner forces and uniform load, so the optimum hoisting points' positions are determined by the length of the column and ropes. For columns of different length, determination of hoisting points and rope systems drafted by optimization is necessary.

Conclusions

1. Double-crane and Double-rope system are practice means for hoisting slender R.C. columns.
2. Selection of hoisting points' positions and rope systems drafted is important after determination of the total number of hoisting points, which can lessen inner forces and convenience hoisting.
3. "Grid optimization" and "Simplex optimization" are effective methods for determination of hoisting points. They are easy but feasible.

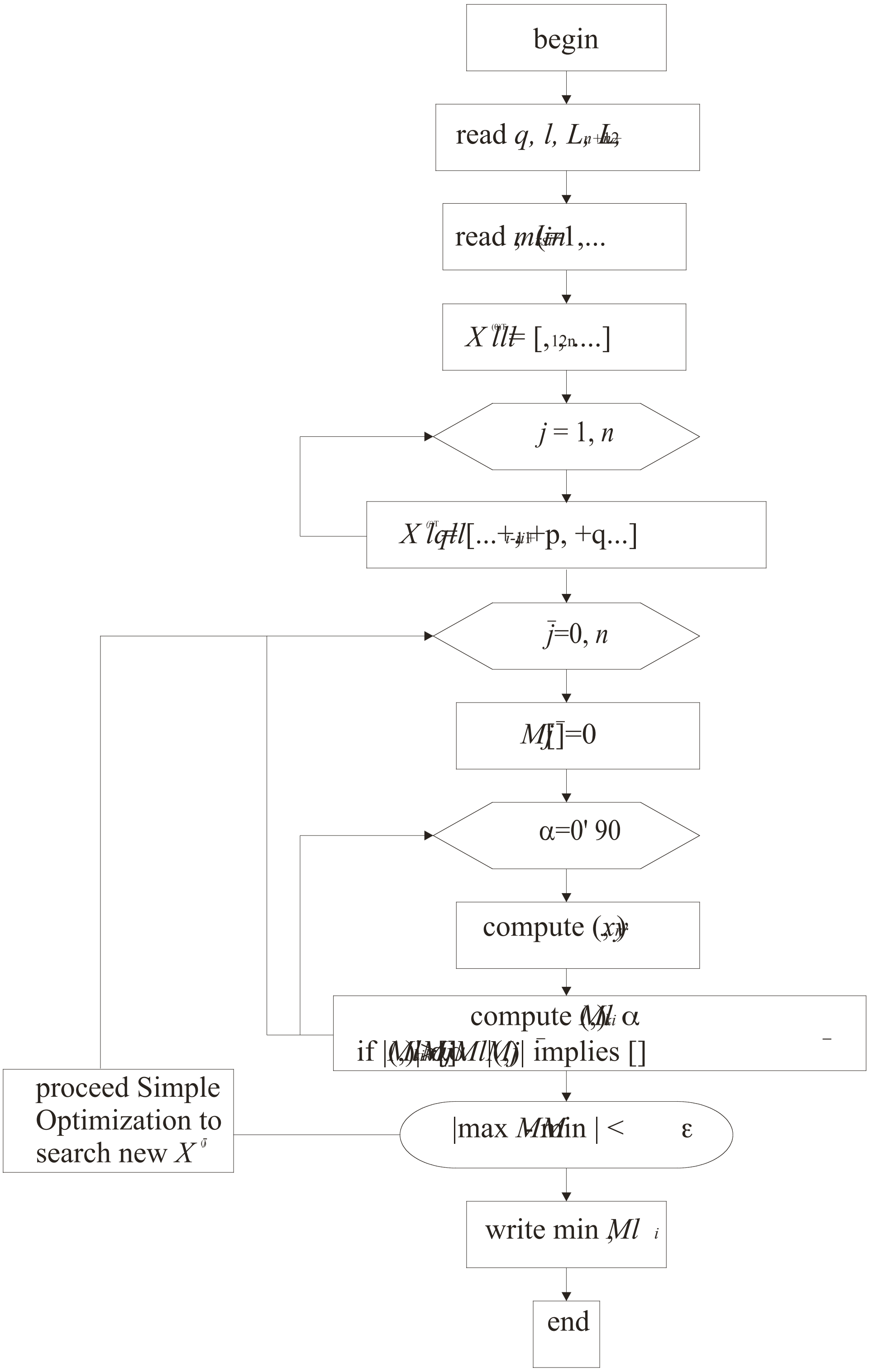
Reference

[1] Xiangdu Chen, Mechanics of Binding Systems of Ropes and Pulleys, Huazhong University of Technology Press, 1995.

[2] Xiangdu Chen, Chengjie Xu, and Yansong Zhao. ,the Mechanics Problem Existed Long of Hoisting Slender R.C. Columns, Journal of Harbin university of Architecture 29(1996) 2.

[3] Binghua Zhang, Chang Hou, Design of Architectural Structure by Optimization, Tongji University Press, 1995.

Appendix



begin
read q, l, L
X
j = 1, n
j=0, n
α=0' 90
compute
compute
implies
proceed Simple Optimization to search new X
|max
min | <
ε
write min
end

APaCHE – A PARTNERSHIP FOR CONSTRUCTION HEALTH

Gibb, Alistair Department of Civil and Building Engineering, Loughborough University, UK
Haslam, Roger Department of Human Sciences, Loughborough University, UK
Gyi, Diane Department of Human Sciences, Loughborough University, UK
Torrens, George Department of Design and Technology, Loughborough University, UK

Construction's Ill-Health Problem

WHO, the World Health Organisation, defines health as a "state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (WHO, 1998). The authors have developed this argument to apply to organisations as well as individuals. Healthy organisations operate to meet their objectives efficiently, providing healthy, fulfilling employment for their workers. In promoting healthy individuals and organisations, prevention is considerably more effective than cure. To be effective, prevention requires a holistic, whole-system, complete life-cycle approach recognising and addressing the complex influences arising from individual and collective attitudes and actions.

To date significant effort has been directed towards the more immediate, high profile (and perhaps more easily solvable) problem of safety rather than the more elusive health matters. Health and safety is often used by experts and non-experts alike to represent only safety. Most health and safety managers, supervisors or inspectors have little more that a very rudimentary knowledge of occupational health issues. However, ill-health continues to kill and disable many construction workers world-wide. In fact, the delay in the effects becoming evident is one of the key reasons why the subject should be taken more seriously.

Every year many thousands of construction workers suffer from work-related ill health. In 1995, the UK's 1995 Self-reported Work-related Illness Survey found an estimated 134,000 construction-related workers reported a health problem caused by their work, resulting in an estimated 1.2 million days lost in a work-force of 1.5 million. The construction sector prevalence rate for self-reported work-related illness was 6.8% compared with an all-industry average of 4.7%. In particular for construction, asbestos related disease resulted in about 700 deaths annually; there were 96,000 musculoskeletal disorder cases; 15,000 respiratory disease cases; 6,000 cases of skin disease and 5,000 noise induced hearing loss cases. Recent research also indicates that construction workers are particularly at risk from hand-arm vibration although this was not evident in the 1995 figures. Many of these conditions have a long latency period between exposure and onset of symptoms, leading to difficulties attributing the root causes of the ill health condition.

The UK Government estimates that asbestos-related diseases will kill up to 10 000 people each year by the year 2020 (Croner 1998) and 36000 people will suffer from 'vibration white finger' with over a million considered to be at risk (HSE 1998). UK and US construction workers have the third highest rate of skin disorders (Burkhart 1993) and cement is believed to cause up to 40% of the UK's occupational dermatitis (Beck, 1990). The problem is just as bad elsewhere in Europe. For example, in 1993, the 2000 largest Portuguese enterprises lost more than 7.7 million working days as a result of illness, representing 4.5% of all working days for these companies (Gründemann & van Vuuren, 1998). 20% of sickness absence among 15 to 66 year-olds in Denmark is caused by the working environment (Gründemann & van Vuuren, 1998). Dermatitis is becoming the main reason for absence from work in Germany (Berger 1998).

The European construction sector is aware of these ill health issues, but they have difficulty managing them because of the highly mobile workforce, lack of continuity of employment, predominance of self-employed workers, and short-term, rapidly changing workplaces. There are also other, more general, life-style-health issues for construction workers, often linked with the peripatetic aspects of their employment. Furthermore, it has been estimated that 80% of construction workers have not even registered with their local doctor.

There are variations in the way that health and safety legislation and control are handled in the various European States (European Commission 1995 & 1997), however, in general, health and safety are considered together, with health very much the poor relation.

Managing Construction Health Risks

Clients and contractors have a duty to develop effective health risk management systems, based on full and careful appraisal of the health risks to which all their employees (including subcontracted workers) will be exposed. The main difficulties regarding occupational health management include:

- Health is a complex issue
- Health traditionally has a low profile compared to safety
- Health management is associated with potentially large set-up costs
- Benefits are not immediate and are consequently difficult to demonstrate.
- The latent effect of illness is difficult to quantify
- Exposure to health risks can be multiple with changes in the nature and level
- Long term strategies are required
- The workforce is sizeable, temporary and mobile
- Many workers are not directly employed
- The workers are often not interested, perhaps due to possible loss of livelihood or the endemic 'macho culture' of construction workers
- There is a lack of health expertise within the industry (Gibb *et al*, 2001)

These are real problems, however, construction must avoid using them as excuses and grasp the opportunity to do something about this unacceptable situation.

Strategic Health Management Should Lead to Benefits

The main aim of health management is prevention rather than cure after the event. Effective, strategic management action by senior managers will reduce accidents and incidents leading to injury and ill-health. However, despite this knowledge, even though construction managers understand their role in safety and the prevention of injury they are less clear regarding the prevention of ill-health (Gyi *et al* 1998). This 'reality-gap' must be acknowledged and eradicated. There is little available guidance on health management in construction, at least in the UK. In fact, one of the only health management manuals is the ECI guide to managing health in construction (Gibb *et al*, 1999). The UK HSE have been planning to release a manual for some years but this has still not materialised. However, there are indications that the topic is starting to turn the corner with various key parties beginning to show considerable interest.

Whilst the first action for senior management is to address these issues strategically, they must also be worked out at the project-level as explained in the ECI health manual (Gibb *et al*, 1999). Health protection remains a line management responsibility with doctors, medical professionals and other experts assisting in the development and implementation of health management programmes. It is also essential to determine the need for and type of medical support on site before an appropriate health risk management system can be developed. The management of both client and contractor must ensure that appropriate control measures are provided, and their effectiveness evaluated.

The Exploration & Production Forum (1993) stated that a successful health management system should cover the following areas:

- Formulating policy and developing the organisation. This includes identifying health objectives and reviewing progress towards their achievement
- Planning, implementing and auditing of health activities and standards
- Performance measurement and reporting

They also advise that at least the following actions should have been taken:

- Roles defined
- Resources allocated
- Means of achieving objectives specified
- Performance monitored
- Specific task targets and procedures defined
- Compliance checked

Health risk management tends to concentrate on the identification of health hazards that may arise. The client or designer can do this assessment, often called 'Hazcon 1' at this stage of a project, however, the client must take the ultimate responsibility. The Hazcon approach is described further in the ECI SHE manual (ECI 1995). Hazcon 1 should include the following:

- Overall project method statement
- Experience gained from previous projects including close out reports
- Similar activities in relevant locations
- Health audits carried out on similar project
- General background information on planned areas of operation
- Environmental issues
- Major risk factors
- Substances already at site and those that will be taken to site
- Emergency response procedures
- Incident reporting procedures
- Published guidance by enforcing authorities (ECI 1995)

Figure 1 shows the sort of items that could effect the health of an employee.

Physical	**Chemical**	**Biological**	**Mechanical**	**Psycho-social**
noise	liquids	insects	posture	stress
vibration	dusts	fungi	movement	work pressure
ionising radiation	fumes	bacteria	repetitive tasks	monotony
non-ionising radiation	fibres	viruses		unsociable hours
heat and cold	mists			ergonomic
electricity	gases			
pressure	vapours			

Figure 1 Factors affecting workers health (Gibb *et al*, 1999)

Healthy Construction Products and Processes

The UK's Health and Safety Executive (HSE) has started to raise the profile of construction health following the launch of their 'Backs for the Future' guidance and a conference in October 2000 entitled 'Tackling Health Risks in Construction'. Health and safety is beginning to be seen by employers and employees as an important issue to be addressed collaboratively, as exemplified by the trades union/ employers (TUC/CBI) Partnerships in Prevention programme. There are potential synergies from the recent "people first economy" strategy developed by the Department for Trade and Industry (DTI, 2001), with Respect for People, Investors in People, the Learning and Skills Councils and the commitment to lifelong learning becoming more prominent. With health issues closely linked to construction processes, techniques and technology, an industry/academia/government collaboration is much needed, providing the essential support required for real improvement to be achieved – APaCHe has responded to this challenge.

The construction process leads to health consequences in the way in which construction is undertaken and the risks that arise. Project teams make choices about how to build and these directly affect the health of workers, for example decisions taken whether to use pre-assembly or to fabricate on-site. Pre-assembly should lead to better safety and health. However, at present, influences on health are not understood sufficiently to support endorsement of the pre-assembly on the basis of health. Furthermore, the industry invariably uses the changing, one-off nature of sites as an reason not to plan and organise the workplace efficiently and this is to the detriment of the health of operatives. Construction projects are becoming more complex, with time and cost constraints more severe and increased reports of stress amongst construction personnel are being associated with this (Madine, 2000). Recent initiatives such as Haliburton's Stress Toolkit training pack are beginning to address this issue.

Construction technology and techniques, tools and equipment are rarely designed with the health of users in mind. Several leading organisations working with Loughborough University are addressing some of these challenges. These include

- piloting an innovative electric breaker tool to reduce hand/arm vibration;

- improving glove design to provide enhanced grip and dexterity (making it more likely that the PPE will be used); and
- developing seat design for construction plant as many drivers spend their whole working day, including breaks, in their seats leading to a significant risk of increased back pain.

Healthy Construction Organisations and Industry

The ECI Health Management Manual claims that larger organisations are just starting to take health seriously but, to date, many small to medium sized enterprises (SMEs) have not had the infrastructure, resources or awareness to address these matters. The development of organisations with a health orientation has been severely hampered by construction's sub-contract and sub-sub-contract culture and recent 'right-sizing' exercises in many organisations. There is a significant opportunity for expertise and technology transfer, as well as a need for development of appropriate strategies and practices.

The UK's Construction Design & Management (CDM) regulations (derived from the EU Directive on Temporary and Mobile Construction Sites) seek to eliminate hazards through the design process. However, there have been concerns about the effectiveness of legislation implementation questioning the extent to which it has resulted in a real reduction of health and safety hazards following consideration by design teams. Also, most recent evaluation has concentrated on safety rather than health. Furthermore, taking a human factors perspective, design extends to include the design of the work place, tools and techniques as well as the finished building or structure which goes beyond the traditional use of the term design implicit in CDM.

A major challenge for UK construction is the current shortfall between the supply of qualified new recruits and increased industrial demand. The growth rate of UK construction output is expected to vary between 2.2% and 3.5% from 2001 to 2005, with 64,000 new workers needed each year. At the same time, a 'major cause for concern is the sharp decline in the proportion of younger workers in the industry, and an increase in those aged 45 and over' (DTI, 2000). To make matters worse, low levels of unemployment in most sectors mean that construction will have to compete harder to fulfil its labour requirements. There will be skill shortages if replacement falls below the yearly forecasted requirements especially in the largest occupations such as carpenters & joiners, bricklayers, plumbers and electricians. The steady loss of workers due to ill health is something the industry must now address.

The recent 'Revitalising' initiative from the UK's Health and Safety Commission (HSC) has set construction targets to:

- reduce the number of working days lost per 100,000 workers from work-related injury and ill health by 30% by 2010
- reduce the incidence rate of fatal and major injuries by 10% by 2010
- reduce the incidence rate of cases of work-related ill health by 20% by 2010
- achieve half of the improvement under each target by 2004

These targets will not be achieved unless there is a considerably greater emphasis on occupational health by the construction industry than at present.

Healthy Construction Workers

Whilst healthy products, processes, organisations and industry are key objectives, the ultimate aim of any health strategy is that the health of individuals will improve. Current research at Loughborough has identified that poorly designed and inappropriately used tools and equipment may be a significant contributory factor to accident causality. This issue is described further in another research paper presented at this conference (Gibb et al, 2002).

This section summarises a pilot study carried out at Loughborough University to provide evidence of the nature of the forces applied to the body of a worker during concrete breaking and the postures they took up to maintain control during this task. This has been published in more detail elsewhere (Torrens et al, 2000). The anthropometric measurements of a male subject who was an experienced construction worker were taken, together with measures such as grip and pinch strength, finger friction and finger compliance. A motion capture system (CODA, mpx30) was used to record the postures taken back the subject during the task performance. Forces taken through the handle of the powered breaker were recorded using a universal grip dynamometer that was attached between the handle and the hammer body. Vibration travelling through the handle was monitored using an accelerometer located between the handle and the subject's hands. The work resulted in recommendations for the reduction of vibration absorption and exposure of joints to repeated vibration and force loading in the form of design specifications for the power hammer.

Conclusion

To be successful, any industry depends on the commitment, innovation and productivity of its people at all levels, managerial, professional, skilled and unskilled. Therefore, construction needs healthy and well motivated workers. APaCHe (A Partnership in Construction Health) is a UK-based partnership between industrialists, academics and government which aims to stimulate a step change in the physical, psychological and social health of all those involved in the industry. The vision is a construction industry with:

- healthy workers
- healthy work systems and practices
- healthy work organisations

Construction's desperate heritage of worker ill-health is not going to change overnight, but at least some organisations seem to be starting to take it seriously.

References

Beck, M H. 1990. Letter to editor. British Medical Journal. 301: 932.

Berger, J. 1998. Cement Dermatitis – an International Problem, Proceedings of CIB W99 Conference, Environment, Quality and Safety in Construction, Lisbon, June: 1-8.

Burkhart, G. *et al.* 1993. Job Tasks, potential exposures and health risks of labourers employed in the construction industry. American Journal of Industrial Medicine. 24: 413-425.

Croner (1998) TUC urges asbestos switch. Construction safety Briefing, Croner Publications Ltd., Iss 35, August, p.3.

DTI, 2000, Excellence and Opportunity, a Science and Innovation Policy for the 21st century, 2000, Department of Trade and Industry, para 33, p10.

DTI, 2001, Opportunity for all in a World of Change – A White Paper on Enterprise, Skills and Innovation, 2001, Department of Trade and Industry, section 2.

E&P Forum (1993) Health management guidelines for remote land-based geophysical operations (Report No. 6.30/190). Oxford: Words and Publications.

European Commission (1995) Labour Inspection (Health & Safety) in the European Union Senior Labour Inspectors Committee. Copies available from: Unit 5 Accident/Injuries, The European Commission, The Plateau de Kirchberg, L-2920 Luxembourg.

European Commission (1997) Labour Inspection (Health & Safety) in the European Union – A Short Guide (Austria, Finland, Sweden). Senior Labour Inspectors Committee. Copies available from: Unit 5 Accident/Injuries, The European Commission, The Plateau de Kirchberg, L-2920 Luxembourg.

ECI, (1995) Total Project Management of Construction Safety, Health and Environment, European Construction Institute, 2nd Edition, Thomas Telford, London: pp. 206, Editors: Gibb, A.G.F., Tubb, D. & Thompson, T. ISBN 0-7277-2082-1.

Gibb, A.G.F., Haslam, R.A., Gyi, D.E., Duff, R., Hide, S. & Hastings, S (2002), ConCA – Preliminary results from a study of accident causality, 3rd International Conference on Implementation of safety and Health on Construction Sites, Conseil Internationale de Batiment, Working Commission W99, Hong Kong, May.

Gibb, A.G.F., Haslam, R.A. & Gyi, D.E. (2001), Cost and benefit implications and strategy for addressing occupational health in construction, Conseil Internationale de Batiment, Working Commission W99, Barcelona, October, ISBN 84-7653-790-5, pp. 29-38.

Gibb, A.G.F. Gyi, D.E. & Thompson, T. (eds) (1999), The ECI guide to managing health in construction, Thomas Telford, London, 170 pp. ISBN 0-7277-2762-1.

Gründemann, R.W.M. & van Vuuren, C.V. (1998) Preventing absenteeism at the workplace: a European portfolio of case studies, European Foundation for the Improvement of Living & Working Conditions, Dublin, Ireland.

Gyi, D.E., Haslam, R.A. & Gibb, A.G.F. (1998) Case studies of occupational health management in the engineering construction industry, Occupational Medicine, Vol. 48, No. 4, pp. 263-271, ISSN 0962 7480/98

HSE, 1998. Ignore workers health and profits will suffer warns chairman at launch of new HSE health campaign. Health and Safety Executive Press Release. 22 May, E114: 98.

Madine, V., 2000, The stress time bomb, Building, The Builder Group, London, 3 November, pp. 20-22.

Torrens, G.E., Mansfield, N.J., Newman, A., Gyi, D.E. & Gibb, A.G.F., 2000, Task and product analysis of an electric breaker tool, Managing Workplace Injuries: and ergonomic approach, Proceedings of international conference MSD 2000, Dublin, June 2000, Health & Safety Authority & Irish Ergonomics Society, pp.1-10.

ConCA – PRELIMINARY RESULTS FROM A STUDY OF ACCIDENT CAUSALITY

Gibb, Alistair Department of Civil and Building Engineering, Loughborough University, UK
Haslam, Roger Department of Human Sciences, Loughborough University, UK
Gyi, Diane Department of Human Sciences, Loughborough University, UK
Hide, Sophie Department of Human Sciences, Loughborough University, UK
Hastings, Sarah Department of Human Sciences, Loughborough University, UK
Duff, Roy UMIST, Manchester, UK

Key Issues Raised from the First 25 Accident Studies

Issues relating to the studies and methodology

- Difficulty in obtaining studies and accessing involved persons
- Defensive attitude by many parties
- Minor nature of the incident consequences

Key aspects identified from the interviews

- Accident investigation
- Management / supervision
- Communication, language and instructions
- Tools, equipment, materials, PPE and task execution
- Individual factors, motivation, culture and tradition
- Time, cost and work pressure
- Method statements / risk assessments
- Abilities, skills transfer and training
- Working environment, ergonomics and health factors
- Legal and contractual aspects
- Design issues

In each case the issue is discussed, drawing on comments made by interviewees and observations by the research team.

Issues Relating to the Studies and Methodology

Difficulty in obtaining studies and accessing involved persons

Despite considerable interest shown in the project at the start and the recent emphasis on health and safety issues by industry leaders and the UK Government, the research team has had great difficulty in obtaining suitable accidents and incidents to study. There may be many reasons for this and the issue will be discussed in more detail in future publications once further data have been gathered. Also, these comments must be read in the context of the difficulties that all researchers experience in gathering 'real' field data, especially in industries like construction. There is a general distrust of research and researchers combined with a belief that research and its results are irrelevant to 'real-life'.

However, the following particular aspects are becoming apparent:

- Some may be paying lip-service to the desire to really understand accident causality.
- Commercial pressures, to not delay the works at all cost, are still very evident.
- As a result people are often 'too busy' to be involved in the studies.
- The transient nature of both workforce and supervision/management mean that involved persons have often moved on from the particular site within a short period after the incident.

Defensive attitude by many parties

Most of the injured persons were happy to talk about their experiences. However, in many cases, other parties seemed to be taking a very defensive position, taking great care to demonstrate that they were not to blame. This was despite the fact that the research team stressed that assessing blame was not one of the aims of the study. This reaction may be considered to be merely human nature, however, it does suggest a climate of fear and a blame-culture in the industry. This seems to be particularly the case when speaking to designers or suppliers of equipment. In fact, in some cases this attitude has prevented certain aspects being followed up by the team. As a response to this the research team are considering tabling some of the more contentious cases (suitably anonymised) to a panel of practitioners (e.g. designers or suppliers) in order to obtain their response as to what action might have been taken to reduce the likelihood of the incident occurring.

Minor nature of the incident consequences

The start of this project coincided with a change of the UK's HSE policy with regard to investigating accidents. The policy was to investigate many more accidents than had previously been the case. The research methodology stipulated that incidents that were likely to be investigated by the HSE would not be covered in this research project. This has meant that the types of accident consequence that the research team has been able to study have been of a more minor nature than had been initially envisaged.

Whilst some of the incidents may have had much more serious consequences if the circumstances had been slightly different the team can not be completely certain that the causal links for more serious incidents would necessarily be the same. The minor nature of the incidents may also have had an effect on some of the interviewees who may not have treated the situation as seriously as they would have done for a more severe incident.

Key Aspects Identified from the Interviews

Accident investigation

Invariably it has been found that the accident has been incorrectly documented and does not reflect the exact circumstances described during interview. Reasons for this may be:

- record not completed or endorsed by the involved person (IP)
- record completed by 'unknown personnel' & not seemingly related to the accident
- insufficient space for much detail text about the accident
- insufficient exploration of peripheral factors
- the style of some forms may contribute towards the lack of lateral thinking
- there is often some form of blame attribution or fatalism in accident investigation
- this misleading record induces incorrect assumptions about causes
- there seems to be a reluctance to challenge what is seen as best practice H&S (such as method statements, risk assessments, inductions etc) – the content of these seems to be a fairly rigid boundary against which judgement is made)
- there is an unwillingness or perhaps lack of ability to address non 'politically correct' issues (e.g. race, poor English, poor reading skills, culture of not 'grassing' - telling tales/snitching).

Time, cost and work pressure

The pressure of time was very prevalent to the interviewees – this seemed to be a major issue although most interviewees were keen to stress that time pressure did not 'cause' the accident (in their opinion). Many of the supervisors and managers appeared reluctant to spend the time speaking to the research team. Several declined the interview explaining that they were too busy. In some cases interviewees suggested that short-cuts were taken to save time, or that work was not completed as diligently as it may otherwise have been. However, in most cases this seemed to be accepted as 'the way things were'.

Management and workers seemed to have different perceptions of time pressure. Management and supervisors did not see time pressure as an issue, however some of the workers clearly felt that they were under pressure to perform at a faster rate. This was despite the fact that most of the workers were not paid on the basis of piece-work and 'time and motion' studies were not the norm. It would seem that it is just a background expectation that the work had to be done quickly. The extensive hours worked were acknowledged but not seen as too significant by the interviewees – this may indicate an acceptance of 'hard-work' as part of the construction culture. This also applied to the long times between work breaks that were in evidence in some situations. In addition to long work hours some were also travelling considerable distances to work and this added to the time pressure.

There appeared to be acceptance that work done at weekends and outside the normal working day was more likely to be done on a 'job and finish' basis and often had less supervision. Some interviewees felt that this led to increased health and safety risks. Specific cost issues have not featured greatly in the first 25 accident studies. However, there is clearly a strong link here to the time issues, which can often be directly correlated to costs. It is also fair to say that, so far, most of the interviewees have tended to be operatives, supervisors and these staff tend to see things in terms of time rather than cost. There was also considerable discussion regarding the nature of employment and individual's preferences regarding payment. Performance related pay was seen by some to encourage corners to be cut, however, most of the involved persons were not paid based on their output.

Management/Supervision

The interview discussed the relationship between workers and supervisors / managers / safety-related staff. The impression gained of these relationships varied considerably from site to site even within the same organisation. This highlights the significance of individual staff and their attitudes to others in the organisation. There are some very good examples of supportive, proactive management. However, there are also examples of old fashioned 'them and us', 'who cares about the workers' attitudes. There was evidence of considerable 'passing of the buck' and an underlying 'blame culture'.

Overall, safety is at times seen as a necessary evil and the safety role is seen in the context of 'policing' or 'refereeing'. Reactive monitoring of safety performance is dominant and impressions given by some in a full-time safety role are that their work is often isolated or unwelcome, denigrated by same status peers and perceived as wet nursing. There is also indication that the role is not always entirely assumed on a voluntary basis! In a related context some specified safe working practice (SWP) is often perceived by operatives as poorly conceived, ritualistic and inappropriate to the skills, experience and practice of the individuals undertaking the work – a compromise to earning. On the other hand the very presence of the SWP measures is seen by those in a supervisory /managerial role as a safety net to endorse a push upon production.

Method statements / Risk assessments

Method statements (MS) and risk assessments (RA) are clearly central to the effective working of health and safety legislation (including CDM). They seem to be a yardstick of best practice and considerable effort is made in their formulation and in maintaining the system of development, information dissemination and record keeping of all interactions with these documents. However there seems to be a high number of problems not only with the content of these materials, but also with the very system itself. There is considerable suggestion that they are merely being given 'lip service' by many projects and individuals within projects. There is little evidence of method statements or risk assessments being seen as relevant to operatives' everyday work.

At this stage of analysis MS and RAs have been included together as they are often included in the same document. In some cases the terms are used interchangeably. Clearly 'method' aspects are also included in comments on tools, work environment and training. In several cases the documentation was not available during the interviews and in a few there appeared to be no knowledge of it. This section discusses MS and RA preparation, content, style and dissemination.

MS/RA preparation

- MS and RAs are invariably absent for some of the site activities during which the accident occurred for example:
  - set-up
  - transit / transport
  - maintenance
  - clearing up
- Where there is 'standard building practice' bespoke MS / RA documents are not prepared yet there is no obvious criteria to define standard building practice.
- Generic documents are available, but the text at times seem glib and a 'rubber stamp' to complete the document rather than convey any real meaning.
- Consultation among personnel involved in the MS preparation sometimes seems muddled and drives to canvas opinions from different employee grades may be more good intention than reality.
- Materials are prepared by senior personnel removed from task execution - the drive seems to be more in the preparation of the document rather than from the development / consideration of best work practice that can be achieved by operational staff.

- Where it is known that the document needs to be updated this often may not occur until some time after the ‘need’ is agreed. The impression is that the documentation is seen as a necessary bureaucracy that runs in parallel with actual practice rather than influencing and controlling it.
- Some of those preparing the materials are untrained and adapt the information from existing documents, which is likely to perpetuate any existing problems.
- A number of people are highly committed to developing these materials and believe that this is in the best interest for those undertaking the work. Despite best efforts in fulfilling the criteria required of them, it is demoralising when failure continues to occur.

MS/RA content

- Whilst the MS is often very exact on process sequence there seems to be little information related to work techniques necessary to achieve the sequential stages of the work.
- Lack of consideration of the work techniques results in a poor range of risk assessments.
- The MS information, prepared in advance, describes the work element under optimal conditions. However the reality, at the time of the work, is that there are a considerable number of additional factors that will affect the actual operation itself (e.g. timeliness of the work, availability of the necessary tools / equipment / personnel etc). Management of these factors is not documented. Whilst the skills of those involved in making the best of the available information and resources will be a determinant of the success of the activity, the whole work process is an informal but imperative underground movement - essentially run in parallel to the documentation.

MS/RA style

- The meaning of score systems used in some risk assessments is not clear and does not necessarily convey any meaning or direct action to address problems.
- There is abundant paperwork for the MS, RA and any supporting documentation. Given that these materials are the main vehicle for instruction and training, the volume, presentation style and language does not seem to facilitate the information transfer.

MS/RA dissemination

- In order to convey information about the work, the materials are invariably either read out / given out for reading. Given the shortcomings in content and application under the prevailing work circumstances, the value of this is questionable.
- Provision of the MS / RA is often seen as task training – yet the content shortcomings must surely impact upon the learning that can be attained.
- Information in the MS / RA at times appears mixed or muddled. The distinction or purpose of the documentation often seems more directed towards preparing comprehensive paperwork rather than offering operational value.
- There is an institutionalised approach re the practice of signing for conveyance of information (reading MS /RA /induction etc). Whilst it is understood that records need to be kept, there is also an atmosphere indicating that the signature transfers responsibility to the signer for the safety of the work.

The system and bureaucracy of the paper-based procedural / management issues is well established and consumes considerable time and energies. The development of the documents however can often be seen as an end in itself. Expectations of the application, value and usability of these documents is very high yet the nature of the accidents studies shows that an unofficial and undocumented management system runs in parallel to these formal processes.

Communication, language and instructions

In several cases there was some evidence of a breakdown in communication. Sometimes this surfaced as a lack of consultation, sometimes as known information not reaching the ‘at-risk’ individuals and occasionally as poor communication between individuals. There are potentially many different underlying causes of this lack of communication that will be drawn out in the main analysis.

Lack of cohesion among contractor groups and a poor sense of common ownership among those on site is apparent from the interviews. Whilst there are meetings and formal methods to ensure that the site build process progresses, the delineation of roles and responsibilities is unclear. Rather than creating a comfortable overlap the lack of certainty seems to have resulted in 'encapsulated' contractor teams. There were also a few incidents where a person's apparent lack of ability in English may have been a factor. Some of the communication initiatives such as safety committees etc were seen as useful but sometimes not very accessible. Generally consultation with the workforce was not seen as being effective. There was some suggestion of poor instructions from designers and/or manufacturers. The researchers found that significantly less liaison appeared to exist between suppliers of plant and equipment than would be the case in most other industry sectors. This section is closely linked to 'tools/equipment'.

Abilities, skills transfer and training

There is a high dependence upon core skills and capabilities. Determining competence of new starters on site is required but this seems a very ad hoc arrangement – invariably led by gut reaction to an individual or by knowing where that individual has been employed in the past. Often too it is assumed that 'the men' will inform upon a poor quality worker – although whether this role is appreciated among operatives is debatable.

A number of situations have been noted where there is low accommodation / tolerance of those perceived to have a lack of skill & experience – these comments relate to:

- slow / less sharp trainees
- the young and unfamiliar
- people 'nowadays'
- contract labour
- foreign labourers

Skills and training issues are also linked to poor quality and use of instructions from manufacturers and suppliers of equipment.

Training

Training was covered in the interview proforma and the picture was mixed. There was strong evidence that the projects did not have a grasp on the actual skills that their workers had or even on those that would be needed for the job in hand. There was a strong reliance on custom and practice. At a certain level the training provision was clearly identified, but there seemed to be significant gaps in its coverage.

The need for training has a high profile and is seen as a fundamental requirement. Issues relating to the use of MS / RAs for training have already been noted, but further issues are also present relating to inadequacies in skill based training:

- Core skills are not refreshed.
- There is heavy emphasis on 'ticket'-orientated skill development, and although this may enable the individual to undertake additional tasks in the work process it is not known how spurious knowledge of work elements contributes to that person's individual skill development.
- Training is often seen as merely being the time that an individual has spent on the job.
- Training is seen as necessary to fulfil H&S requirements rather than transfer skill.
- Although thought of as 'training' certain measures are not always perceived as such at operative level (e.g. induction, tool box talks, informal chats and the provision of booklets).
- Formal training does not appear to be available for some trades (e.g. concrete and air conditioning duct workers)
- The route for trade training was also unclear and the trainee appears quite vulnerable at times:
- Sometimes perceived as cheap labour.
- The criteria for development and 'finishing off' is very dependent on subjective impressions of the supervisors and managers.
- Most of the training is 'Sitting with Nellie' style – purely observational rather than genuine instruction.
- The value of the training is completely dependent on to whom the trainee is appointed to watch or 'gofer'.
- The trainers are untrained in training provision.

- Training not only fails at operative level, but there is an all round lack of formal ongoing skills development even the more senior and professional.
- H&S training is thin among many interviewees – a few with a full-time safety role have studied to diploma standard, yet the role and job title is as commonly applied to those with training from just two days and upwards.

Tool box talks were seen to be effective in some cases, but seemed often to react to problems that had occurred rather than be a strategically planned programme of training. There was some evidence to suggest that the industry expectation was that someone who had been in a job for a certain period must have been trained. This is likely to lead to an unwillingness of individuals to come forward and admit their lack. There was little evidence that the training received had covered much about manual handling or other basic health and safety issues. There is much that exists in other industry sectors that is being overlooked by construction.

Inductions
Very varied comments have been received about induction – many quite negative and worrying given the weighting that is put upon this as an instructional method. The problems associated with them were that they are boring, overly generic & inappropriate, not valued and 'just a booklet'. Contents remembered at times tied into those with a high public profile (e.g. fire, needlestick injuries) than uniquely construction issues. In some instances workers and supervisors were shown to rely on tradition and standard practice rather than specific training.

Tools, equipment, materials, PPE and task execution

Many of the accident studies have revealed shortcomings in task related aspects, such as the tools and equipment that are used, the nature and presentation of materials and problems with PPE. Whilst the shortcomings observed during the accident studies are also common outside the construction industry, it is notable that here there has been very little acknowledgement of these issues either in accident investigation or in appraisal of work conditions. It seems that problems are not noticed but rather are accepted and worked around unquestioningly.

In some cases the equipment appeared to be inadequate, in some there was a lack of training and instruction, sometimes it was inappropriately used. The ad-hoc nature of tool and equipment purchase seems to put construction at a disadvantage when compared to other construction sectors where close liaison with manufacturers and tool suppliers is taken for granted. Common problems were noted among the use of plant, tools, equipment and materials and these relate to:
- Poor range and quality for task
- Rudimentary / dated tools –especially those self-purchased
- Lack of maintenance or requiring high levels of maintenance
- Poor presentation for use (weight, design, interface)
- Lack of knowledge of or unwieldy manufacturers' instructions
- No apparent purchasing criteria, low knowledge of range and possible self-purchase restrictions among self-employed
- Lack of parts interdependency for a critical task
- Lack of feedback on correct use / misuse
- Safety features inappropriate for accident event
- Insufficient / inflexible hire periods

Use of these products revealed a number of problems, such as:
- Inappropriate selection for task
- High dependence upon brute force
- Ad lib work techniques. Techniques evolve, but without input / review for best practice
- Techniques adapted to get around poor set out area
- Operatives reluctant to complain or accepting of inadequacies
- Limited knowledge of task technique alternatives, but everyone thinks they're right!
- Lack of skill in dealing with unplanned events

Generally, the attitude towards PPE was less than ideal. There appeared to be several situations where provision or training in use were inadequate and evidence of inappropriate design for use.

Working environment, ergonomics and health factors

These issues included concerns about the immediate work environment that may have had some influence on the incident. The research team acknowledges that the construction industry is not the same as manufacturing in that the workplace is changes periodically. However, there appears to be a tolerance of bad practice in terms of workplace design and housekeeping that cannot be explained away totally by construction's special status.

There are also comments about general site housekeeping and welfare facilities that may give some insight into the overall project culture. Significantly, these site-wide issues appear to be of importance to the operatives involved and contribute to a general perception on some sites of a lack of care for the well-being of individuals. Issues relating to manual handling (MH) have been included in this section. They are closely linked to training, tools and work environment aspects. There appeared to be little consideration for these ergonomic issues when compared to other industry sectors. Occupational health was not a major consideration in these studies, however, a few of the incidents exposed OH issues which may have had some influence on the incidents.

Individual factors, motivation, culture and tradition

Issues relating to the individual IP are covered here. In some cases they were actions or in-actions, in some cases they suggest other personal issues such as prejudice, conflict, relationships, attitude to work etc. There is not enough data to comment on whether these are more or less prevalent in construction than other sectors.

Surprisingly, poor morale and motivation were often raised by interviewees. There may be some link here with the culture and tradition in the industry. Establishing the nature and extent of the underlying safety (or lack of safety) culture will require further analysis of the interview texts. However, there were suggestions of a strong macho culture in terms of attitudes to accidents, PPE etc. Linked to culture is tradition, where the interviewees suggested that this was the way that things had always been done, rather than looking at the issues with an open mind.

Legal and contractual aspects

Not surprisingly, given that the main interviewees to date have been operatives and supervisors, not enough data have been collected on these issues to draw any valid conclusions as to their significance at this stage. There are some early suggestions that the passing of responsibility (and therefore blame) between parties occurs irrespective of the form of contract.

Design issues

Permanent works design did not feature highly in the 'site' interviews. Although the awareness of designing for safety seems to be gathering momentum amongst project teams, it has not yet permeated to the workface on site. However, design was identified by the reviewers as worthy of follow-up and in their opinion, several of the accidents may have been avoided had the design been changed. One of the challenges in this respect however, is that there are still so many obvious proximal causes that the more distal aspects such as permanent works design seem somewhat remote to many site operatives. There is also a certain level of acceptance that 'that is just the way things are' that seems to permeate from some interviewees. The research team expect that further design-related issues will come to light as the follow-up work continues. However, 'design', in terms of the design of the workplace, procedures, working environment, was clearly identified. This definition of design is much more accepted in other industry sectors, but tends to be ignored in construction.

Conclusions

As the accident studies are still at an early stage, conclusions from this paper on the first 25 accidents are by necessity preliminary. They will need to be reviewed again once further follow-up work is completed and more accident studies are analysed.

Nevertheless, to date, challenges have been identified in the following areas:
- Accident investigation
- Time, cost and work pressure
- Management / supervision
- Method statements / risk assessments
- Communication, language and instructions
- Abilities, skills transfer and training
- Tools, equipment, materials, PPE and task execution
- Working environment, ergonomics and health factors
- Individual factors, motivation, culture and tradition
- Legal and contractual aspects
- Design issues

In addition, the research team must address the following:
- Difficulty in obtaining studies and accessing involved persons
- Defensive attitude by many parties
- Minor nature of the incident consequences

References

Hide, S., Hastings, S., Gyi, D., Haslam, R.A. and Gibb, A.G. 2001. Using focus group data to inform development of an accident study method for the construction industry. Proceedings - Contemporary Ergonomics 2001 (edited by M. A. Hanson). Taylor and Francis, London. 153-158.

Hide, S., Gibb, A.G.F., Hastings, S., Haslam, R., Gyi, D., Suraji, A. & Duff, R., By accident or design? Causal factors in construction industry accidents, Proceedings of the International Conference of the European Construction Institute and the CIB Working Commission W99, London, June 2000, Designing for Safety & Health, Gibb, A.G.F. (ed), pp 45-52, ECI, Loughborough, ISBN 1 873844 48 4.

IDENTIFICATION OF FACTORS CAUSING FATAL CONSTRUCTION ACCIDENTS

Goh, Y.M. National University of Singapore, Department of Civil Engineering, Singapore
Chua, K.H.D. National University of Singapore, Department of Civil Engineering, Singapore

KEYWORD

Construction; accidents; investigation; causation; categorisation; database

Introduction

Safety had always been a persistent problem in the construction industry. In the United States, it was reported that construction industry accounted for 20% of all occupational fatalities, when they made up only 5% of the United States' work force (National Safety Council, 1997). In Kuwait, the industry accounts for 42% of all occupational fatalities (Kartam and Bouz, 1998) and in Hong Kong the industry accounts for more than a third of all industrial accidents over the last ten years (Tam and Fung, 1998). These studies are among many others that shows that the industry has a very poor safety performance record. In order for the industry to improve, it needs to learn from its mistakes.

The identification of the accident sequence and causal factors of accidents, in particular the underlying factors, forms the first step in the learning process. The acquired information like these can then serve as invaluable inputs for preventive measures. However, there had been very few comprehensive studies on how and why construction accidents happen. Whittington *et al* (1992) attempted to analyse the management and organisational factors of construction accidents, but it was realised that the accident data available within most companies were insufficiently detailed to permit a comprehensive analysis. Most other studies on construction accidents focuses on immediate causes, characteristics of accident victims or accident sequence (Kartam and Bouz, 1998; Cattledge *et al*, 1996; Jeong, 1998; Hinze *et al*, 1998). Information like these are important, but they will not be complete without compilations of the frequency of occurrence of underlying factors and Safety Management System failures.

Thus, this paper is part of a larger project that attempts to identify how (accident sequence) and why (immediate factors, underlying factors and safety management system failures) construction accidents occurs and to make appropriate recommendations to improve construction safety.

The Modified Loss Causation Model

In order to have a meaningful analysis of the accident data, there is a need for a fundamental accident causation model that highlights the main accident events and main types of causal factors. Based on the accident causation model, a comprehensive set of accident variables taxonomy can then be developed to code the accident data.

The choice of accident causation models is based on the intended usage. After reviewing existing literature on accident causation model, the Loss Causation Model (Bird and Germain, 1996) was modified to suit the objectives of the project. The Modified Loss Causation Model (MLCM) is presented in Figure 1.

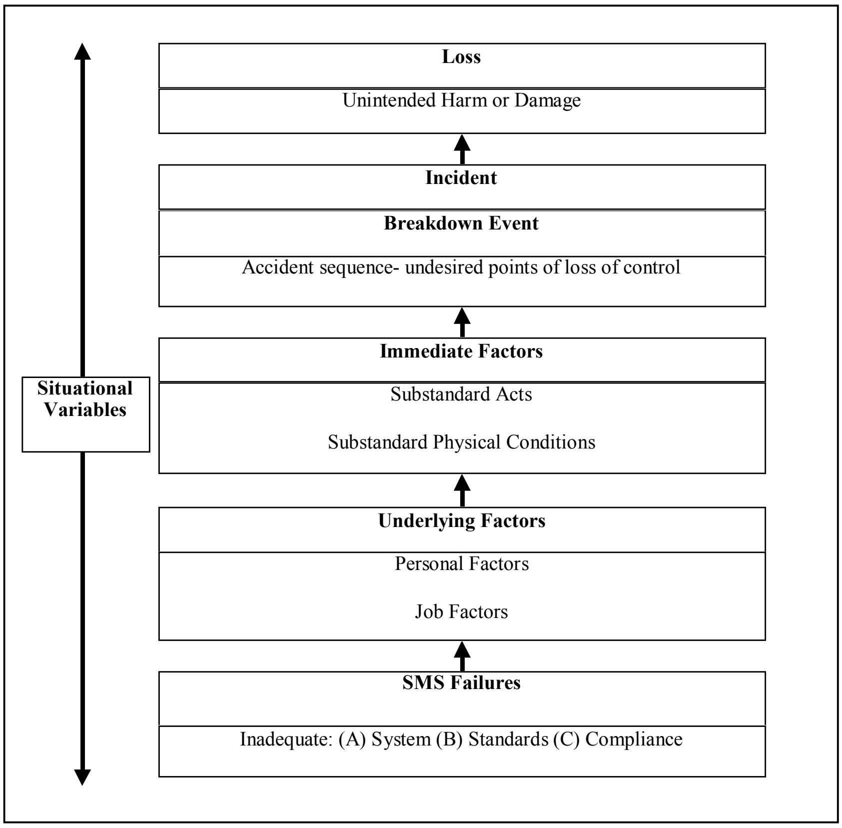


Figure 1: The Modified Loss Causation Model

The main modifications are highlighted as follows. Firstly, the component "situational variables" is included into the model. For each chain of accident causation there is a need to identify the critical characteristics of the context or situation in which the accident occurred. In this way, the information and learning points derived from the accident can be more easily applied to similar context or situations. Furthermore, the situational variables will act as stratifying variables during data analysis, so that the differences in stratifying variables will not affect the outcome of the analysis. In this paper, the main stratifying variable used is the type of work that the main participants of the accident were involved in just before the accident.

Secondly, the accident sequence was elaborated with more details by including the breakdown event. This is defined as a point of loss of control of a source of energy that leads to the occurrence of an incident. In contrast, incident focuses on events that describe the contact of the victim with the source of energy. With the richer description of accident sequence, preventive measures can then be planned more precisely, hence improving safety performance.

Thirdly, the "lack of control" domino in the LCM is replaced by Safety Management System (SMS) failures. The SMS refers to an organised and inter-related group of preventive safety measures that have the common purpose of preventing accidents, improving and monitoring safety performance of an organisation. The advantage of using the term "SMS failures" is that it brings into focus the full set of measures and steps involved in improving safety performance. In contrast, the term "lack of control" tends to highlight control measures like supervision and enforcement of rules.

The use of the MLCM as the fundamental accident causation model has several other advantages. As in most other sequential model, the MLCM can be used to analyse accident sequence and causation chain clearly and logically. The model is also very well structured; hence it facilitates the development of the accident variables taxonomy. Another advantage of the model is that it leads to proactive thinking (Covey, 1989). By ending each accident investigation with an examination of the SMS, prompts organisations to accept the responsibility to respond to accidents and not blame it on the individuals or physical conditions. In this way, the SMS can be improved, thus improving safety performance.

Accident Variables Taxonomy

A thorough literature review on existing accident variables taxonomies and classifications was conducted. The aim is to identify suitable categorisations for each of the components in the MLCM. During the search for suitable categorisations, it was realised that most of the available taxonomies lack a strong underlying accident causation model (Hinze *et al*, 1998; Kartam and Bouz, 1998; Feyer and Williamson, 1991; Sawacha *et al*, 1999), this makes the logic structure of the taxonomies harder to grasp. Bird and Germain (1996), and Gordon (1998) developed taxonomies that were relatively comprehensive, but they were not tailored to the context of construction industry. Hence, causing difficulty in the classification of accident variables, in particular the job factors. Furthermore, some parts of the taxonomies were split into very fine factors without sub-categorisations, hence causing difficulty in statistical analysis (as the data would be too sparse). Whittington et. al. (1992) came up with a taxonomy based in the construction industry, but due to a difference in the underlying accident causation model and research objectives, the taxonomy developed by Whittington *et al* (1992) could not be fully adopted.

There were also several works in the human error areas (Reason, 1990; Rasmussen 1982) where the classification requires cognitive information that are often missing or inconclusive in construction accident investigation reports. These conceptual level classifications (Reason, 1990) often require expertise and resources that are not readily obtainable in the construction industry. Furthermore, the conceptual level classification does not fit into the MLCM, as the substandard act component refers to observable behaviours that are more objective and direct. Thus, conceptual level classifications were not suitable for the context of the research. However, human error classifications that focus on behavioural aspects, for example Swain and Guttman (1983), can be more easily adapted into the substandard act component of the MLCM.

Even though, there was no single taxonomy that can be fully adapted to be used in the research, a compilation of the taxonomies from the literature review and the coding that were already in use in OSD was developed to fit the framework of the MLCM. A draft taxonomy was first used to analyse forty accident cases. Following that, the taxonomy is evaluated and changes were made based on the evaluation. During the actual analysis, the taxonomy was constantly re-evaluated and minor changes were made as and when it was deemed necessary. The main categorisation of the taxonomy adopted in the study is summarised in Figure 2.

Method of Investigation

The source data for the study is based on the accident investigation reports that were produced by the OSD. As the reports are in free-text format, the accident variables identified in the reports has to be classified according to the MLCM taxonomy to allow statistical analysis. In order to minimise errors due to subjectivity during classification, the MLCM taxonomy was clearly defined. Furthermore, the causal factors are identified only if clear statements describing it were stated in the reports, in this way subjective inference by the researchers could be kept to a minimum.

In order to ensure that the data for analysis are of sufficient quantity and quality, the study focuses on accidents with at least one fatality. That is because the depth of investigation usually increases with severity; hence fatal cases usually reveal more objective description of the accident and causal factors. After reviewing the fatal accident investigation reports between 1993 and 1999, 140 accident investigation reports were chosen for analysis.

Discussion of Results

The results presented in this section represent the main findings at the time of writing. Figure 3 shows the summary of the preliminary results. It can be seen that about 60% of the fatal accidents occur during the execution of structural work and architectural/renovation/finishing work. The results might be affected by the greater occurrence of the two types of work. Still, the figures itself already warrants attention to both types of work.

Within the scope of accident sequence, the findings with respect to type of incident agree with the findings of several other works on construction accidents (Hinze, *et al*, 1998; Jeong, 1998; Kartam and Bouz, 1998), where fall of person is the main type of incident in construction industry (55%). In the study, struck by falling object is the next highest occurring type of incident, although at a much lower frequency (19.3%). With respect to breakdown event, lost of balance (31.3%) is the main type of breakdown event and the next highest occurrence is the collapse of temporary structures (22.1%). The findings regarding accident sequence tallies as the high occurrence of lost of balance and collapse of temporary structure naturally leads to a high occurrence of fall of persons and struck by falling objects.

Situational Variables- Type of Work

1. Architectural/Renovation/Finishing work
2. Building services work
3. Geotechnical work
4. Material/equipment handling/transportation
5. Plant/machinery/equipment maintenance/dismantling/installation
6. Structural work
7. Other types of work

Types of Incident/ Breakdown Event

1. Fall of person
2. Struck by falling objects
3. Caught in or between objects
4. Over-exertion or strenuous movements
5. Fire/explosion
6. Exposure/contact with extreme temperature/pressure
7. Exposure/contact with electric current
8. Exposed to harmful substances/radiations
9. Other types of incidents

Other Types of Breakdown Event

1. Collapse of object
2. Lost of balance
3. Object fall off surface
4. Loss control of plant/transport
5. Other types of breakdown event

Types of Substandard Physical Conditions

1. Substandard plant/machinery/equipment/tools
2. Substandard construction material
3. Substandard structures/parts of structure
4. Substandard work environment
5. Other substandard physical condition

Types of Substandard Acts

1. Extraneous Acts
2. Improper equipment usage
3. Inappropriate response to emergency
4. Omission of basic safety measures
5. Spatial error
6. Improper work procedure
7. Other substandard acts

Types of Job Factors

1. Factors related to designers
2. Factors related to operatives
3. Factors related to project management/corporate
4. Factors related to site management
5. Other job factors

Types of Personal Factors

1. Lack of knowledge/skill
2. Mental/psychological factors
3. Improper motivation
4. Physical/physiological factors
5. Other personal factors

Types of SMS Failures

Inadequate: (A) System, (B) Standards or (C) Compliance in one of the following elements

1. Safety policy
2. Safe work practices
3. Safety training
4. Group meetings
5. Incident investigation and analysis
6. In-house safety rules and regulations
7. Safety promotion
8. Evaluation, selection and control of sub-contractors
9. Safety inspections
10. Maintenance regime for all machinery and equipment
11. Hazard analysis
12. The control of movements and use of hazardous substances and chemicals
13. Emergency preparedness
14. Occupational health program

Figure 2: Main headings of MLCM taxonomy

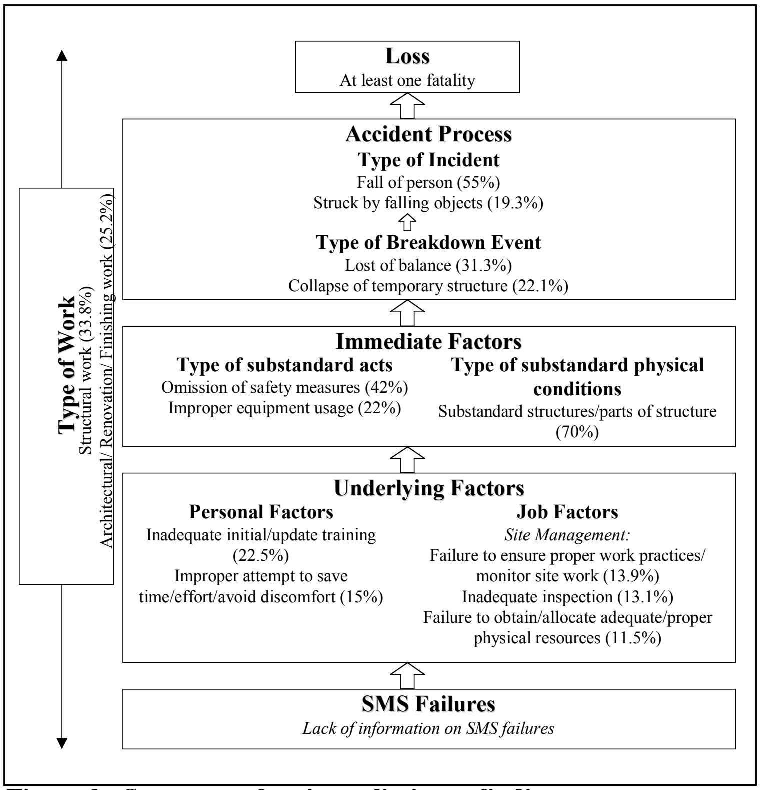


Figure 3: Summary of main preliminary findings

As indicated in MLCM (refer to Figure 1), immediate factors are spilt into substandard acts and substandard physical conditions. Findings on substandard acts reveals a high occurrence of omission of basic safety measures (42% of all substandard acts) like wearing of personal protective equipment (PPE) and checking of the vehicle's rear before reversing. The other main substandard act is improper equipment usage (22%), some common examples are workers using defective mobile scaffolds for work, and using employee lifts to transport construction materials. With respect to substandard physical conditions there is a high concentration of factors in the substandard structure/parts of structure (70% of all the identified substandard physical conditions). This usually refers to lack of safety structure like guardrails or barriers for open sides of buildings and shoring for trenches.

Within the scope of underlying factors (job and personal factors), most of the job factors belong to the category of site management. This shows that site management plays an important role in construction safety. The three most frequently cited factors concern failure to ensure proper work practices/monitor site work (13.9%), inadequate inspection (13.1%) and failure to obtain/allocate adequate/proper physical resources (11.5%). When there is a lack of supervision on site and inadequate provision of physical resources to operatives (e.g. workers, technicians and plant operators) causes the operatives to commit substandard acts and be exposed to substandard physical conditions.

As for personal factors, the main factors are inadequate initial/update training (22.5%) and improper attempt to save time/effort/avoid discomfort (15%). Furthermore, the personal factors usually refer to operatives instead of site management and other job categories. The findings show that training and education of operatives can be a vital link in reducing substandard acts and physical conditions. However, deeper analysis of the factors would be needed to identify the specific strategies in reducing the factors. For example, a training needs analysis will be needed in order to reassess current training courses and develop new courses.

One specific example on how the results of study can be used is the construction of event tree diagrams. Figure 4 shows an example of an event tree diagram that is constructed based on the results of the study. The number next to each event on the diagram indicates the number of occurrences of the event. An event tree like this can then facilitate risk assessment by practitioners. The event tree diagram identifies the possible routes of accident and the number of occurrences of each event can assist the practitioners in assigning the probability of each event recurring. With more data, more detailed event trees can be drawn and the diagrams will be invaluable to the industry.

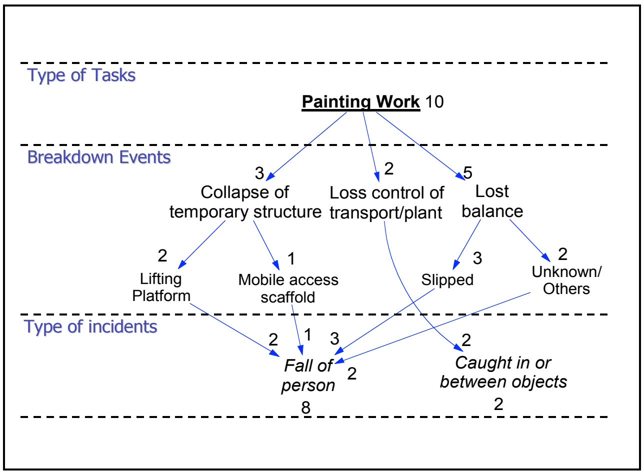


Figure 4: An example of Event Tree Diagram

Furthermore, the statistical results on immediate and underlying factors can also be used as training material, in training needs analysis, and to guide inspection, enforcement and promotional efforts. The continuous monitoring of the accident variables over time can also serve to provide critical information to practitioners and government safety department with regards to the actual effectiveness of safety efforts. For example, after the implementation of a national campaign to emphasise the importance of safety inspection on sites, it would be expected that if the campaign was successful the number of accident causal factors related to inadequate inspection would be reduced, if not a reassessment of the campaign may be necessary.

The MLCM taxonomy can also be used to develop accident database at national and organisational levels. Where consistent and careful application of the taxonomy to classify factors will allow the industry to learn from its mistakes and improve its safety performance.

Conclusions

In this paper the MLCM, its accompanying taxonomy and the statistical analysis of 140 construction accidents were presented. The MLCM traces the accident causation from the losses due to the accident to deep-rooted SMS failures. Based on the MLCM taxonomy, the 140 fatal accidents analysed reveals several main characteristics and causal factors of construction accidents. Examples on how the results can be used were also presented.

The MLCM and its taxonomy seek to ensure that critical learning points can be obtained from each accident. As with each accident, precious resources are lost and if the industry does not learn from the accident, the cost of each accident actually multiplies. However, the safety performance of the construction industry cannot be improved overnight. It is only through consistent and proper feedback, such as the implementation of the MLCM taxonomy, then can the industry's safety performance be improved permanently.

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References

Bird, F.E. and Germain, G.L., 1996, *Practical Loss Control Leadership*, (Georgia: Det Norske Veritas).

Cattledge, G.H., Hendricks, S. and Stanevich, R, 1996, Fatal occupational falls in the U.S. construction industry, 1980-1989. *Accident Analysis and Prevention*. **28(5)**, pp. 647-654.

Covey, S.R., 1989, *The 7 Habits of Highly Effective People*, (London: Simon & Schuster UK Ltd).

Feyer, A.M. and Williamson, A.M., 1991, A classification system for the causes of occupational accidents for use in preventive strategies. *Scandinavian Journal of Work Environment and Health*, **17**, pp. 302-311.

Gordon, R.P.E., 1998, The contribution of human factors to accident in the offshore oil industry. *Reliability Engineering and System Safety*. **61**, pp. 95-108.

Hinze, J., Pedersen, C and Fredley, J, 1998, Identifying root causes of construction injuries. *Journal of Construction Engineering and Management*, **124 (1)**, pp. 67-71.

Jeong, B.Y., 1998, Occupational deaths and injuries in the construction industry. *Applied Ergonomics*, **29(5)**, pp. 355-360.

Kartam N.A. and Bouz, R.G., 1998, Fatalities and injuries in the Kuwaiti construction industry. *Accident Analysis and Prevention*. **30 (6)**, pp. 805-814.

National Safety Council, 1997, *Accident facts*. Itasca, Ill.

Rasmussen, J., 1982, A taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents*, **4**, pp. 311-333.

Reason, 1990, *Human Error*, (USA: Cambridge University Press).

Sawacha, E., Naoum, S. and Fong, D., 1999, Factors affecting safety performance on construction sites. *International Journal of Project Management*, **17 (5)**, pp. 309-315.

Swain, A. and Guttmann, H., 1983, *Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications* (NUREG/CR-1278), (Washington, DC: Nuclear Regulatory Commission).

Tam C.M. and Fung I.W.H., 1998, Effectiveness of safety management strategies on safety performance in Hong Kong. *Construction Management and Economics*. **16 (1)**, pp. 49-55.

Whittington, C., Livingston, A. and Lucas, D. A., 1992, Research into management, organizational and human factors in the construction industry. *HSE Contract Research Report No. 45/1992,* (Sudbury, Suffolk, HSE Books).

ATTITUDES OF CONSTRUCTION MANAGERS TO THE PERFORMANCE APPROACH TO CONSTRUCTION WORKER SAFETY

Haupt, Theo C. Department of the Built Environment, Faculty of Engineering, Peninsula Technikon, South Africa

KEYWORDS

Performance approach, worker safety, change, change management

Introduction

The performance approach to construction worker safety and health involves identifying and satisfying user requirements that must result from applying a safety standard, regulation or rule without setting out the specific technical requirements or methods for doing so (Haupt, 2001). This proactive approach describes what has to be achieved to comply with the regulations leaving the means and methods of doing so up to the contractor. It demands the involvement in the safety and health effort of all participants in the construction process - from owners to construction workers. In terms of this performance approach contractors are not solely and exclusively responsible for construction worker safety. Consequently, the performance approach to construction worker safety and health demands a paradigm shift from the traditionally prescriptive approach (Haupt and Coble, 2000).

In the United States the prescriptive approach prevails. It describes means, as opposed to ends, and is primarily concerned with the type and quality of materials, method of construction, and workmanship (CIB, 1992). This approach attempts to standardize the work process using prescriptive rules and procedures usually backed by the monitoring of compliance and by sanctions for non-compliance (Reason, 1998). On the other hand, the performance approach requires a culture change that relies on a continuous and long-term commitment to understanding, evaluating and improving construction activities and processes (Coble and Haupt, 1999; 2000). This paper discusses the results of an attitudinal survey of construction managers in the United States regarding a performance approach to construction safety.

Change - Nature and Need

All people and organizations are affected by change. In particular, organizations have to cope with globalization of the economy, new market opportunities, technological advancements, emergence of new management approaches and paradigms, and appropriate responses to the needs of workers.

According to Bennis (1993: 19),

"if change has now become a permanent and accelerating factor in American life [and elsewhere], then adaptability to change becomes increasingly the most important single determinant of survival. The profit, the saving, the efficiency, and the morale of the moment become secondary to keeping the door open for rapid readjustment to changing conditions."

According to Nadler (1988) and others people resist or reject change because of the following:

- fear of the unknown;
- possibility of economic insecurity;
- threats to social relationships;
- failure to recognize the need for change;
- lack of confidence in the party promoting the change;
- lack of evidence of any benefit to be gained for themselves from the change;
- preference for things to remain comfortably the way they are; and

– fear that the change will affect them adversely.

For the performance approach to be implemented successfully and effectively, organizations will need to depart radically from their old way of doing things (Nadler and Tushman, 1989; 1990) until it becomes a corporate culture and part of the way business is done. Change may result in adjustments in the interconnection of any of the four components of people, task, technology, and structure. Such change will affect the culture of the organization, transforming it in the process.

Change and top management

The importance of the role and commitment of management in supporting the safety and health effort in their organizations is well documented (Hinze, 1997; Levitt and Samelson, 1993).

"Management's reaction to change determines [the] success [of change]. When upper management 'buys in' to the changes, it ensures success." (Petersen, 1996:278)
Change, such as a paradigm shift from a prescriptive towards a performance approach, is difficult and almost impossible unless top management is totally committed to supporting and driving it. Management leadership, commitment and accountability are crucial (Statzer, 1999). According to Boles and Sunoo (1998), the largest barriers to managing change are lack of management visibility and support, employee resistance, and inadequate management skills. Management is the key that allows safety performance improvements to occur in organizations (Freda, Arn and Gatlin-Watts, 1999; Hinze, 1997; Levitt and Samelson, 1993; Statzer, 1999). Few managers acknowledge the need for a change in their management beliefs and values to support and nourish the new cultural reality (Almaraz, 1998; Boles and Sunoo, 1998) that the performance approach to construction worker safety represents. The importance of top management commitment and the issues of organizational culture cannot be underestimated. Improved safety and health performance within an organization has to become a strategic choice. The extent to which top management chooses to support the program of change will determine its ultimate success. Managers and supervisors must strive to demonstrate safe work practices and make decisions that reflect their commitment to safety (Cook and McSween, 2000).

The influence of leaders on the performance of their organizations may be summed up as follows:

"...organizational decision-makers, managers and professionals alike hope to ensure that their central values and beliefs influence the performance of their organizations by designing functional arrangements and hierarchies to facilitate and support those views." (Ranson et al., 1980:199)
The values of individuals holding the top organizational positions are the ones that are promoted and perpetuated throughout organizations (Hage and Dewar, 1973). Enz (1986:42) echoes this view when she claims

"...clearly, top management is a critical group in examining values because of its control over organizational design and functioning. To understand the role of values in an organizational context requires close examination of the organizational leaders and how their beliefs operate to influence the activities within the firm."

Major change is impossible unless the upper management of organizations actively and demonstrably supports and understands the need for the changes they introduce (Freda, Arn and Gatlin-Watts, 1999). Not only is pressure to change required but also support in the form of time, financial resources, and decision-making authority.

Research Design

In this particular study, the sample for the self-administered attitudinal questionnaire survey was drawn from a database of 843 construction organizations throughout the United States, compiled by the M.E. Rinker, Sr., School of Building Construction at the University of Florida. In order to select 100 organizations from the sampling frame, the probabilistic procedure of systematic random sampling was used. The number of completed questionnaires received were 67, representing an overall response rate of 68.4%, taking account of 2 questionnaires returned blank. Given the nature of the study, the length of the questionnaire, and the time and budgetary constraints the response was considered to be acceptable. No further attempts were made to increase the number of responses.

Analysis of findings

– Profile of respondents

Most of the respondents (54.5%) held traditional upper or top management positions within their firms. Of these management positions that were not directly related to safety and health involvement, 38.8% were CEOs, Presidents, Vice-presidents or General Managers of their firms. A further 14.9% were either Project or Contracts Managers. Slightly more than half of the respondents (53%) had held their current position within the management structures of their firms for 5 years or less.

Of the sample, 42.4% firms employed between 0 and 100 employees, 37.9% employed more than 250 employees.

The majority of firms in the sample (51.7%) engaged in general contracting, while 14.2% were subcontractors. Those that engaged in design-build contracting arrangements made up 11.5% of the sample.

– Understanding of prescriptive and performance approaches

Most of the respondents (78.5%) felt that they understood the approaches well enough to be able to distinguish the differences between them. The reasons given for their preference for either approach are shown in Table 1. These reasons compare very well with the features that characterize each approach.

Prescriptive	Performance	Total	Reasons for preference
	9	9	Differing conditions may require different approaches
	3	3	Minor changes allowed due to site conditions
16		16	More definitive and compliance can be measured objectively
6		6	Workers need specific instructions to avoid shortcuts
	16	16	Provides contractor with flexibility
	1	1	Easy for workers to understand requirements
	3	3	Responsibility of solution choice vests in contractor
	1	1	Allows for innovation and ingenuity
	1	1	Consistent structural strength better maintained
	1	1	Unit president concept resembles performance approach
1		1	Contractors caused safety issue in first place
1		1	Minimum prescriptive standards help subcontractor management
	1	1	Minimizes liability exposure to general contractor
1		1	Eliminates subjective inspections
	1	1	Better working rapport with supervision
1		1	Lack of knowledge to use performance approach
	1	1	No strong preference
1		1	Contractor should be responsible for safety
27	38	65	

Table 1 Reasons for selecting prescriptive or performance approach

– Importance of issues with respect to an approach to construction safety management

Respondents were asked on a scale of 1 to 7 (1 = not important at all; 4 = neither important or unimportant; 7 = extremely important) to rate the importance of 5 issues with respect to construction safety management. The ranking of the means of the responses to each issue according to how important it was regarded is shown in Table 2. Respondents ranked the potential to improve safety performance on sites as being most important with respect to an approach to construction safety management. They regarded the ease with which the compliance requirements could be understood as next important.

Rank	Issue	N	Mean	Std. Deviation
1.	The potential to improve safety performance on sites	66	6.3182	1.0548
2.	The ease of understanding compliance requirements	66	6.0455	.9516
3.	The ease of implementation of the approach	66	5.8333	1.1311
4.	Support for innovation, new materials and technology	66	5.3939	1.4345
5.	The cost effectiveness of approach	65	4.7692	1.7657

Table 2 Importance of issues with respect to an approach to construction safety management

- Sponsors of major change

With respect to who usually sponsors major change within their firms, respondents responded as follows:

- 53.6% top management;
- 16.1% middle management;
- 19.1% site management;
- 6.0% workers; and
- 5.2% supervisors (foremen).

- Importance of change driving factors

Respondents who preferred the performance approach were asked on a scale of 1 to 7 (1 = not influential at all; 4 = neither influential or not influential; 7 = extremely influential) to rate the influence of 13 factors in driving change in their firms. These change-driving factors were ranked according to the means of their responses. The results are shown in Table 3.

The improvement of the safety record of the firm was the most influential factor in driving change according to CEOs and Safety Directors. Project Managers only ranked this factor 7th. To them, the improvement of the financial performance of their firms was the most influential change-driving factor. The next influential factors to them were the generation of quality improvements, and keeping up with competitors. The improvement of the financial performance of their firms, and complying with the requirements of owners and clients were the next influential factors to CEOs and Safety Directors. Factors such as meeting worker demands, responding to third party claims, occurrence of accidents, and staff turnover consistently ranked lowest according to all.

- Importance of worker participation

Respondents were similarly asked to rate the importance of 5 issues to worker participation in change and change management. They regarded the receptiveness of supervisors and foremen to change as being most important in improving worker participation in change. Building credibility and trust was regarded as next important. The ranking according to the means of responses of issues affecting worker participation is listed in Table 4.

Issue	Sample Rank	CEO/President/Vice-president/MD/ General Manager Rank	Project/ Contracts Manager Rank	Safety Director/Manager Rank
Improvement of financial performance	1	2	1	2
Improvement of your safety record	2	1	7	1
Generating of quality improvements	3	4	2	4
Complying with owner/client requirements	4	3	4	3
Exploitation of new market opportunities	5	8	5	8
Keeping up with competitors	6	6	3	6
Introduction of new technology	7	9	6	9
Meeting new insurance requirements	8	7	10	7
Responding to management initiatives	9	5	8	5
Meeting worker demands	10	10	9	10
Responding to third party claims	11	11	11	11
Occurrence of accidents	12	12	12	12
Staff turnover	13	13	13	13

Table 3 Influence of factors in driving change

– Importance of issues that affect the implementation of a new approach

Respondents were asked to rate the importance of 10 issues that would affect the implementation in their firms of the performance approach. The ranking of the means of their responses is shown in Table 5. All management groups regarded open communication as being most important for the approach to succeed in their firms. CEOs and Safety Directors regarded top management support as being next important, followed by mutual trust between workers and management. Project Managers regarded the provision of adequate resources as being next important followed by effective coordination of construction activities. All the groups regarded incentives and rewards as being the least important issue. The continuous improvement of the safety performance of their firms did not rank as highly as was expected.

Rank	Issue	N	Mean
1.	The receptiveness of first-line supervisors and foremen	65	6.2000
2.	Building credibility and trust with workers	65	6.1667
3.	Enlisting the opinions of workers	66	5.7424
4.	Breaking down the resistance or workers to change	66	5.6970
5.	Willingness of workers to accept change	66	5.1061

Table 4 Importance of worker participation in change and change management

– Importance of actions for the successful implementation of the performance approach

The introduction and support of appropriate training programs was the most important action to be taken for the successful implementation of the performance approach according to CEOs and Safety Directors. Both groups regarded the demonstration of consistent and decisive leadership as next important. Project Managers regarded this action as most important, and the allocation of adequate financial, equipment and staff resources as next important. They also regarded the motivation of workers to implement changes for continuous improvement as important. The ranking according to importance of actions to be taken for the successful implementation of the performance approach is shown in Table 6.

	Sample	CEO/President/ Vice-president/ MD/ General Manager	Project/ Contracts Manager	Safety Director/Manager
Issue	**Rank**	**Rank**	**Rank**	**Rank**
Top management support	1	2	4	2
Open communication	2	1	1	1
Mutual trust between workers and management	3	3	6	3
Effective coordination of construction activities	4	5	3	5
Continuous improvement of safety performance	5	7	8	7
Adequate resources	6	6	2	6
Workshops and training	7	4	9	4
Joint labor/management problem solving	8	9	5	9
Creativity	9	8	7	8
Incentives and rewards for supporting the change	10	10	10	10

Table 5 Importance of issues that affect the implementation of the performance approach

Conclusions

In the United States the introduction and implementation of the performance approach to construction worker safety requires a paradigm shift from the current largely prescriptive approach encapsulated in the OSHA regulations. Construction firms need to embrace a new and different corporate culture and necessarily depart radically from their old way of dealing with worker safety and health. The successful implementation of the performance approach will be dependent on the capacity and willingness of the management of construction organizations to introduce and support the changes necessary. Without top management supporting and driving it, this change will be difficult and almost impossible. This management support needs to be not only cognitive, emotional, and financial, but also tangible and visible.

This study suggests that the management of construction firms in the United States have a good understanding of the performance approach, and that given the option they would prefer it. They have shown that for the performance approach to succeed open communication, top management support and mutual trust between workers and management are imperatives. In order to improve worker participation, supervisors and foremen had to be receptive of the new approach. Further, top management recognized that a demonstration of consistent and decisive personal leadership was needed accompanied by the introduction and support of appropriate training programs.

	Sample	CEO/President/ Vice-president/MD/ General Manager	Project/ Contracts Manager	Safety Director/ Manager
Issue	**Rank**	**Rank**	**Rank**	**Rank**
Demonstration of consistent and decisive personal leadership	1	2	1	2
Introduction and support of appropriate training programs	2	1	6	1
Allocation of adequate financial, equipment and staff resources	3	6	2	6
Encouragement of worker participation at all levels	4	4	8	4
Motivation of workers to implement changes for continuous improvement	5	5	3	5
Measuring and evaluating progress of the changes regularly introducing new plans of action if necessary	6	3	4	3
Changing the organization's systems, policies and procedures to augment the changes	7	7	7	7
Rewarding workers for being innovative, and looking for new solutions	8	8	9	8
Amending the corporate vision and mission	9	10	11	10
Changing the organizational structure and hierarchy to make it more flexible and responsive to change	10	9	10	9
Comparing the performance of the company with competitors	11	11	5	11

Table 6 Importance of actions for the successful implementation of the performance approach

References

Almaraz, J. (1998), "Quality Management and the Process of Change," *Journal of Organizational Change Management.*

Bennis, W. (1993), Beyond bureaucracy: Essays on the development and evolution of human organization, San Francisco, Jossey-Bass Publishers.

Boles, M. and Sunoo, B.P. (1998), "Three barriers to managing change," *Workforce*, vol. 77, no. 1, pp. 25-28.

CIB (1992), *Working with the Performance Approach in Building,* Publication 64, Rotterdam, CIB.

Coble, R. and Haupt, T.C. (1999), "Safety and Health Legislation in Europe and United States: A Comparison," In Gottfried,A., Trani, L., and Dias, L.A. (eds), *Safety Coordination and Quality in Construction*, Proceedings of International Conference of CIB Working Commission 99 and Task Group 36, Milan, Italy, 22-23 June, pp. 159-164.

Coble, R. J. and Haupt, T.C. (2000), "Performance vs. Prescription Based Safety and Health Legislation - A Comparison," *The American Professional Constructor,* vol. 24, no. 2, pp. 22-25.

Cook, S. and McSween, T.E. (2000), "The Role of Supervisors in Behavioral Safety Observations," *Professional Safety*, Journal of the American Society of Safety Engineers, vol. 45, no. 10, pp. 33-36.

Enz, C.A. (1986), Power and shared values in the corporate culture, Ann Arbor, UMI Research Press.

Freda, G., Arn, J.V., and Gatlin-Watts, R.W. (1999), Adapting to the speed of change," *Industrial Management*, Nov/Dec, pp. 31-34.

Hage, J. and Dewar, R. (1973), "Elite versus organizational structure in predicting innovation," *Administrative Science Quarterly,* vol. 18, pp. 279-290.

Haupt, T.C. (2001), The Performance Approach to Construction Worker Safety and Health, University of Florida, Unpublished Ph. D. dissertation

Haupt, T.C. and Coble, R.J. (2000), "International Safety and Health Standards in Construction, *The American Professional Constructor,* vol. 24, no. 1, pp. 31-36

Hinze, J.W. (1997), *Construction Safety*: Prentice-Hall, Inc : New Jersey.

Levitt, R.E. and Samelson, N.M. (1993), *Construction Safety Management,* New York, John Wiley and Sons, Inc.

Nadler, D. (1988), "Concepts of the Management of Organizational Change," In Tushman, M. and Moore, W. (eds.), *Readings in the Management of Innovation,* Cambridge, Ballinger.

Nadler, D. and Tushman, M. (1989), "Beyond the Magic Leader: Leadership and Organizational Change," In Tushman, M., O'Reilly, C. and Nadler, D. (eds.), *The Management of Organizations,* New York, Harper and Row, pp. 533-546.

Nadler, D. and Tushman, M. (1990), "Beyond the Charismatic Leader: Leadership and Organizational Change," *California Management Review,* vol. 32, pp. 77-97.

Petersen, D. (1996), *Human Error Reduction and Safety Management*, New York, Van Nostrand Reinhold.

Ranson, S., Hinings, C.R., Greenwood, R., and Walsh, K. (1980), "Value preferences and tensions in the organization of local government," In Dunkerly, D. and Salaman, G. (eds.), *The International Yearbook of Organizational Studies,* London, Routledge and Kegan Paul, pp. 197-221.

Reason, J. (1998), "Organizational controls and safety: the varieties of rule-related behavior," *Journal of Occupational and Organizational Psychology,* vol. 71, no. 4, pp. 289-301.

Statzer, J.H. (1999), "An integrated approach to business risk management," *Professional Safety* – American Society of Safety Engineers, August, pp. 30-32.

AN INVESTIGATION INTO THE EFFECTIVENESS OF PARTNERING IN PROMOTING HEALTH AND SAFETY MANAGEMENT ON CONSTRUCTION SITES

Heath, Brian C. Technology and Computer Science, NEWI, UK

KEY WORDS

Partnering, Health and Safety Management, Procurement, CDM Regulations, Egan, Latham.

Introduction

"To build is to be robbed": Johnson's edict still carries much weight in the modern age. The Latham Report (1994) paints a picture of distrust and conflict, not just between client and contractor but between the design and construction team and within the construction team itself.

The UK Government has attempted since the Latham Report was published in 1994 to change the ethos of the construction industry and make it less conflict orientated. Legislation followed on from Latham in the form of the Housing Grants, Construction and Regeneration Act 1996, and further initiatives in the form of The Egan Report and most recently the Movement for Innovation (M4i). The focus for these initiatives was the performance of the construction industry, principally its inability to satisfy customer expectations, the apparent lack of teamwork between the various contracting parties and the lack of post contract liability. In short, the emphasis was on value for money.

At the same time, initiated by European social legislation, the Construction (Design Management) (CDM) Regulations has provided a focus on health and safety in the design, construction and maintenance phases of construction projects allocating specific responsibilities to those named as function holders under the CDM Regulations.

The issue for consideration within this paper is whether both sets of initiatives can change the culture and focus of the construction industry and act in concert to promote health and safety on construction sites and improve the performance and image of the industry in this respect.

Latham and Egan: A Construction Industry Perspective

Both Latham (1994) and Egan (1998) have concentrated on the concept of the team. Sir Michael Latham's Report "Constructing the Team" was commissioned jointly by the Government of the day and the industry itself and represented an in-depth review of the procurement systems and contractual arrangements which permeated the industry. In doing this Latham considered the position of the main contractor as the focus for many of the long standing problems in the industry: principally, that it is conflict orientated and beset by poor working practices (Baden-Hellard, 1995, Critchlow, 1998). The problems highlighted by Latham in terms of poor level of service, poor end product and poor after sales service are linked to the main contractor and the transactional power afforded to him by his central position in the contractual framework (Berry 2000). It is of little surprise, then, that the aftermath of the Latham report was a series of legislative measures designed to limit this transactional power.

It could be argued, however, that the focus on the contractor as the cause of the ills of the industry ignored a more fundamental issue – the effect on the attitudes of the parties to the contract of the use of a procurement system which is based largely on securing the contract at the lowest price. The common view of the industry was that it was competitive on price but not on quality (Barrie, 1988). Other researchers, Hatush and Skitmore (1997) and Lingard and Holmes (2001) support this view.

The Egan Report "Rethinking Construction" was the report of the Construction Task Force chaired by Sir John Egan (Egan 1998) commissioned by John Prescott to advise him on strategies for improving the performance of the construction industry. Like the Latham Report, Egan was concerned that the Construction Industry was not performing to the best of its abilities and was concerned with customer satisfaction and process and product development. It highlighted a number of drivers for change: committed leadership, a focus on the customer, integrated processes and teams, a quality driven agenda and commitment to people. It also stated that the industry must provide "decent and safe working practices and improve management and supervisory skills at all levels" (Egan 1998 @ p.7). Egan spoke also about commitment to people and the need to motivate operatives through a mixture of supervision and training in a "no blame culture based on mutual interdependence and trust" and set a target to reduce the number of reportable accidents by 20% per year " (Egan 1998 @ p.19).

Equally importantly, Egan made a number of points regarding the attitude of clients and the nature of the industry. Clients were seen as being overly concerned with cost, equating it to value, making selection decisions in relation to both contractors and designers based solely on price (Egan 1998 @ p.10). The industry was seen as being fragmented with the vast majority of companies in the construction industry employing less than eight people (Egan 1998 @ p.11). The picture is one of an industry dominated by small to medium sized enterprises (SMEs), a picture reinforced by Egan's comments regarding a "crisis in training" and the dearth of research and development. These two issues of client orientation and industry fragmentation are, it is suggested, central to the problems facing the construction industry in seeking to change attitudes and performance in respect of health and safety on construction sites.

Key to the achievement of the targets set was the strategy outlined by Egan of Partnering. Inherent in this is the role of the client and the focus on the client as the lead player in implementing change.

Latham and Egan: A Research Perspective

Latham and Egan focused upon partnering as a key strategy in promoting change. Partnering has been described in a number of ways. Typically, the CII (1991, p. iv) refer to it as "long-term arrangements between companies to co-operate to an unusually high degree to achieve separate yet complementary objectives"; Day (1996) saw partnering as the essential element in helping conflict through the eradication of the traditional barriers between client and contractor. The emphasis in these and other definitions of partnering (CII 1991, NEDO 1991) is essentially financial: savings in cost, increases in productivity

To be effective, therefore, partnering must produce tangible benefits for all parties (Critchlow 1998) and to do this requires, it is suggested, a radical reworking of the culture, attitudes and mind-set of all those engaged in the construction process (Marler 2000). Atkinson (1998) identified the importance of the individual in reducing errors on site and as a result improving health and safety and the quality of the construction process as a whole. The question remains, however, as to whether a solution which addresses business objectives is compatible with achieving a solution to health and safety issues which are essentially human relations orientated.

Berry (2000) in a case study based research project investigated the nature of conflict in the construction industry and came to a number of conclusions: that, given the nature and structure of the present procurement methodology, conflict in the construction process is unavoidable; that the dimensions of conflict identified are largely negative and that this negative conflict manifests itself in the form of stress and that negative stress leads to errors which themselves have repercussions which are time, cost and quality related; that management of the individual, though proved to be effective, is often neglected in the construction industry; that the contractor is in a central position to positively control conflict for his own and the client's benefit

In arriving at these conclusions Berry undertook a study of six projects maintaining for each a site conflict diary in which events were initially recorded. From this the events were classified according to four operating levels. From this initial classification the conflict diary was re-written retrospectively and the events reclassified to identify both the causes and effects of conflict. A narrative was also provided and a flow chart of events was prepared to enable a clear picture of the chronology of events and to enable conflict and its financial and operational effects to be accurately traced back to the initial cause.

The advantage of this approach was that it provided depth of analysis to the somewhat one-dimensional level provided by the quantitative analysis of the diary events alone

From this combined analysis it was clear that the particular type of contract had little effect on emergent conflict within the case studies. More prevalent than inter-organisational conflict was intra-organisational conflict arising from both the client and the contractor. For the client this originates with his method of procurement of design and other consultants and continues with the on-going concentration on cost as being the dominant factor in the project. This attitude demonstrably influenced the behaviour of all parties to the contract and contributed to dysfunctional behaviour at critical points in the project life. For the contractor such behaviour exhibited itself *inter alia* through allocation of resources: failing to match resources to requirements through the inappropriate choice of site management personnel, inappropriate transfer of risk and responsibility at subcontract level.

The issues raised in this and other research (Djebarniu 1996, Loosemore 1999, Loosemore and Tan 2000 and Fraser 2000, Bresnen and Marshall 2000a) all support the points made by Latham and Egan in respect of the main drivers for change; committed leadership, a focus on the customer, integrated processes and teams, a quality driven agenda and commitment to people. All, however, are essentially critical of the focus of the procurement process which is essentially cost and, by extension, conflict orientated.

It can be further surmised that current methods of management within the construction industry appear to owe more to Taylor than to Locke. This is an important distinction when one considers that the drive in health and safety is towards personal responsibility and behaviour based safety management (Lingard and Rowlinson 1998) and poses fundamental questions regarding the ability of the industry to change. An important issue is the attitude of client and contracting organisations towards partnering and the benefits it will provide.

Attitudes to Partnering: Survey and Results

Bresnen and Marshal (2000b) make the point that there is little empirical evidence of the effectiveness of partnering in practice. Indeed, there is little agreement on the form partnering should take: strategic or project based. For the most part the benefits are expressed in terms of profitability, productivity, cost and quality The disadvantages are also couched in the same terms: lack of competition (Davies 1995); additional partnering costs through workshops (Bennett and Jayes 1995, Barlow *et al* 1997); lack of flexibility in the market place (Critchlow 1998); the domination of existing adversarial attitudes (Berry,2000). The negative comments apply equally to the contractor/subcontractor as well as the client/contractor interface raising concerns about the construction industry's ability to adopt supply chain management as part of its partnering strategy. The implications for the creation of a health and safety culture on site are, it is suggested, a cause for some concern.

In an attempt to further investigate the issues raised above, an investigation was undertaken into the attitudes of parties to the construction process was undertaken to determine their attitudes towards partnering and the benefits its produces.

A total of 86 questionnaires were sent out: 40 to contractors, 46 to client organisations. In selecting the sample group a combination of purposive and systematic sampling was used. The questionnaire was designed to test a number of hypotheses: that partnering is infrequently used in the construction industry; that partnering has the potential to improve client/contractor relations; that partnering has the potential to improve product quality and reliability; that attitudes to partnering from the client side tend to focus on their own accountability; that attitudes from contractors tend to focus on the profit element; that partnering can convey to the parties a number of benefits.

The questionnaire was selected as the most appropriate method of data collection given the time limits imposed on the study and the intention, which was to provide empirical evidence of the use of partnering. The questionnaire content expanded on the hypotheses given and was comprised mainly of closed questions with only two open questions which asked the respondents to expand on their responses to questions relating to the impact of partnering on quality, reliability and supply chain management.

Of the 40 questionnaires sent out to contractors 35 were returned a response rate of 87%. Of the 46 questionnaires sent out to clients 26 were returned a response rate of 56%. A response rate overall of 71%. The breakdown of the respondents is as shown in Table 1 below:

	Client %	Contractor%
Quantity Surveyor	38	29
Project Manager	27	28
Director	11	23
Client Manager	8	0
Engineer	8	2
Architect	4	0
Designer	4	0
Recruitment Manager	0	2
Head of Procurement	0	16

Table 1

While Quantity Surveyors and Project Managers dominate the sample, the sample is, it is submitted, representative of organisational structures in client and contracting organisations (Berry 2000). All respondents felt that they were aware of the general principles and objectives of partnering with 73 % of the client group and 91% of the contractor group having had involvement with partnering in the past. For the most part partnering appeared to be client driven with only 20% of respondents reporting contractor driven partnering arrangements.

81% of the client group and 91% of the contractor group were aware of the Latham and Egan Reports though 75% and 51% of the groups respectively felt that it was too early to tell if the targets were being achieved. Confidence in the effect of the reports was marginally higher in the contractor group who were also more confident that the relationship between client and contractor had improved since the Latham Report: 60% compared with 38% in the client group and that the potential for conflict was lessened.

The vast majority of the sample group felt that partnering to succeed must be applied throughout the supply chain. This was one of the questions where the respondents were requested to expand on their choice of answer. The written responses echoed fairly closely the rationale for partnering provided by Egan and other researchers: cost reduction; elimination of waste; improvement in quality and value; fair apportionment of risk. This was supported in a further response where 77% of the client group and 72 % of the contractor group felt that partnering was an aid towards quality enhancement and increased reliability. Again this was expanded upon in written comments which cited the following reasons: clearer communication; clearer risk apportionment; greater commonality of objectives. Overall, a high degree of synchronicity with the findings of Egan and the findings reported by Bresnen and Marshall (2000a) in their critical review of partnering in construction.

Given the level of compatibility with existing research this allows a number of conclusions to be drawn from the data gathered in the survey relating to issues of accountability, profit and specific effects. The results are shown in Table 2 below.

		Client	Contractor
Do you feel that a true partnering arrangement can never exist owing to the opposing interests of he two parties	Yes No	38 62	28 72
Do you agree that partnering has been well received or disagree and feel that is there still a degree of apathy and cynicism	Agree Disagree	31 69	23 77
Where partnering is used do you feel that clients place too much emphasis upon their own accountability at the expense of the true aims of partnering?	Yes No Sometimes	15 27 58	43 8 49
Would you say that contractors pay too much attention to the profit element that is generated rather than embracing the overall objectives of partnering?	Yes No Sometimes	77 15 8	34 57 9
Do you feel that partnering will one day replace the more traditional competitive tendering process?	Yes No	15 85	14 85

Table 2 (From Hughes 2001, p.61)

Despite the clear appreciation of the benefits of partnering there still remains a strong suggestion of cultural problems within the construction industry. There is clearly a reluctance to depart from the traditional methods of cost control through competitive tendering. This, combined with evidence that the contractor is still overly concerned with profitability and the client team with accountability, does not portray a picture of an industry likely to put health and safety first. This was reinforced to an extent by a further series of propositions put to the respondents the results of which are shown in Table 3 below.

	Client			Contractor		
Partnering….	True	P/T	False	True	P/T	False
Aids speedy resolution of contract disputes	38	58	4	40	54	6
Avoids costly overruns	15	69	16	29	69	2
Promotes better design criteria	23	46	31	40	43	17
Produces safer working practices and sites	31	23	46	26	49	25
Produces increased turnover and profit	27	65	8	11	57	32
Produces increased productivity	27	46	27	29	57	14
Apportions risk fairly	38	42	20	43	49	8
Helps promote teamwork	62	27	11	85	13	2
Merely provides a means to an end	38	31	31	29	40	31
Reduces exposure to litigation	15	53	31	37	51	12
Helps parties to understand each others Objectives	65	27	8	74	24	2

Table 3 (From Hughes 2001, p.63)

Whilst it may be argued that providing a middle option enables the respondent to avoid a decision it can be proposed that any entries in the true or false columns carry further weight. This being said some interesting conclusions can be drawn from these responses.

On the positive side, there is a definite reinforcement of the utility of partnering in fostering communication and teamwork, this is supported by the small percentage of respondents who felt that there were no benefits in the form of either the avoidance or speedy resolution of disputes. Beyond this general position, however, the messages are considerably more divided and potentially negative

The contractor group were in general less enthusiastic about the financial impact of partnering; 32% did not feel that it increased turnover and profit and only 29% felt definitely that it increased productivity. In the same context 46% of the client group and 25% of the contractor group felt that partnering did not produce safer working practices and sites: only a minority, 31% and 26% respectively felt that there was an improvement. It is suggested that the contractor group responses reflect something of a split between attitudes to the client and attitudes to subcontractors and that whilst there may be better communication between contractor and client, the same does not necessarily hold true for the interface between contractor and subcontractor.

This suggestion is supported by statements made by respondents to the questionnaire where the relationship between contractor and subcontractor was still seen as confrontational despite the importance of the supply chain philosophy. This, it is further suggested, has fundamental implications for the implementation of effective health and safety management systems.

Implementing Health and Safety Management

The overarching strategy for implementing health and safety is legislative; principally the Health and Safety at Work Act 1974 and the Construction (Design and Management) Regulations 1994 (HSE 1994) (CDM) which became active in 1995. There is some debate, however, regarding the effectiveness of the CDM Regulations in improving the safety record of the construction industry. The HSE (1997) in investigating the effectiveness of the CDM Regulations found that both clients and contractors were generally supportive of the regulations and had reacted positively to them in terms of amending their own policies but that there were some concerns which existed relating to the increase in bureaucracy which the regulations imposed which had no apparent impact on efficiency.

The role of the Planning Supervisor was understood as was the need for the Pre-tender Health and Safety Plan but this was undermined by comments contained in the evaluation which suggested that clients were more concerned about the financial benefits to be gained from any new management control system and that contractors were concerned about the application of the regulations to subcontractors and the quality of the information with which they were provided. The results were to some degree inconclusive: there was support for the regulations and a feeling that they provided the vehicle for an increased awareness of safety issues but that it was too early to decide whether they were effective. Further research, however, has provided support for the issues raised by the HSE survey.

The central role of the Pre-tender Health and Safety Plan has been considered by Tam *et al* (2001) in the context of the Hong Kong construction industry, which has a poor safety record comparative with the UK. They considered the effect of the introduction of the Supervision Plan (comparable with the Construction Health and Safety Plan) and recorded a positive response in terms of awareness on site of health and safety issues. The research findings were qualified, however, by comments regarding the strength of the change and the need to reinforce the message of safety against competing messages of cost and time. Tam and Fung (1998) had earlier established a correlation between the use of sub-contractors and the incidence of accidents on construction sites. These were related also to a lack of safety training and a lack of awareness of the operational and financial effects of accidents amongst small contractors.

Dainty *et al* (2001) considered the difficulties surrounding effective supply chain management in the construction industry where SMEs employing 24 or less workers comprise almost 98% of companies operating in the construction sector. Like Bresnen and Marshal, Dainty et al found that partnering was restricted to the Client-Contractor interface with the SME section of the industry, who are largely subcontractors having little managerial input. In addition, they found that the SME section was itself layered with varying levels of managerial competence. Supply chains were in themselves fragmented with many SMEs working for a range of contracting organisations. It was clear from their investigations that relationships at the contractor-subcontractor interface were problematic and conflict orientated stemming from the transactional power of the contractor and the tendency of the contracting organisation to focus on costs rather than value. A view supported by Heath *et al* (1994) and Heath and Berry (1996).

In the same context, Bresnen and Marshall (2000b) investigating the utility of financial incentives as a basis for behaviour modification in the context of partnering, concluded that the financial incentives that form the basis of partnering agreements are of insufficient valence to effectively influence individual behaviour given the complexity of the social and organisational structures normally present on construction sites. The culture on site is not, it is suggested, one which promotes compliance as a normative response.

Griffith and Phillips (2001) in examining the influence of the CDM Regulations on the procurement and management of small building works commented upon the increase in managerial workload imposed by the Regulations, a workload which could not always be borne by the SME. They also found that this top down legislative control did not act to positively change the culture of the organisation and that the way forward to improved health and safety practice was through better training, clearer contractual accountability and improved workplace control.

In a general sense it is accepted that the most effective implementation of health and safety takes place at the level of the individual (Duff *et al* 1994). This viewpoint has been supported by Lingard and Rowlinson (1998), who linked the improvement of safety on site with motivation of the individual, and Lingard (2001) who associated site based first aid training with improved safety performance on site. The implication being that strategies for improvement must be centred on the individual, suggesting that a top-down approach to behaviour modification on site will be of limited effect. This results in something of an impasse for an industry dominated by top down management and populated by operatives who are traditionally resistant to change and often oblivious to the need to work safely .

Conclusions

There is evidence to suggest that the Government’s legislative initiatives in respect of health and safety management in the construction industry have been beneficial in the sense that the CDM Regulations do have a positive effect on safety on site. It is not as easy to establish, however, that the effect is both wide ranging and long lasting – a change in culture. It appears that a number of barriers exist which act to prevent this. The structure of the construction industry, the financial orientation of the procurement process and the adversarial nature of contractual relationships within the industry all combine to limit the effect of health and safety initiatives in the workplace.

Partnering has been proposed as the strategic mechanism through which the culture of the industry will change. The research evidence presented in this paper suggests, however, that this is not the case. It is clear that partnering has some beneficial effects on the client-contractor interface but it is equally clear that this does not extend to the contractor-subcontractor interface. The result is an industry with a fragmented approach to the management of health and safety on site where the cost of health and safety is secondary to considerations of time, cost and quality.

Although the research would suggest that long term improvements can only be achieved through strategies that encourage the individual to be come more safety conscious and establish a minimum level for individual behaviour in this context, a top down strategy is, it is suggested, needed to provide the environment within which this change can occur. Despite the emphasis placed upon the pivotal role of the contractor in determining the culture of contractual relations, the key issue for health and safety lies in the pivotal role of the client in influencing the status of health and safety management as a key issue in the procurement process rather than its present position as being one item on a list dominated by the lowest cost as a criteria for selection.

References

Atkinson, A. (1998) Human error in the management of building projects, *Construction Management and Economics,* 16, 339-349.

Baden-Hellard, R. (1995) *Project Partnering, Principles and Practice,* Thomas Telford, London.

Barlow, J., Cohen, M., Jashapara, A. and Simpson, Y. (1997) *Towards Positive Partnering,* The Policy Press, Bristol.

Bennett, J. and Jayes, S. (1998) *Trusting the Team: The Best Practice Guide to Partnering in Construction,* Centre for Strategic Studies in Construction/Reading Construction Forum, Reading.

Berry M.J. (2000) *The Incidence and Effect of Conflict arising as part of the Construction Process*, PhD Thesis, University of Wales, Unpublished.

Bresnen, M. and Marshall, A. (2000a) Partnering in construction: a critical review of the issues, problems and dilemmas, *Construction Management and Economics,* 18, 220-237.

Bresnen, M. and Marshall, A. (2000b) Motivation, commitment and the use of incentives in partnerships and alliances, *Construction Management and Economics,* 18, 587-598.

CII (1991) *In Search of Partnering Excellence,* Construction Industry Institute, Austin, Texas.

CII (1994) *Benchmarking Implementation Results, Teambuilding and Project Planning,* Construction Industry Institute, Austin, Texas.

Critchlow, J. (1998) *Making Partnering Work in the Construction Industry*, Chandos, Oxford.

Dainty, A.R.J., Briscoe, G.H. and Millett, S.J. (2001) New perspectives on construction supply chain integration, *Supply Chain Management,* 6 (4), 163-173.

Davis, L. (1995) Two’s Company, *Chartered Surveyor Monthly,* May 1995, RICS, London.

Day, T. (1996) The key to success in construction contracts, *Chartered Surveyor Monthly,* October 1996, RICS, London.

Djebarni, R. The impact of stress in site management effectiveness, *Construction Management and Economics,* 14, 281-283 .

Duff, A.R., Robertson, I.T., Phillips, R.A. and Cooper, M.D. (1994) Improving Safety by Modification of Behaviour, *Construction Management and Economics,* 12 (1), 67-78.

Egan, J. (1998) *Rethinking Construction, The Report of the Construction Industry Task Force,* DETR, London.

Fraser, C. (2000) The influence of personal characteristics on effectiveness of construction site managers, *Construction Management and Economics,* 18 (1), 29-36.

Griffith, A. and Phillips, N. (2001) The Influence of the Construction (Design and Management) Regulations 1994 upon the Procurement and Management of small building works, *Construction Management and Economics,* 19, 533-540.

HSE (1994) *The Construction (Design and Management) Regulations) 1994,* HMSO, London.

HSE (1997) *Evaluation of the Construction (Design and Management) Regulations 1994,* CRR158/1997. HMSO London.

Hatush, Z. and Skitmore, M. (1997) Criteria for Contractor Selection, *Construction Management and Economics,* 15 (1), 19-38.

Heath, B.C., Berry, M.J. and Hills, B. (1994) "The Nature and Origin of Conflict within the Construction Process" *International Council of Building Research, Studies and Documentation (CIB) Publication No 171 Construction Conflict: Management and Resolution,* 35-48 International Council for Building Research, Studies and Documentation.

Heath, B.C. and Berry, M.J. (1996) An examination of the issues arising on site from the use of standard and non-standard procurement methods and the implications of the same for project success. *Proceedings of the CIB W92 Symposium,* 200-212 International Council for Building Research, Studies and Documentation, Hughes, G. (2001) *An Investigation into the Concept of Partnering within the Procurement Process,* BSc Dissertation, University of Wales, Unpublished.

Latham, M. (1994) *Constructing the Team, Final Report on Joint Review of Procurement and Contractual Agreements in the UK Construction Industry,* HMSO, London.

Lingard, H. (2001) The effect of first aid training on objective safety behaviour in Australian small business construction firms, *Construction Management and Economics,* 19, 611-618.

Lingard, H. and Holmes, N. (2001) Understandings of occupational health and safety risk control in small business construction firms: barriers to implementing technological controls, *Construction Management and Economics,* 19, 217-226.

Lingard, H. and Rowlinson, S. (1988) Behaviour based safety management in Hong Kong's construction Industry: the results of a field study, *Construction Management and Economics,* 16, 481-488.

Loosemore, M. (1999) Responsibility, power and construction conflict, *Construction Management and Economics,* 17, 699 –709.

Loosemore, M. and Tan, C.C. (2000) Occupational stereotypes in the construction industry, *Construction Management and Economics,* 18, 559 –566.

Marler, J. (2000) Construction Partners, *Local Government News,* April, 2000.

NEDO (1991) *Partnering, Construction without Conflict,* HMSO, London.

Tam, C.M. and Fung, I.W.H., (1998) Effectiveness of safety management strategies on safety performance in Hong Kong, *Construction Management and Economics,* 16(1) , 49-55.

Tam, C.M., Fung, I.W.H. and Chan, A.P.C. (2001) Study of attitude changes in people after the implementation of a new safety management system: the supervision plan, *Construction Management and Economics,* 19, 393-403.

ACCIDENT RATE ON BUILDING SITES AS A QUALITY DATA IN A SIMULATION MODEL OF PRODUCTION

Kaplinski, Oleg Poznan University of Technology, Poland

Introduction

Presented in the first part of this paper is accident rate characteristics in building firms in a region of Poland. Adaptability of such data to a simulation model is then discussed, followed by an example of such analysis, concluding these considerations. They are based on the assumption that it is possible to include data on accidents in other quality data and then, after combining them with quantity data, to bring them to a series with a simulation model of investigation into production reliability.

Accident Rate on Building Sites and in Building Firms in Poland

A fraction of GNP is spent in every country on compensations for accidents at work and occupational diseases. Regrettably, such accidents and health hazard are being more and more of a problem in Poland. The incidence of accidents at work in 1998 was 16.2% higher compared with 1990. The incidence of occupational diseases increased by 28.5% in the same period of time.

Since 1999, as much as 96% of the entire building production has been in the hands of private contractors while merely 4% has been provided by the public sector. There has been a significant growth in the number of private firms in the building industry, although its production potential in Poland is still extremely dispersed. Small building firms with up to 20 employees provide over 45% of building and assembly work, even though they occupy 97% of the whole building sector. Merely 0.6% of the total number of building firms are large enterprises with more than 100 employees but they are responsible for more than 33% of the whole production.

It is in the small and medium building firms that the hazard of accidents at work is the highest. The emerging building firms, frequently family businesses with little expendable capital, are unwilling to invest in the machines and equipment that provide safe work conditions and personal protection measures to the personnel. There are a number of reasons for such a situation:

- subjective causes (orientated to maximize profit, inadequate qualifications, insufficient knowledge of applicable rules and laws);
- objective causes (lack of long-term orders, low number of orders, fluctuating and seasonal possibilities to carry out building work).

The hazard of accidents may be analysed with the use of TOL (Techniques, Organization, People) systematics, saying that it is the three domains where such hazards originate from. In Polish regulations, an accident is defined as a sudden event arising in connection with work, triggered by an external factor and causing injury to a person. A pattern is proposed in the form of a sequential model of an accident, taking into account the hazard condition and the damages (c.f., Korona, 2000). The former element concerns indirect causes (relating to economy, subject matter, psychological and sociological factors, responsibility etc.). On the other hand, the indirect hazard of the accident may arise in so-called 'pressure conditions' which account for the formation of the element itself. The latter element is formed by the circumstances and causes of the immediate hazards of the accident – these may be inert, active or time sensitive. It is the kind of hazards that are there, 'waiting' to be activated. Having visualized the probability and size of the risk and the causes and extent of the hazards, one is able to either eliminate or substantially reduce them before an accident happens.

All occupational accidents in Poland are recorded by the State Labour Inspectorate (PIP). What will now follow is detailed data gathered in the North-Central region in Poland, with Bydgoszcz as the first city (according to GUS, 1990-1998; GUS, 2000, and Korona, 2000).

Although the quantity of enterprises in the region has grown by one-third since 1990, their workforce is one-third smaller. The potential of the building production has been dispersed, affecting both employment and equipment. Orientated to maximize profit, which is mainly the case with small building firms, leads to limited expenditure, especially on protection of work stands, proper organization of building sites, adequate hygiene and sanitary facilities. It is a typical practice in tenders for building works to offer reduced costs, usually by cutting down on work protection spending.

The persons injured in accidents at work in building firms in the North-Central region in the years 1990 - 1999 represent a variety of occupations: masons, plasterers, stove fitters and the like are the largest group (13.1%) in the total number of those injured in the accidents. The second and third largest groups are painters (4.9%) and welders, solderers and drivers of automotive vehicles (4.7%), respectively. Fatal accidents at work usually happened to drivers of automotive vehicles (7 deaths).

Taking into consideration the material source of accidents, such objects as certain elements of the scaffolding and auxiliary structures present on building sites are the largest group (14.2%), followed by trucks (10.2%), rocks, ground, gravel, sand and soil (8.2%).

In this analysis, 313 accidents at work that occurred in the years 1990 - 1999 were grouped by their indirect and direct organizational causes, showing that most of them were caused by neglect of building supervisors, tolerant to disregard of work safety rules (16.9%). Next, there are cases of absence of any supervision at all (13.4%), personnel's inadequate qualifications (12.4%), improper arrangement or storage of objects (11.5%).

Among the causes of accidents that originate from human behaviour, reckless disregard of hazardous conditions (e.g. acts of bravado and rashness) is number one with 15.5%, followed by improper handling (grip or hold) of material objects (12.2%). Heavy drinking is number four (10.9%), with a clearly downward tendency.

A number of such cases of faultiness originate from general fluctuations observed in the business. Detected and eliminated from one site, a hazard will be spotted in another work stand or building site, where the building work may even be carried by the same persons.

Accident rate is an unstable phenomenon observed in our building business. Having analysed the accidents, some changes were observed in the structure of the causes of occupational accidents in building firms. Without going into much detail, some typical examples of neglect and hazards occurring on building sites are indicated:

- improper handling (passing and collecting) of tools and materials, storage of materials;
- improper or inaccurate assembly or improper positioning of scaffolding and security devices;
- inappropriate methods of communication during work at high altitudes, climbing up or down the scaffolding;
- lack of personal protection equipment;
- failure to pay attention to electrical connections, wiring, cables etc.;
- inappropriate clothing for work or for specific weather conditions;
- inappropriate performance of work, disregard of work safety rules,
- working while intoxicated.

The question is, how to include phenomena such as the above in models of production processes.

Accident Rate in Reliability Model of Production

The investigation of a production system's efficiency by means of mathematical modelling (in this simulation) does not solve all the problems facing a manager. Such notions as risk management, efficiency of action, costs, mechanization of technological processes, accidents on building sites and in plants are closely connected with the reliability of production. Increased demand, in this respect, especially currently, implies the use of more adequate methods for determining the reliability of processes which form the production process. An unsatisfactory level of applying reliability theory in construction industry is due to two sets of reasons:

Firstly, to the unique character of construction production, the complexity of these processes, the various connections between them and the environment.

Secondly, to analytical difficulties and the small degree to which reliability and efficiency are connected. There are problems with taking into consideration the quality data. Of course, breakdowns of machines and equipment (ability and disability) are typical numerical data. But the author states: these events like absenteeism, accidents, organizational factors can be included in quality data[1] of the production model.

Analysis of these reasons helps to precisely define another approach to the evaluation of production system reliability. The following prerequisites are considered:

i. The traditional use of the probability of disruptions, or the probability that the realization time will be kept, is insufficient to the needs of engineering practice.
ii. The distribution of the proper functioning in the system is a better measure of reliability, useful in the evaluation of production systems.
iii. The notion of systems reliability must be expanded: apart from inefficiency resulting from the breakdown of machines and equipment, there is also inefficiency caused by improper functional structure, organizational factors, absenteeism, accidents, decreased workforce efficiency, shortages in material supplies etc.
iv. Significant functional and reliability features of the system may first be distinguished in the system as appropriate elements (phases) and, next, through homomorphic transformation, they can be brought to a series reliability structure. General view of the series model is presented in Figure 1.
v. Reliability structure in a system is achieved through a synthesis of its subsystems. A functional structure, the influence of the system's environment and disruptions of the system are basic factors which form the reliability structure.
vi. In order to quantitatively evaluate the influence of the environment on the system, the connections should be mapped by means of phases and connected in series to the reliability structure. Prerequisites (iv), (v) and (vi) influence the system's decomposition and synthesis procedure.
vii. Every disruption can be treated as an independent phase and connected in series to the formerly determined reliability structure. The time during which the phase is in one of the two states (work and inefficiency) may be described by the probability function, a histogram or the deterministic value. The phases can have a simple or complex form, e.g., series, parallel, with reserves, with inertia etc.
viii. Partial evaluations of subsystems will be used in further calculations as a characteristic of appropriate phases on a lower level decomposition.

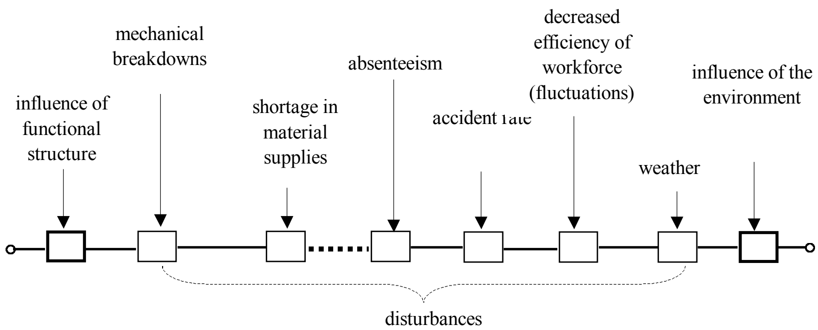


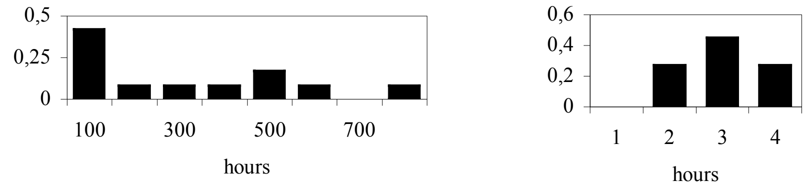
Figure 1.1 Fundamental elements of a series model

The Simulation Model

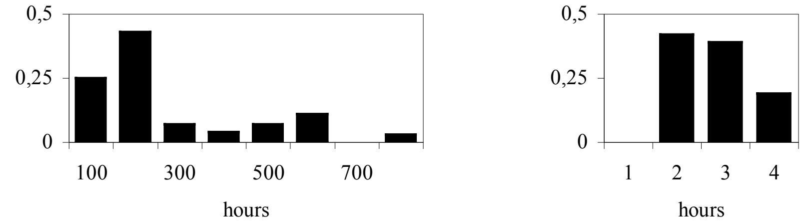
The suggested method of investigation and evaluation of production system reliability utilizes the prerequisites discussed above. The following main elements may be distinguished:

- a system's decomposition for investigational needs,
- influence of the environment,
- determination of disruptions and the manner in which they can be accounted for during calculations,
- synthesis of the system,
- interpretation of system time work (during simulation).

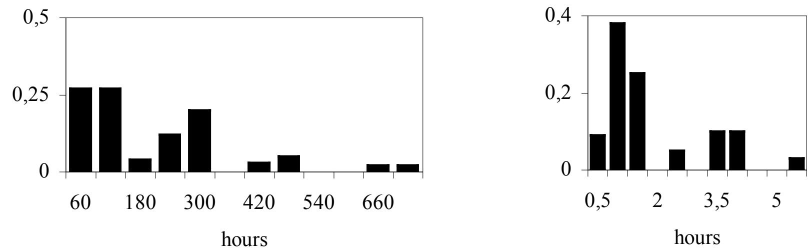
[1] By 'quality data' we mean data about the quality of a construction process.



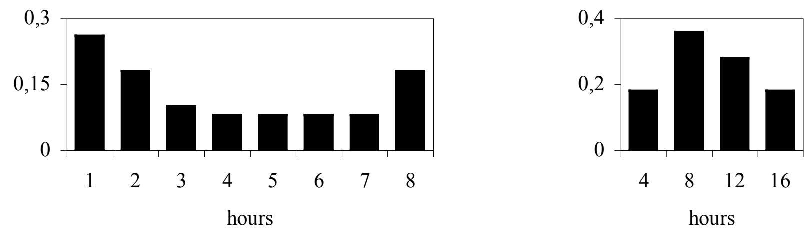
a) Histograms of ability and disability of workpeople: Production of small size celluar concrete elements



b) Abillity and disability of overhead traveling crane



c) Work time and down time: cassette moulds in prefabrication plant



d) Concrete heating and lack of streem: water vapour in Flow Production Line

Figure 1.2 Examples of distributions (input of one phase in simulation model)

A programmed model of a production system (working as a simulator) is an investigational instrument. It is a two-state model with a series structure. The structure of the program is oriented to events of changes of a phase state and events of changes of a system's state. The duration of these states of functioning and non-functioning is determined in accordance with prerequisite (vii). This model is programmed in GPSS. The simulator has been verified using three methods: statistical comparison of results with theoretical data, comparison with another simulation program, and comparison of a simulator generated distribution with theoretical and empirical ones.

As for the results of computer calculations we got: the mean time of properly functioning segments; the mean time of non-functioning segments; global work time of the system; the time of system non-functioning; the availability factor and all statistical data.

The Empirical Investigations

Investigations were carried out in numerous building sites and in prefabrication plants and the following phenomena were discovered:

- a variety of functional structures,
- the validity of the thesis about the series formulation of reliability structure with its variant solution of individual phases as subsystems,
- work time distributions and the non-functioning of mechanical devices near the exponential distribution,
- distributions of shortages of raw materials are symmetric (rectangular and normal).

Generally, a synthetic reliability model of a plant is fairly complex and individual analysis, due to a great number of elements (phases), is impossible (c.f., Kaplinski. 1989). Examples of the distributions as an input of one phase in a simulation model are presented in Figure 1.2.

1.6 AN EXAMPLE OF SIMULATION INVESTIGATIONS

An example of simulation investigations of subsystems Flow Production Line FP-03 from the Figure 1.3 is presented below.

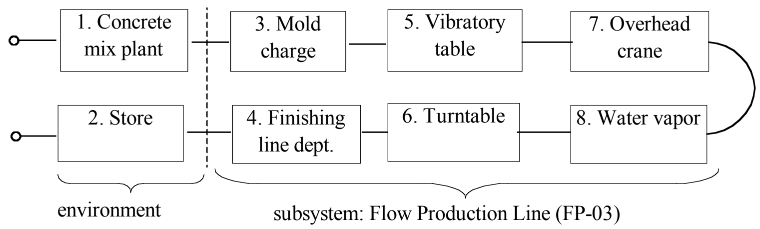


Figure 1.3 Example of the analysis

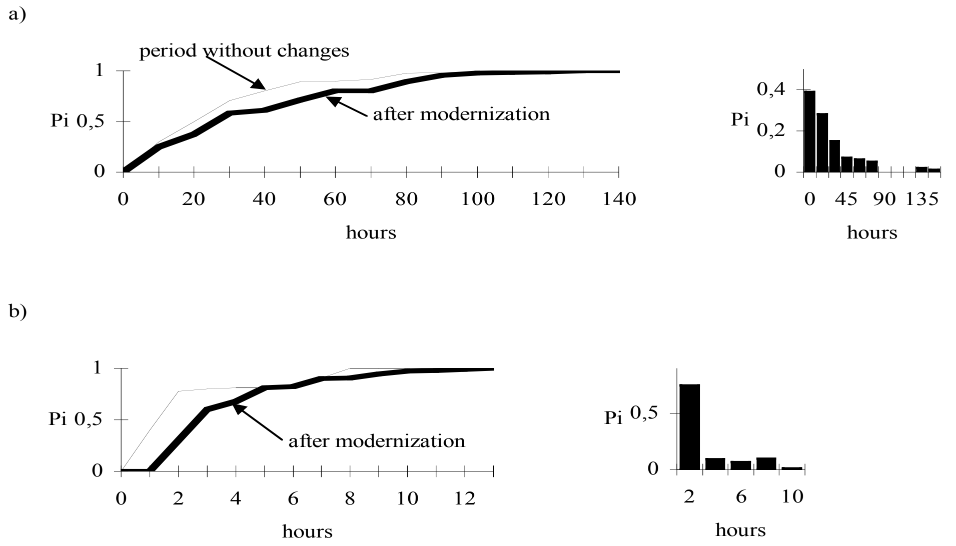
Some empirical data in the form of histograms (ability and disability), an analyzed subsystems, and some results (in the form of distribution functions and numerical data) have been adapted from the building enterprise in Suchy Las near Poznan in Poland. The latter results, obtained from simulation (in the form of distribution functions, the global system work time and the system's mean segments of work and non-functioning) constitute a basis for determining the system's efficiency and for working out an appropriate course of action in order to increase the system's work reliability.

For subsystem presented in Figure 1.3, the following results were obtained:

total time of the system's work	4946 hrs.
total time of the system's breakdowns	626 hrs.
availability factor	0.8876
average time of segments of the system's proper work	24.009 hrs.
average time of the system's unfitness	3.038 hrs.

Results obtained in the simulation are illustrated in Figure 1.4 in the form of histograms and distribution functions**.** They are points of departure in determining the system's efficiency and an adequate manner of reliability control.

Figure 1.4 Results of simulation of segments of proper work (a) and breakdowns (b) of the subsystem under investigation.



At the beginning of the following year of these investigations, mechanical changes were introduced in the turn-table and organization of the finishing line department. Downtime due to failure of equipment and injury to employees was eliminated by nearly 100%. The reliability model in Figure 1.3 was altered: 8 elements (phases) were replaced by 6 as no failure occurred in the two elements mentioned. Under the new conditions (including histograms), the availability increased to 0.904.

Other examples can be investigated in the same manner.

Final Remarks

The method is an example of inclusion of data on accidents at work in production modelling. The problem of accident rate is to a large extent of a quality nature, therefore, it is difficult to identify and interpret them as quantity data in simulation models.

There are good reasons to believe that data on accident rate will be considered as quantity data as soon as data bases with records of equipment failure, downtime, accidents – e.g. in the form of histograms or coefficients have been created. Such comprehensive data bases, especially those on building firms, are still lacking.

Acknowledgements

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References

GUS, 1990-1998, Roczniki statystyczne, (Warsaw: Glowny Urzad Statystyczny, from 1990 to 1998).

GUS, 2000, Rocznik statystyczny pracy, (Warsaw: Glowny Urzad Statystyczny).

Kaplinski O., 1989, Different mode of connection of quality and reliability in construction process organization. In *Proceedings of the XIth International Congress on Quality for Building Users Throughout the World*, (Paris, CIB), pp. 87-95.

Korona L., 2000, Analiza wypadkowosci w przedsiebiorstwach budowlanych regionu kujawsko - pomorskiego. In *Proceedings of the Conference on Risk Management in Enterprise*, edited by Bizon-Gorecka J., (Bydgoszcz - Ciechocinek: BGJ-Consulting Press), pp. 255-266.

EXCAVATION AND TRENCHING SAFETY: EXISTING STANDARDS AND CHALLENGES

Lew, Jeffrey Department of Building Construction Management, Purdue University, West Lafayette

Abraham, Dulcy School of Civil Engineering, Purdue University, West Lafayette

Wirahadikusumah, Reini School of Civil Engineering, Purdue University, West Lafayette

Irizarry, Javier School of Civil Engineering, Purdue University, West Lafayette

Arboleda, Carlos School of Civil Engineering, Purdue University, West Lafayette

Introduction

Trenching fatalities and injuries continue to plague the construction industry. While complete and accurate records of the actual number of fatalities occurring in trenching incidents are not maintained, "the estimate of 100 fatalities per year due to cave-ins and other excavation accidents (Hinze and Bren 1996)", and 7000 injuries, is perhaps a reasonable approximation of the magnitude of the problem. In addition to the possibility of trench cave-ins, workers in trenches can "be harmed or killed by engulfment in water or sewage, exposure to hazardous gases or reduced oxygen, falls, falling equipment or materials, contact with severed electrical cables or improper rescue (ELCOSH website)."

Findings of a mail survey conducted by Equipment World (1998) show the following alarming statistics:

- Nearly 41% of all respondents said they experienced a trench collapse on one of their jobs. Out of this group, 29.4% said that someone was injured or killed in the collapse.
- Of the nearly 41% who had experienced a trench collapse on a job, 76.5% said that the trench collapse was due to unstable soil, 29.4% said it was due to human error, and 11.8% said it was due to insufficient shoring/shielding.

In addition to fatalities, injuries caused due to unsafe trenching practices are costly in terms of direct and indirect costs to the construction industry. The direct costs include medical and workers' compensation payouts. In 1995, construction accounts for 15% of all workers' compensation spending while construction workers are only about 6% of the labor force (CPWR 1998). The employers and society also pay large indirect costs. Hinze (1991) estimated that the ratio of indirect to direct costs for injuries resulting in lost work time was 20 to 1. The indirect costs range from lost productivity among co-workers and management, and lawsuits, to reduced worker morale, especially when fatalities occurred.

In September 2001, Purdue University received a grant from the National Institutes of Occupational Safety and Health (NIOSH) to develop strategies for safer trenching operation. This paper discusses the initial findings of this study and focuses on the following issues:

- Role of the competent person in excavation safety
- OSHA regulations related to excavation safety
- Causes of accidents
- Characteristics of accidents

Role of the Competent Person in Excavation Safety

To function as a competent person at an excavation site a competent person must be:

1. Thoroughly knowledgeable with excavation safety standards including soil classification.
2. Capable of identifying existing and predictable and hazards and unsafe conditions.
3. Knowledgeable in the proper use of protective systems and trench safety equipment.
4. Designated to have the authority to stop work when unsafe conditions exist.

A person must have documented experience and training in the first three requirements, and be designated as the competent person by the employer with the authority indicated in requirement four. Construction management must be aware of these requirements, and that the responsibility to comply with these requirements rests with the managers or owners of construction companies.

OSHA Regulations Related to Excavation Safety: OSHA Standard 1926 Subpart P

The OSHA (Occupational Safety and Health Act) standard consists of three main sections with six (6) appendices. The first section contains definitions clearly defining the terms used in the excavation standard. It is important that these definitions be understood before reading the standard and applying the rules of the standard to the worksite.

The second section contains the general requirements. All underground and aboveground installations must be located before starting excavation work. Access and egress must be provided for employees in excavations over 4 feet in depth to prevent falls when entering or exiting excavations. Employees working in trenches shall be protected from cave-ins, loose rock and soil, from falling loads, and hazardous atmospheres. Both surface and subsurface water must be controlled with water removal equipment supervised by a competent person. Adjacent structures must be underpinned before start of excavation work. All required inspections shall be conducted by a competent person on a daily or as needed basis. Fall protection must be provided where appropriate in excavations and over trenches.

The third section specifies the actual Requirements for Protective Systems that must be provided by the employer to protect workers who enter excavations. The standard requires that employees entering excavations which are five feet or greater in depth be protected from cave-ins. The eight OSHA options are the methods that must be used to protect the employees and must be understood by the competent person. The requirements for protective systems are divided into two categories, *sloping and benching* and *support systems*, each of which contains four options, thus eight OSHA options are available to the competent person. *Support systems* include *shoring systems* and *shielding systems.*

It must be noted that the competent person can use the standard to a maximum depth of 20 feet. Excavations deeper than 20 feet require the approval of a registered professional engineer

The primary appendices of the standard are: Appendix A, Soil Classification; Appendix B, Sloping and Benching; Appendix C, Timber Shoring; and Appendix D, Aluminum Hydraulic Shoring.

Causes of Accidents

Data on occupational accidents can be obtained from several agencies: the Bureau of Labor and Statistics (BLS), the Occupational Safety and Health Administration (OSHA), and the National Institute for Occupational Safety and Health (NIOSH). Each agency maintains its database for different specific objectives; thus, the types of information included in the database and the focus of the investigation varies from agency to agency.

The National Safety Council has adopted the BLS figures (beginning with the 1992 data year), as the authoritative count for work related deaths in the United States. However, the categories in the BLS system on fatal injuries do not isolate “trench-related” injuries. While most injuries would be classified as “caught in or crushed in collapsing materials” or “excavation or trenching cave-in,” trench-related injuries could also be categorized as “falls,” “contact with electric current,” etc. Using the BLS data alone, the death or injury counts can be misleading and they are in most cases, understated. Therefore, to measure the trenching hazard and to study the causes of trench-related accidents, the database from all three agencies should be used concurrently.

In order to understand the fatalities causes associated with trenching operations, and to develop the intervention strategies, it is necessary to access the National Institutes for Occupational Safety and Health

(NIOSH), specifically, the Fatality Assessment and Control Evaluation (FACE) program. This is a research program designed to identify and study fatal occupational injuries. The goal of the FACE program is to prevent occupational fatalities across U.S by identifying and investigating work situations at high risk for injury and then formulating and disseminating prevention strategies to those who can intervene in the workplace.

As a bibliographic reference, the research project funded by NIOSH has considered and studied 52 (48 out 52 construction operations) reports associated with Trenching and Excavation Operations. All reports were extracted from NIOSH web site. The reports covered the period from 1985-2000.

The preliminary results show a similarity with previous research studies (Hinze 1998). Again, sewer systems (35%) and water supply systems (15%) are areas with the highest trenching related fatalities. It was revealed that electrocutions in trenching accidents are increasing.

An analysis of the ***type of accidents***, cave-in was cited as the main cause in seventeen cases. In sixteen+ cave-in cases (94%), the walls were not protected by shoring, shielding or sloping. Eighteen equipment related accidents were included in the FACE reports. These accidents were due to improper equipment operations, equipment working near trenching areas, lack of signals, inexperienced operators and mechanical deficiencies.

The ***month of occurrence*** of the accident was examined. Figure 1 identifies August and October as the months with the highest percentages of fatalities.

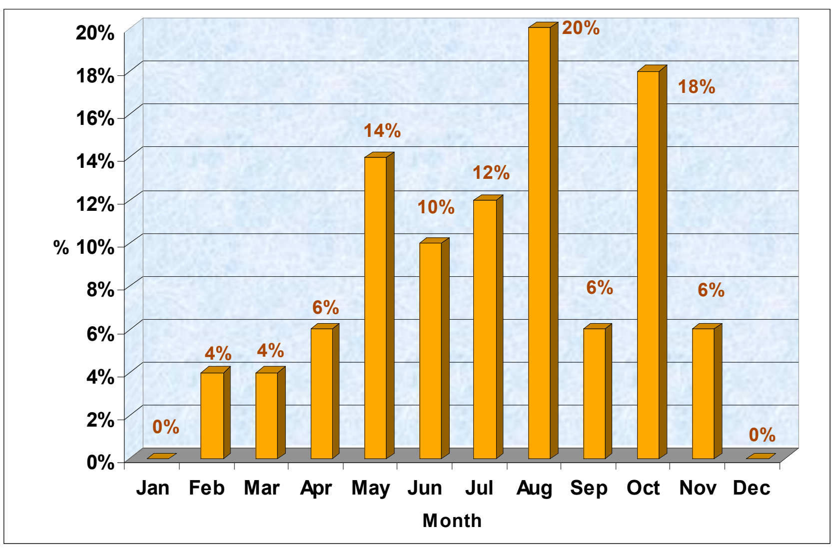


Figure 1 Month of occurrence vs. fatalities

Next, ***Company Safety Programs*** were analyzed. In fifty percent of the cases, the company had an Official Safety Program, but in sixty of the cases, a competent person did not conduct a safety site evaluation prior to the accident.

Another characteristic that was analyzed was the worker's age. In seven percent of the cases, the workers were younger than eighteen. Figure 2 shows the age range for all cases in the FACE reports. It is noted that fifty one percent of the workers were younger than thirty-five.

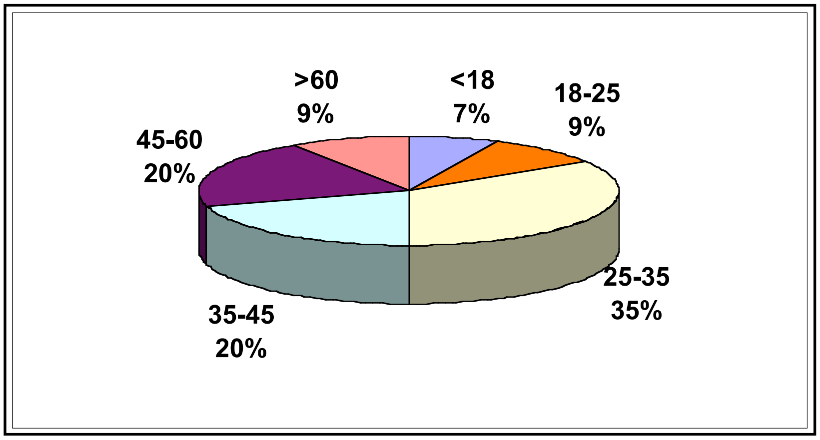


Figure 2 Age vs. percentage of trenching accidents

Characteristics of Accidents

Another source of important information related to trenching related accidents are the OSHA investigation reports, which make up the largest single source for this type of information. To analyze this information a total of fifty fatal and non-fatal cases were identified from 1996 to 1997. The data was obtained from the OSHA Database System. The following parameters were studied, and the observations of this study are discussed in this section:

- Month of event
- Accident outcome (injury or fatality)
- Gender of workers affected
- Classification by SIC code
- Time of day of accident
- Union status of workers
- Trench characteristics.

Month of event: In 1996, twenty one percent of the accidents occurred during the month of October. In 1997, eighteen percent of the accidents occurred during the month of December. Overall the month with the highest incidence of accidents during the period of investigation (1996-1997) was October (16%). Figure 3 shows this information in a graphical format.

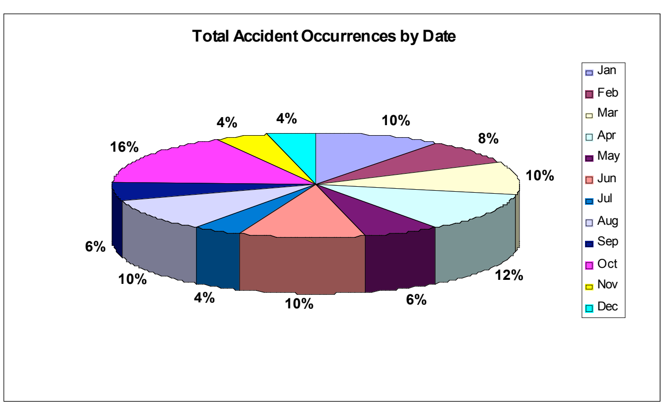


Figure 3 Total accident occurrence by month

Accident Outcome: Of all the cases studied more than half (65%) resulted in fatalities and only 35% resulted in injuries.

Gender of workers: From the data obtained from the OSHA reports, it was observed that all of the workers involved in trenching accidents were male.

Classification by SIC code: According to the data from the OSHA reports forty percent of the accidents reported involved workers for water, sewer, and pipeline contractors, i.e., SIC (Standard Industrial Classification) Code – 1623.

SIC Code	Accidents	%
1389	1	2%
1521	1	2%
1541	2	4%
1542	1	2%
1622	1	2%
1623	20	40%
1629	3	6%
1711	3	6%
1731	1	2%
1761	1	2%
1771	3	6%
1781	1	2%
1794	7	14%
7353	1	2%
9199	1	2%
9511	1	2%
Not Reported	2	4%
	50	100%

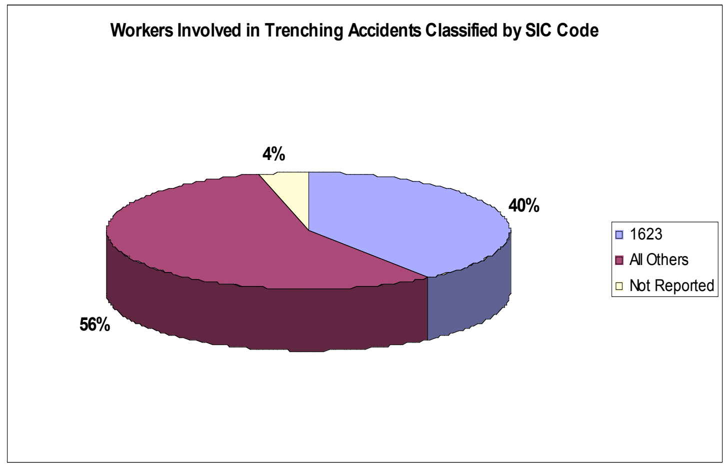


Figure 4 Total accident occurrence by SIC code

Time of day: From the data available a comprehensive analysis of the time of day of occurrence of the accidents was not possible. The time of day of the accidents was reported on only seven (14%) of the 50 cases analyzed.

Union status: The majority of the workers involved in trenching related accidents were non-union workers (98%). This gives us an indication that workers who are not union members are more likely to have accidents due to lack of training.

Trench characteristics: Of the fifty cases studied, twenty-seven reported information related to the depth of the trenches in which the accidents took place. The depth of the trenches varied from 0 to 20 ft with ten instances (37%) in the range from 0 to 5 ft. This gives us an indication that even in shallow trenches the possibility of accidents still exists.

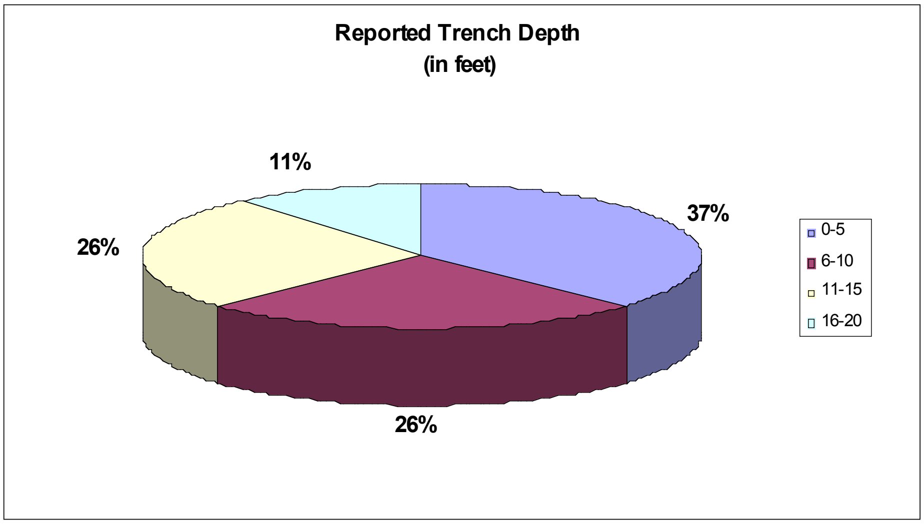


Figure 5: Total accident occurrence by trench depth

Conclusions

This paper discussed the role of the competent person in excavation safety and analyzed characteristics of accidents based on FACE and BLS records. Based on these initial findings, continued site visits and interviews with craftspeople, and front-line supervisors, potential intervention strategies can be identified. These may include recommendations to OSHA regarding the existing standards for trench safety, engineering controls, and safety management issues in construction. Two key observations from the initial review of records point to the need for a competent person at the work site and effective worker training prior to the commencement of construction operations.

References

Bureau of Labor Statistics (2000). National Census of Fatal Occupational Injuries, 1999. United States Department of Labor, Washington, D. C.

Equipment World (1998). Digging Deeper: Survey on Trench Shoring Practices.

Hinze, J. (1991). Indirect Costs of Construction Accidents. The Construction Industry Institute (CII), Austin, Texas. *Source Document* 67.

Hinze, J., and Bern, K. (1996). Identifying OSHA Paragraphs of Particular Interest. ASCE, *Journal of Construction Engineering and Management*, (Vol. 122, No. 1) March 1996: 98-100.

Hislop, R. D. (1999). Construction Site Safety – A Guide for Managing Contractors, Lewis Publishers, Boca Raton, Florida.

OSHA Standard 1926 Subpart P, *U.S. Department of Labor, Occupational Safety and Health Administration*, July, 1992.

Rekus, J. F. (1992). Safety in the Trenches. *Occupational Health & Safety*, February 1992: 26-37.

Stanevich, R. L., and Middleton, D. C. (1988). An Exploratory Analysis of Excavation Cave-In Fatalities. *Professional Safety* (Vol. 33) 1988: 24-28.

Thompson, L.J. and Tannenbaum, R.J., Responsibility for Trenching and Excavation Design. *Journal of the Geotechnical Engineering Division*, ASCE, Vol. 103 April 1977, p.p. 327-338.

Thompson, L.J., Trenching and Excavation Safety *ASCE Specialty Conference on Construction Equipment and Techniques for the Eighties*, March 28-31, 1982, Purdue University, West Lafayette, Indiana, p.p. 302-307.

U.S. Department of Labor: Occupational Safety and Health Administration (1995). *29 CFR 1926/1910; Construction Industry-OSHA Safety and Health Standards*. Revised July 1, 1995. Washington, D.C.

FIRST AID AND OCCUPATIONAL HEALTH AND SAFETY: THE CASE FOR AN INTEGRATED TRAINING APPROACH

Lingard, Helen Faculty of Architecture, Building and Planning, The University of Melbourne, Australia

KEY WORDS

Safety, attitudes, training, first aid, behaviour

Introduction

Theories of social psychology have postulated a causal relationship between attitudes and behaviour (Fishbein and Ajzen 1975, Ajzen 1991). Harvey *et al* (2001) argue that this theoretical connection is likely to apply to occupational health and safety (OHS) behaviours, as it does to other behaviours. There is some empirical research evidence to support this link. For example, Donald and Canter (1994) identified a significant correlation between safety attitudes and accident rates. Attitude theories acknowledge that attitudes can be changed and therefore, it is possible that beliefs about OHS risk and the salience of OHS in one's job can be influenced by organizational interventions, including training. If one accepts that attitudes and behaviour are causally linked, then this attitudinal change could bring about enhanced OHS performance. The study reported in this paper investigated the effectiveness of first aid training in changing the OHS attitudes of operatives working in small construction firms in Australia.

Attitudes and Safety

The general safety literature contains much information about the role that attitudes play in shaping safety behaviour. For example, it is recognised that people's perceptions of risk are more important than objective assessments of probability in influencing risk response behaviours (Hale and Glendon 1987). Attitudes towards risk-taking are also salient. Perceived control over the situation has been related to risk-taking to the extent that a high level of perceived control is associated with acceptance of a higher level of risk (Horswill and McKenna 1999). Attribution theory also suggests attitudinal influences on safety behaviour. For example, the tendency to attribute negative occurrences involving others to internal causes and negative events involving oneself to external or situational causes has been observed in previous risk research (DeJoy 1994). DeJoy (1994) suggests this 'self-other bias' could inhibit safety behaviour. Accidents are statistically rare events and risk taking and risk exposure over time can also lead to a perception that 'it won't happen to me.' Indeed, Weinstein (1980) discovered that a sense of 'unrealistic optimism' about the probability of being involved in an accident increased with experience. Harvey *et al* (2000) suggest that a by-product of this effect is a perception of luck or chance or the belief that accidents 'just happen.' For example, Saari (1988) reports that 40% of foremen in his survey attributed occupational accidents to chance, an attitude that is likely to discourage workers from taking appropriate preventive action. Cooper and Cotton (2000) also suggest that many people may simply accept risk-taking as part of their everyday life at work. Such a fatalistic resigtnation has been noted in previous studies in the Australian construction industry (Holmes *et al* 1999).

The Importance of Training

Training is an important component of any OHS management programme. There is evidence to suggest that effective training is a feature of companies with exemplary OHS performance (Cohen *et al* 1975) and that training is an aspect of a positive safety culture (Zohar 1980). Cooper and Cotton (2000) comment that the provision of training is not only fundamental to satisfying employees' basic rights to be protected from workplace hazards but is also a statutory requirement in many jurisdictions. Yet recent European research suggests that task and OHS training on construction sites is inadequate (Laukkanen 1999). Furthermore, there is widespread criticism of the failure to evaluate the training that is provided to ensure that it is having the desired effect (Mukherjee *et al* 2000, McQuiston 2000, Vojtecky and Schmitz 1986).

First and Training

Research conducted in the nineteen-seventies and early nineteen-eighties investigated the impact of first aid training on the prevention of occupational injuries. This research identified an association between traditional first aid training and a lower incidence of workplace injuries (Miller and Agnew 1973; McKenna and Hale 1981). The early research also revealed that people trained in first aid expressed a greater willingness to take personal responsibility for safety and a willingness to adopt safe behaviour (McKenna and Hale 1982). This research suggests that first aid training might be used to supplement more traditional OHS training programmes to provide a positive motivational influence. However, these early studies were not undertaken in a construction industry environment. Furthermore, the choice of injury rates, a notoriously problematic indicator, as the principal safety performance measure rendered the results inconclusive. Cooper and Cotton (2000) identify a shift towards the use of "softer" performance measures in evaluations of training programmes. For example, Harvey *et al* (2001) used an attitude survey to determine the impact of training on safety culture in the nuclear power industry.

Small construction firms

The Australian construction industry is characterised by a multitude of small firms and the domestic building sector is predominantly serviced by such firms. Research suggests that small construction firms do not manage OHS risk as effectively as larger businesses in the industry (Holmes 1995) and experience a higher incidence of occupational injury than larger firms (McVittie *et al* 1997). In this context it is unlikely that formal training programmes will be implemented. Indeed, many operatives in this sector would have learned their trades through on-the-job apprenticeships with minimal formal vocational instruction. As a result of this, the 'top-down' method of delivering OHS messages is of limited utility in small firms (Mayhew 1997). Furthermore there is evidence to suggest that OHS messages 'from above' may be rejected at the shop floor (Harvey *et al* 2001). These findings suggest that alternative insertion points for the OHS message may need to be found to reach workers in small firms. Mayhew (1997) recommends the use of 'bottom up' or laterally inserted messages. First aid training may provide one opportunity to insert the OHS preventive message from the 'bottom up.'

Methods

A 24-week experiment was conducted on small domestic housing construction sites in Melbourne, Australia. A purposeful, typical case sampling strategy was used to recruit a sample of 25 participants from 10 different construction industry small businesses operating in this sector. Three participants subsequently dropped out of the study leaving a sample of 22. Participants' OHS-related attitudes were explored during in-depth interviews were conducted at two times during the study. Interviews were conducted at T1, before participants underwent first aid training, and again at T2, following their completion of a first aid training course.

A structured interview theme list was developed to explore participants' OHS attitudes. The interview questions were open-ended and designed to elicit personal anecdotes from participants' workplaces. Weidner *et al* (1998) suggest that employees' 'stories' provide a valuable data source in the evaluation of the effect of a training intervention. A structured approach was suited to the research purpose in that it is useful in ensuring the comparability of data and enabled the identification of similarities and differences between participants' understandings before and after their receipt of first aid training (Maxwell 1996). A coding framework was developed independently by two researchers and the interview data were then analysed to identify to identify the importance of key themes.

Results

The important themes emerging from the interview data at T1 and T2 are presented in Table 1. These themes indicate that participants' attitudes changed in some important respects following their receipt of first aid training.

Theme	Pre-training (T1)	Post training (T2)
OHS risk perception	▪ Immediate effect OHS risks (Falls, power tools, trenches) ▪ Fatal consequences, permanent damage, dread	▪ Acute effect OHS risks (Falls, power tools, trenches) ▪ Fatal consequences, permanent damage, dread ▪ Infectious diseases
OHS risk attribution	▪ Carelessness or complacency (other workers) ▪ Inexperience (other workers) ▪ Chance (self)	▪ Carelessness or complacency (other workers and self) ▪ Inexperience (other workers)
Likelihood of injury/illness	▪ Low probability ▪ 'Won't happen to me'	▪ Medium to high probability ▪ 'Can happen to me'
OHS risk-taking	▪ Accept risk taking to 'get the job done.' ▪ Don't think of consequences	▪ Unwilling to take certain risks to 'get the job done.' ▪ Consideration of the costs/benefits of risk-taking ▪ Aware of consequences

Table 1 Important themes emerging from interview data

Risk perception

During both T1 and T2 interviews, participants' awareness of OHS risks relevant to their work focused on acute effect injuries. Chronic or delayed effect risks were mentioned much less frequently. In the post-training interviews, one participant expressed this as follows:

"*I suppose with heights you are more prone to falling. With dust and things like that, you don't realise it until later on in life so you look at things that happen there and then rather than the long term*."

The only change in participants' perception of risks in their workplace following first aid training was the increased awareness of infectious diseases. During the T2 inteviews, almost half of the participants identified these illnesses as being relevant to their work. Before first aid training, participants thought of minor injuries such as nicks, cuts, scratches as a cost of doing business and indicated that they would often ignore such wounds. Johnson (1999) identified the importance of first aid training in increasing individuals' awareness of the need to treat minor cuts and abrasions immediately to prevent infections from untreated wounds. However, it appears that other than raising awareness of the risk of infection, first aid training had little impact upon participants' perceptions of workplace OHS risks.

Risk Attribution

Before training, OHS incidents were understood to occur as result of individual factors. The most commonly cited source of OHS risks affecting other workers was their carelessness or complacency. For example one participant said

"You can educate people till the cows come home. Overconfidence causes most of the problems and there is nothing you can do about it…You can put up a handrail and provide someone with a harness, but they have to choose to use the harness and they have to operate within the boundaries of the handrail. If someone decides it is a nuisance, they will take it down."

However, although before training participants tended to believe accidents to others were attributable to a lack of care or complacency about OHS, they did not regard carelessness as being relevant to their personal experience of OHS risk. Almost half of the participants expressed the belief that accidents to themselves were attributable to factors beyond their own control, such as the negligence of others. For example, one participant said "There is always the risk of stepping into a puddle and finding out that someone has been negligent and dropped a power cord in there and there is a fault in the leakage switch." Another commented "Well hopefully I won't but things can happen where it is not your fault either, I mean someone could drop a hammer and it could hit you in the head…there is nothing you can do."

During the T1 interviews, participants also expressed the fatalistic view that their own personal experience of occupational injury or illness was a matter of luck or chance. For example, one participant said "Put it this way, in ten years I've had one injury that has taken me to hospital, so that is not to be I think." Another commented "I think it is hard to say. Its your own fate." During the T2 interviews, participants still largely attributed OHS risks to individual factors, such as complacency or carelessness. However, the perception that they could not control their own personal experience of OHS risk appears to have been reduced. Following first aid training, most of the participants expressed the importance of taking care and concentrating to avoid occupational injury or illness to themselves. At T2, very few participants mentioned fate or the negligence of others as important influences on their personal experience of OHS risk. This indicates an increased recognition by participants that their own behaviour is also important in the prevention of occupational injury and disease.

Likelihood of Injury/Iillness

In the T1 interviews, many participants expressed the unrealistically optimistic belief that 'it won't happen to me'. In comparison to others in their workplace, more than a third of participants indicated that others were more likely to suffer from an occupational injury or illness than themselves. For example, one participant expressed this by saying "*You make scaffolds that aren't up to scratch - I would be the only one to walk on them because I know its safe for me but I wouldn't want any one else doing it*." More than a third of the participants explained their ability to avoid occupational injury or illness in terms of the degree of control they exercised in the work environment. One participant expressed this by saying *"I think if you have got your wits about yourself, you can deal with anything*." At T1, another group of participants attributed their comparatively low probability of suffering a work-related injury or illness to their experience in their job. One participant expressed this by saying "*I'm probably less likely [to have an accident] because I've been doing it a long time. Not like the young guys running around madly..[they] run into things, fall off the roof and try to carry heavy weights too quickly*."

At T2, two thirds of participants indicated that they had a medium to high probability of personally suffering a work-related injury or illness. Only a small minority of participants said the chance of them suffering a work-related injury or illness was low. One of these was an office-based site manager while another had just returned to work on 'light duties' having suffered a work-related back injury.

OHS Risk-Taking

At T1, when asked whether they ever knowingly took unnecessary OHS risks at work, every participant in the sample said that they did. When asked what types of risks these were, 12 participants indicated that they were associated with working unsafely at height, for example using unsafe scaffolding, using improvised means of gaining access to height or failing to use a safety harness when required. A further five participants indicated that they occasionally took unnecessary risks using power tools and another four said they sometimes failed to use the correct personal protective equipment. There was a strong acceptance of risk-taking behaviour as 'part of the job.' Only two participants suggested that risks should not be taken or that they were concerned about taking risks. When asked why they took such risks, the most commonly cited response was 'to get the job done,' reflecting a strong production orientation among construction workers.

Following first aid training, participants did not express such a ready acceptance of risk-taking behaviour. In the T2 interviews, only one third of the participants expressed an unreserved willingness to take OHS risks to 'get the job done.' participants suggested that they would take OHS risks but only under certain circumstances. Five participants indicated that they had taken such risks in the past but that they were less likely to do so now. Three participants said they sometimes took risks that they recognised that they should not take. Four participants indicated that they would consider the costs and benefits before taking an OHS risk and base their behaviour on a 'calculated risk,' only taking risks where the benefits outweighed the costs and where they considered the risk to be 'worth it.'

Discussion

These results suggest that first aid training can have a positive effect on construction operatives' attitudes towards OHS. First aid training appears to enhance construction operatives' awareness of the risk of infectious diseases and develop their understanding of the need to treat minor wounds. The first aid training also appears to change construction operatives' attitudes towards the source of occupational injury and illness, making them more aware of the relevance of their own behaviour in the avoidance of occupational injury or disease. First aid training seems to reduce workers' sense of 'unrealistic optimism' about their likelihood of experiencing a work-related injury or illness and therefore it seems that first aid training could help to overcome the motivational problem that workers' direct personal experience of serious negative OHS consequences is rare. It also seems likely that participants' stronger belief that they could personally suffer an occupational injury or illness, following first aid training, renders them less comfortable about taking unnecessary risks.

This attitudinal change is an essential aspect to any preventive OHS training programme. Goldstein (1993) has observed a low correlation between learning an ability to do something and actual job behaviour. With regard to OHS, this low correlation has been explained by the moderating effect of attitudinal factors (Liddell 1994). Therefore, providing workers with the knowledge, skills and abilities (KSAs) to work safely is insufficient. Most task and OHS training programmes focus on providing these KSAs. However, the results of the present study suggest that first aid training would be a valuable supplement to such training programmes and could enhance their preventive effect.

Similarly, the provision of first aid training on its own is likely to have a limited preventive effect. As the interview data revealed, other than raising awareness of the risk of infectious diseases, the first aid training did not increase participants' understandings of specific OHS risks relevant to their work and it is likely that the extent to which the attitudinal change translates to positive behaviour change will depend upon workers' understandings of OHS risk, knowledge of appropriate risk control behaviours, or their KSAs.

Conclusions

These findings have important implications for the role of first aid training in OHS and task training programmes. Presently, the provision of first aid training is recommended in proportion to the extent of workplace occupational health and safety (OHS) risks. Thus, the greater the risk, the more people trained in first aid are required. The recommended ratio of 'first aiders' to people not trained in first aid ranges from 1:25 to 1:50 depending on the extent of workplace (OHS) risk (Vaaraanen *et al* 1979). The findings of this study suggest that there could be value in providing first aid training to all employees in a workplace, rather than to a limited number of designated 'first aiders.' First aid training could be a useful component of task and OHS training courses and should be viewed as a core competency in the construction trades.

These findings also have important implications for the way that first aid courses may be directed and delivered. First aid training courses should be designed to encourage people to think about OHS risks in their workplace. For example, first aid trainees could be given 'homework' of thinking up three or four commonplace situations they find themselves in at work and asked to imagine emergency situations involving breathing, bleeding, breaks and burns in each of the situations (Cooper 1996). Visual imagery could also be used so that the first aider can relate the training to their own work environment. This is a similar approach to that used in sports psychology in which the athlete is taught to mentally rehearse performance. Alternatively, training could be conducted at the workplace and injury scenarios created by placing the Resusci-Annie at a location on site. First aid trainers could also present information about injuries and illnesses and their treatment in the context of how they could occur in the participants' own workplace. For example, injuries could be related to the OHS risks relevant to participants' work such as discussing wounds occurring while using power tools, burns from bitumen, or occupational asthma arising from exposure to chemicals. This could serve the dual purpose of providing participants with the skills to treat injuries and illnesses and improving their understanding of specific workplace OHS risks.

Limitations and Future Research

The findings of this study provide a good insight into the positive effect of first aid training on OHS attitudes. However, the study was limited by the small sample size which was determined partly by the labour-intensive qualitative research methods adopted. However, the results could be used to devise a questionnaire to quickly and easily elicit individuals' OHS attitudes before and after first aid training. This could enable an assessment to be undertaken on a larger scale. Given a sufficiently large sample size, it would then be possible to generalize the findings.

Also, No attempt was made in this study to consider other factors, such as age, experience or intelligence, that have been found to have an impact upon how receptive workers are to the OHS message (McKenna 1987). These issues could be explored in future work because they may have an implication for training course delivery.

References

Cohen, A., Smith, M., and Cohen, H.H., (1975), Safety Programme Practices in High vs Low Accident Rate Companies - An Interim Report, US Department of Health, Education and Welfare, Publication number 75-185, National Institute for Occupational Safety and Health, Cincinnati, OH.

Cooper, M. and Cotton, D., (2000), Safety training - a special case?, Journal of European Industrial Training, 24/9, 481-490.

Cooper I., (1995), First aid training; a holistic approach, Occupational Health, 47 (4), 128-9.

DeJoy D.M., (1994), Managing safety in the workplace: An attribution theory analysis and model, Journal of Safety Research, 25, 3-17.

Fernandez, J.A., Daltuva, J.A. and Robbins, T.G., (2000), Industrial emergency response training: an assessment of long term impact of a union-based program, American Journal of Industrial Medicine, 38, 598-605.

Goldstein I.L., (1993), *Training in Organizations*, 3rd edition, Brookes/Cole, Pacific Grove, CA.

Hale, A.R. and Glendon, A.I., (1987), Individual Behaviour in the Control of Danger, Elsevier, Amsterdam.

Harvey, J., Bolam, H. Gregory, D. and Erdos, G., (2001), The effectiveness of training to change safety culture and attitudes within a highly regulated environment, Personnel Review, 30, 615-636.

Holmes N., Lingard H., Yesilyurt Z. and DeMunk F., (1999), An exploratory study of meanings of risk control for long term and acute effect occupational health and safety risks in small business construction firms, Journal of Safety Research, 30, 251-261.

Horswill, M.S. and McKenna, F.P., (1999), The effect of perceived control on risk taking, Journal of Applied Social Psychology, 29, 377-391.

Laukkanen, T., (1999), Construction work and education: occupational health and safety reviewed, Construction Management and Economics, 17, 53-62.

Lindell, M.K., (1994), Occupational Medicine: State of the Art reviews, volume 9, No 2, Hanley and Belfus Inc., Philadelphia, 211-240.

McKenna S.P. and Hale A.R. (1981), The effect of emergency first aid training on the incidence of accidents in factories, Journal of Occupational Accidents, 3, 101-114.

McKenna S.P. and Hale A.R., (1982), Changing behaviour towards danger: the effect of first aid training, Journal of Occupational Accidents, 4, 47-59.

McQuiston, T.H., (2000), Empowerment evaluation of worker safety and health education programs, American Journal of Industrial Medicine, 38, 584-597.

Miller G. and Agnew N. (1973) First aid training and accidents, Occupational Psychology, 47, 209-218.

Mukherjee, S., Overman, L., Leviton, L. and Hilyer, B., (2000), Evaluation of worker safety and health training, American Journal of Industrial Medicine, 38, 155-163.

Saari J., (1988), Successful accident prevention: An intervention study in the Nordic countries, Scandinavian Journal of Work Environment and Health, 14, 121-123.

Vaaranen A., Kolivuorii T., Rossi K., Tolonen M. and Hassi J., (1979), First aid preparedness in small workplaces with special reference to occupational health services, *Scandinavian Journal of Work, Environment and Health*, 5, 12-15.

Vojtecky M.A. and Schmitz M.F., (1986), Program evaluation and health and safety training, *Journal of Safety Research*, 17, 57-63.

Weidner, B.L., Grotsch, A.R., Delnevo, C. D., Newman, J.B., McDonald, M., (1998), Worker health and safety training: assessing impact among responders, *American Journal of Industrial Medicine*, 33, 241-246.

Weinstein N.D., (1980), Unrealistic optimism about future life events, *Journal of Personality and Social Psychology*, 39, 806-820.

Zohar, D., (1980), Safety climate in industrial organizations - theoretical and applied applications, Journal of Applied Psychology, 65, 96-102.

JOB DEMANDS ASSOCIATED WITH PROFESSIONAL "BURNOUT" IN THE CONSTRUCTION INDUSTRY

Lingard, Helen Faculty of Architecture, Building and Planning, The University of Melbourne, Australia.

Sublet, Anna Faculty of Architecture, Building and Planning, The University of Melbourne, Australia.

KEYWORDS

Burnout, stress, exhaustion, cynicism, work hours, overload, conflict, engineers

What is Burnout?

Job stress is commonly defined in terms of role demands originating in the work environment. An increasing body of research suggests that a major reaction produced by job stressors is "burnout" (See Lee and Ashforth 1993 and Cordes and Dougherty 1993 for a review of the early research). Since Freudenberger (1974) coined the term "burnout" to describe a state of chronic emotional fatigue, this phenomenon has been the focus of much research interest. The most widely accepted definition of burnout conceptualises the phenomenon as "a syndrome of emotional exhaustion, depersonalization and reduced personal accomplishment that can occur among people who do 'people work' of some kind" (Maslach and Jackson 1996). This reflects the fact that early research work was conducted in the "caring" professions. It is now recognized that burnout can and does occur in a wide range of occupations and is not unique to the human service sector (See for example Dolan's study of senior executives (Dolan 1995). In response to this, Maslach and her colleagues (1996) have developed a new version of their burnout inventory (the MBI) designed for general use outside the human services sector (the MBI-GS). This instrument has been found to possess good factorial validity and satisfactory internal consistency reliability across a range of different occupational groups and countries (Schutte *et al* 2000).

The first component in Maslach's burnout model is emotional exhaustion. This describes feelings of depleted emotional resources and a lack of energy. In this state, employees feel unable to "give of themselves" at a psychological level. The second component, depersonalization, is characterized by a cynical attitude and an exaggerated distancing from clients. The last component of burnout, diminished personal accomplishment, refers to a situation in which employees tend to evaluate themselves negatively and become dissatisfied with their accomplishments at work.

Research evidence suggests that burnout is associated with negative outcomes for both individuals and organizations. For example, at an individual level, burnout has been associated with the experience of psychological distress, anxiety, depression and reduced self-esteem. Burnout has also been positively correlated with unhealthy behaviours, such as substance abuse (Maslach *et al* 2001). In addition to its effect on mental health, the association between burnout and physical health has also come under scrutiny and there is a growing understanding that burnout is associated with physical health problems, such as coronary heart disease (Appels and Schouten 1991, Tennant 1996). When burnout occurs as a response to job stress, it should be regarded as an occupational health issue warranting organizational intervention rather than a matter for the individual. This claim is supported by the fact that occupational stress cases represent Australia's most rapidly increasing category of employees' compensation claims (Schaufeli and Enzmann, 1998).

Failure to address this issue is also likely to have negative impact on organizational effectiveness because burnout has also been associated with absenteeism, turnover, reduced productivity or effectiveness and lower levels of satisfaction and organizational commitment (Maslach *et al* 2001). Furthermore, some research suggests that burnout is contagious, spreading to affect colleagues of those who experience it and even resulting in a negative spillover into home life (Cordes and Dougherty 1993, Bacharach *et al* 1991, Westman et al in press). In an industry that already struggles to attract and retain a skilled workforce, a failure to protect the well-being of employees is likely to reduce an organization's efficiency and ability to compete.

Sources of Burnout

Researchers have identified many job demands (stressors) to be associated with employees' experience of burnout. These stressors include overload, role ambiguity or role conflict, responsibility, uncertainty, job insecurity and quality of inter-personal relationships at work (Cooper and Marshall 1977, Carayon 1992). Many of these known stressors are commonly found in the work of construction industry employees. However, there has been little research into the effect of job demands on employees' well-being in this context. The study reported in this paper aimed to address this gap in our understanding. The aims of the study were two-fold:

- Firstly, the study sought to determine whether the burnout concept is relevant in the construction industry context. This included testing the reliability of the most widely used burnout scale, the Maslach Burnout Inventory (MBI) among a sample of Australian construction industry professionals: and

- Secondly, the study sought to identify which job demands are associated with burnout. This is important because intervention strategies designed to prevent or treat burnout are more likely to succeed if they address the source of the problem.

Methods

Sampling Strategy

The data for this study were obtained from civil engineers engaged in professional practice in consulting and contracting organisations in New South Wales and Victoria. In the first instance, a register of companies employing civil engineers was obtained from the Institution of Engineers, Australia. General managers or human resources managers of listed companies were approached and asked whether the company would participate in the study. Questionnaires were randomly distributed through the internal mail systems of the companies that agreed to participate. Completed questionnaires were returned directly to the researchers in unmarked postage-paid envelopes provided for this purpose. Anonymity of respondents and confidentiality of responses were assured. Of 500 questionnaires distributed, 182 completed and usable ones were returned yielding a response rate of 36%.

Questionnaire Design

Demographic information collected from each respondent included the respondent's age, gender, relationship status, number of children and, where applicable, the age of their youngest child. The employment status of respondents' partners was requested in order to identify differences between employees in dual and single income households. Information was also collected about a respondent's current job, including the job title, their typical work location (eg site or office based) and the average number of hours they work each week.

All of the other variables were measured using scales previously deployed by other researchers. All of these scales have been found to have satisfactory psychometric properties. Organizational and job conditions, identified in the literature to be associated with occupational stress and burnout, were measured using a 36-item instrument. Items were taken from several previously deployed instruments, including the Michigan Organizational Assessment Questionnaire. Respondents were asked to rate items on a Likert-type scale ranging from 1 (strongly disagree) to 7 (strongly agree). Following Dolan (1995), the job demands scales were refined through factor analysis and eight clusters were extracted. These were subjective role overload, responsibility, role clarity, satisfaction with pay, satisfaction with promotion prospects, role conflict, social support (from co-workers) and work pace control.

Burnout, was measured using the Maslach Burnout Inventory - General Survey (Maslach *et al* 1996). This 16-item inventory comprises three sub-scales assessing emotional exhaustion, cynicism and a lack of professional efficacy. The MBI was selected for use due to its brevity and proven reliability and validity of results (Corcoran 1995; Shinn 1982; Gaines and Jermier 1983). Following Maslach et al (1996), since the response formats of intensity and frequency have been found to be highly correlated, only frequency ratings were used.

Results

Factor analysis

Table 1 shows the results of the Principal Components Factor Analysis for the burnout scales. As the item loadings indicate, the Emotional Exhaustion and Cynicism scale items loaded as expected. However, the Personal Efficacy items broke down into separate factors, yielding a four-factor solution overall. This solution accounted for 69% of total variance. The four-factor structure differs from the more commonly produced three-factor model of burnout (Schutte et al 2000). However, when the data were forced into a three-factor structure, the total variance explained by the solution fell to 61%. Furthermore, Table 1 shows a minimal problem with double loading of items, thus suggesting the discriminant validity of a four- factor burnout structure for our sample. The two items that loaded on the fourth factor were examined and both appear to relate to a sense of professional worth (I feel exhilarated when I accomplish something worthwhile in my job) as distinct from personal competence (At work, I feel confident that I am effective at getting things done). These dimensions were labelled Personal Competence and Professional Worth and considered separately in the remaining data analysis. The four-factor structure suggests that engineers experience burnout differently to other professional or occupational groups and may experience a sense of making a worthwhile contribution to society or feel a need to be professionally valued in addition to believing in their individual competence or effectiveness at work.

Item	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Scale**
I feel emotionally drained from my work	.859	.186	.021	-.028	EX1
I feel used up at the end of the work day	.839	.011	-.019	.122	EX2
I feel burned out from my work	.814	.305	-.110	-.065	EX5
I feel tired when I get up in the morning and have to face another day on the job	.742	.319	.007	-.050	EX3
Working all day is really a strain for me	.721	.384	-.077	-.015	EX4
I have become more cynical about whether my work contributes anything	.226	.767	-.335	.060	CY4
I have become less interested in my work since I started this job	.361	.760	.050	-.195	CY1
I have become less enthusiastic about my work	.391	.750	.081	-.182	CY2
I doubt the significance of my work	.189	.707	-.383	-.004	CY5
I just want to do my job and not be bothered	.126	.665	.054	-.090	CY3
At my work, I feel confident that I am effective at getting things done	-.029	-.081	.825	.155	PE6
I can effectively solve the problems that arise in my work	-.168	.041	.753	.017	PE1
In my opinion, I am good at my job	.077	-.009	.612	.422	PE3
I feel I a making an effective contribution to what this organization does	.129	-.348	.570	.279	PE2
I feel exhilarated when I accomplish something worthwhile in my job	-.054	-.102	.139	.894	PE4
I have accomplished many worthwhile things in this job	.017	-.127	.287	.794	PE5

Table 1 Factor loadings for the four-factor model of burnout

Cronbach's alpha coefficients were calculated to test the internal consistency reliability of each of the four subscales. The emotional exhaustion subscale had the highest alspha coefficient (.90) followed by the cynicism scale (.85). Professional worth and personal competence had alpha coefficients of .77 and .70 respectively. These are acceptably high and attest to the internal reliability consistency of the MBI-GS subscales in the construction industry context.

Correlation analyses

The bivariate Pearson Product Moment Correlations between the demographic variables measured, the job demands variables and the four burnout factors are shown in Table 2.

As Table 2 shows, the four dimensions of burnout were correlated with different demographic and job-related characteristics. Of the demographic variables, age (r=-193, p=0.011) and number of children (r=-240, p=0.001) were negatively correlated with the cynicism dimension of burnout. Age of youngest child (r=-.239, p=.025) and tenure (r=-.161, p=.034) were negatively correlated with the emotional exhaustion. Of the job-related variables, three were positively correlated with emotional exhaustion. These were the number of hours worked per week (r=.306, p=.000), subjective overload (r=.351, p=.000) and role conflict (r=.275, p=000). Four job-related variables were negatively correlated with cynicism. These included responsibility (r=-.228, p=.003), role clarity (r=-.193, p=.011), satisfaction with pay (r=-.151, p=.048) and satisfaction with promotion prospects (r=-.381, p=.000). Fewer variables were found to be significantly correlated with the two personal efficacy dimensions. However, role clarity was significantly and positively correlated with personal competence (r=.202, p=008) and satisfaction with promotion prospects was significantly and positively correlated with professional worth (r=.197, p=010).

One way analyses of variance (ANOVAs) were conducted to ascertain whether significant differences existed between the burnout scores of respondents who differed in terms of gender, their marital status or whether they worked predominantly on site or in an office. No significant differences in burnout were found between male and female respondents. However, this finding must be interpreted with caution owing to the very small number of women in the sample (7.8% of the total). The mean emotional exhaustion level for single people was lower than that of respondents who indicated that they were married or involved (F=2.181, p=.092). Cynicism was also found to differ by marital status (F=2.162, p=.094). Single people reported higher levels of cynicism than married respondents. However, the mean cynicism score was highest among respondents who were "involved". The ANOVAs also revealed that site-based employees report a higher level of emotional exhaustion than their counterparts who work predominantly in offices and this difference was close to significance (F=2.550,p=.081).

Discussion

These results suggest that two of the major job-related issues associated with engineers' experience of the emotional exhaustion dimension of burnout is workload or the perception of having too much work for the time available, and time spent on the job. Both of these job variables were found to be strongly postively correlated with emotional exhaustion. This is consistent with results obtained in non-engineering samples (Lee and Ashforth 1996, Gmelch and Gates 1998, Maslach et al 2001).

Work hours are a major issue in the construction industry. A recent survey has highlighted the time-related work pressures experienced by engineers in Australia (APESMA 2000). The survey found that professional engineers work long hours, including significant amounts of regular unpaid overtime. Over the twelve month period studied, engineers reported that the amount of work to be done had increased (63%), the pace of work had increased (62%), and that the amount of stress had increased (52%). APESMA also report that more than a quarter of respondents believed there had been an increase in health problems as a result of their working lives. The most common ailments they identified were those related to excessive workloads, such as continual tiredness (66%) and stress (70%).

The association between work hours and overload and emotional exhaustion suggests that organizational interventions designed to give employees more flexibility and control of their work hours may be needed. Research suggests that even a short respite from the sources of stress can have a positive impact on employees' experience of burnout (Westman and Eden 1997). Thus, the use of "rostered days off" to enable professional construction industry employees to take long weekends or the provision of alternate Saturdays off for site-based employees may be of benefit.

THE METHOD OF INFORMATION CONSTRUCTION FOR FOUNDATION PIT SUPPORT STRUCTURE

Liu, Xiaoli Dept. of civil Engineering, North China Institute of Astronautics, Lang Fang, P.R. China

Dou, Yuanming School of Civil Engineering and Architecture, Hebei University of Technology, Tianjin, P.R. China

Yan, Chi School of Civil Engineering, Tian Jin university, Tianjin, P.R. China

Introduction

There are many foundation pit excavation engineering every year in China, but now the design method is still 1/3 based on it's theory, 1/3 based on it's experience, 1/3 based on it's information feedback controlled. So there are two questions which based on design method be caused:

(1) the result of design is too safety to supporting cost higher;
(2) according to the theory method ,the structures is safety, but may is dangerous.

It is reported that the foundation pit support structures failure or partly failure lead to the safety questions and surrounds questions ,and these questions are about 10%~15% in total engineering projects ,even in soft areas they about 20%.

People always hope to find the balance between safety and economy for the pit-retaining structure which regard it as a temporary structure, that is, achieving the best result at least cost. The result of making a comparison the pit-retaining structure, pile foundation and ground treatment is: the pit-retaining structure being difficult, the designers can't determine whether the design is really reasonable, can't authentic appraise the safety and economy when the soil is digging after the pit-retaining construction is finished. So, one of the most effective ways is developing a computer controlling system at all time and on line, and the designers can immediately sort out and feedback the information data, thus gain a correct understand of the foundation pit about its developing trend and the regular of mutual relations. Then the features and state of foundation pit structure can be analyzed in a coming short time, the monitoring fully directs construction process. The safety of foundation pit structure can be pledged in the whole process.

The Method of Information Construction for the Foundation Pit of a Office Building in Tianjin

Engineering general situation

The building locate in the Red Bridge District, Tianjin. It lies in the West of Dafeng Road, Stone Bridge Street is in the south of it. There is a large space in the north and west.25-storeyed up surface of the building and 3-storeyed in subsurface, the depth of the pit is 8.9m. The foundation bottom sheet size is 52m×37.6m.

Design plan

Plan 1: The bored piles make up the retaining wall; roundness ring supporting system and a row of rock Bolting is used in this structure.

The bored pile are set up along the circumference of the foundation pit, the diameter of piles is 700mm, the distance between the piles is 750mm, the average length of the piles is 16m.One concrete roundness ring beam is set up on the top of the bored piles, the inter diameter of ring beam is 52m, the section size is 2000mm×600mm.

The section size of the cap beam which locate on four corners of the foundation pit is 1000mm×600mm, the diameter of anchor rod is Φ40, the horizontal distance between the rods is 1.5m, locate at 6m beneath the ring beam. There are two rows cement-soil piles interlocking each other are set outside the pit-retaining piles. The cement-soil piles can being sealing installation to prevent the groundwater beyond the pit. The effective length of cement-soil piles is 14.5m. This plan is designed through the data which come from investigation reports.

Plan 2: Based on practical experience for a long time, the technical staff think: first, this pit-retaining structure is a temporary structure, it's foundation is retaining soil; second, the parameters of soil mechanics, such as γ, Φ, c are used in lower value. There parameters can be increased in the practical engineering. So all anchor rods can be canceled according to Plan 1, see Figure 2.1.

For Plan 1 and Plan 2, the contract decides to adopt Plan 2 finally. Then the monitoring work seems much more important.

The content and procedure of the pit-retaining structure monitoring

There are four monitoring works according to the practical engineering required:
(1) monitoring the inter forces and deformation of the ring beam
(2) monitoring the deformation along the bored piles length
(3) monitoring the active earth pressure of bored piles
(4) monitoring the settlement of ground surface around the foundation pit

Monitoring points see in Figure 2.1.

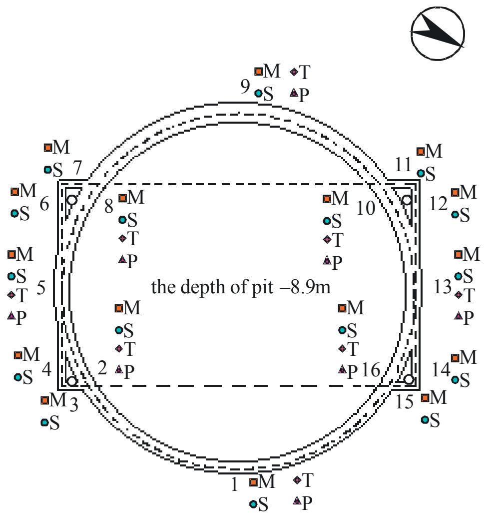


Figure 2.1 The shape of the pit and the arranging of monitoring points

Procedure of the pit-retaining structure monitoring see in Figure 2.2.

The result of monitoring and analysing

There are two steps for the foundation pit excavation. First, excavate 4.1m depth from ground surface, the Directions is the from southern to the northern pit. Then, excavate 4.8m depth to the bottom of the pit. The direction is from western to the eastern of the pit.

The monitoring of the ring beam bending moment

Though the monitoring results, some regularities show as:

(1) During excavating the pit, there is a little bending in the cap beam which at the top of bored piles locate on four corners. Comparatively, there is a higher bending moment in the ring beam. These shows that the ring beam mainly bears the loads which act on the top of the bored piles. The result accords with theory analysis.
(2) On the ring beam, the monitoring points No.1 and No.9 all bear a little bending moment, see Figure 2.3. The reason is: first, the arranging shape of the bored piles is unanimous with the plane shape of the ring beam. They are all circular arc shape and are densely arranged, the forces in a circular arc shape is little than in a line shape; second, there is a partly soil in the pit still, and is set a slope along

the inside of the ring beam. At the same place, a retaining wall is built. So, a little forces act on the bored piles, and then a little bending moment act on the ring beam.

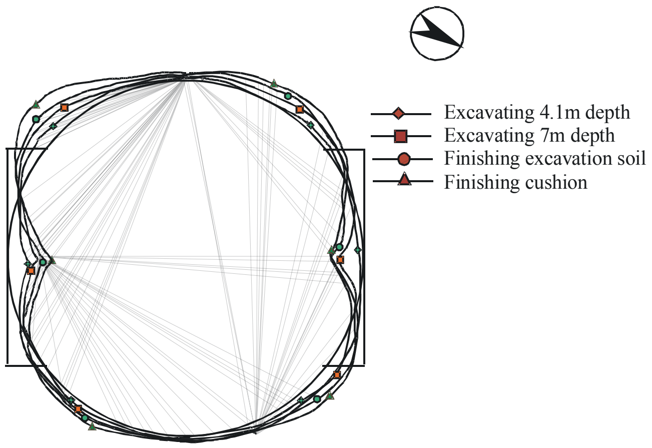


Figure 2.3 The deformations of the ring beam

(3) The southern and the northern of the piles are densely arranged in plane around the pit, and these piles are joined by the cap beam and the ring beam. The active soil pressures act on the ring beam though the cap beam, then the negative bending moment is created at the points of No.5 and No.13.
(4) The largest positive bending moment is: M=270tm, act on the point No.8. And the largest negative bending moment is: M=-331tm, act on the point No.5. The reason is that there is a 0.9m depth in the southern of the pit than in the northern, the more soil loads act on the southern piles than the northern piles.
(5) After finished the bottom plate, there is a decreased bending moment in the ring beam. Though the decreased value isn't large, the result shows that the bottom plate begins to play the supporting role.
(5) When the ring beam is cut off at No.10 and No.16, the ring beam bending moment changed: the bending moments of No.11, No.12 and no.15 are rapidly increased. Especially, the bending moment of No.11 is 2196tm. At that time, the constructors heard a loudly voice which came from No.11, and then the ring beam is cut off. The ring beam axial forces are set free to the cap beam though No.11, the cap beam bears too large force to creating the concrete failure. But the bottom plate and basement wall play the supporting role, the pit-retaining structure is still safe.

The monitoring of the ring beam deformation

During the whole construction process, the ring beam is monitored every each day. Its horizontal deformations see Figure.2.4. The largest value is 7mm at No.5.

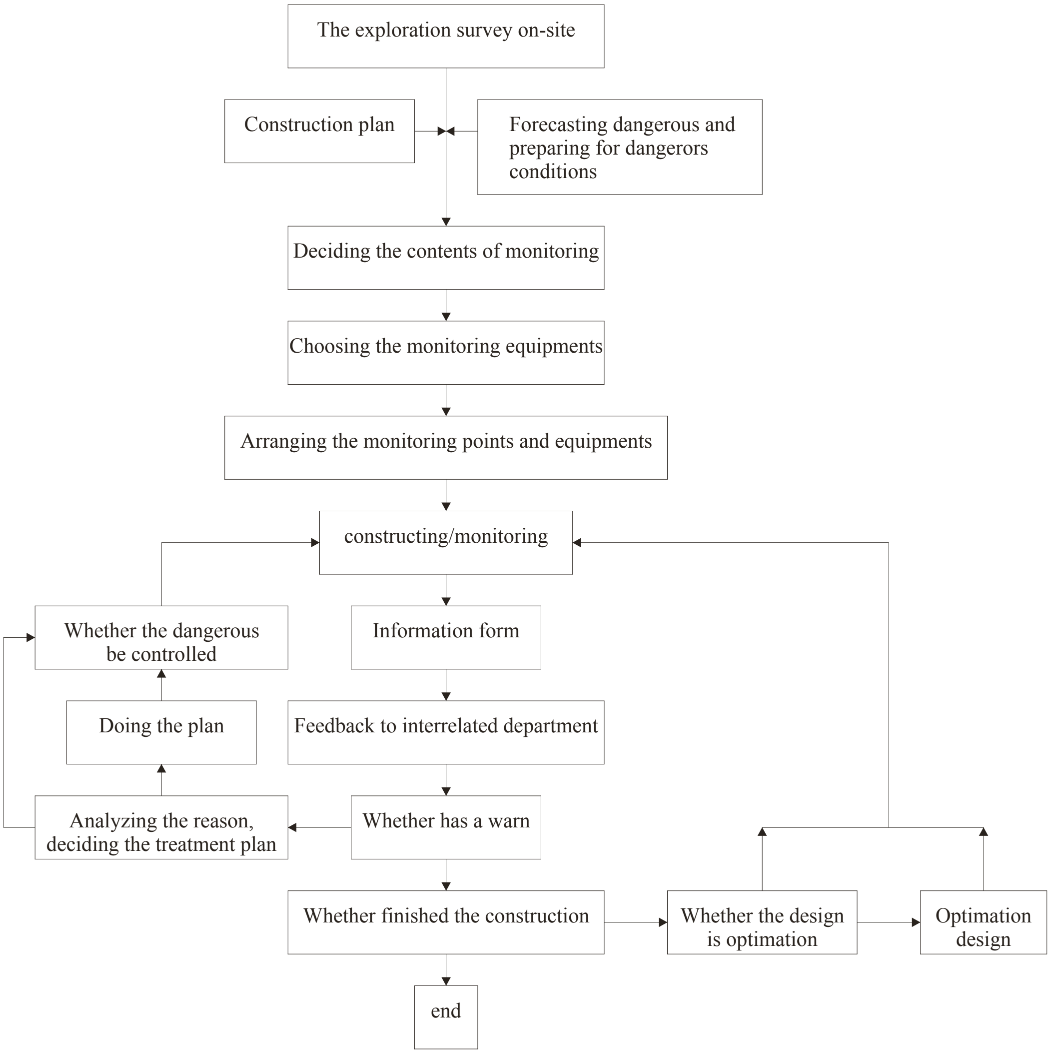


Figure 2.2 The process of the information construction monitoring

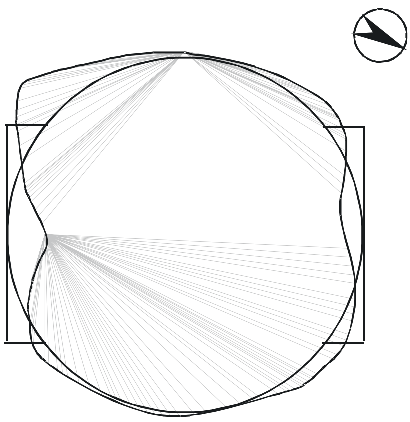


Figure 2.4 The horizontal deformations of the ring beam

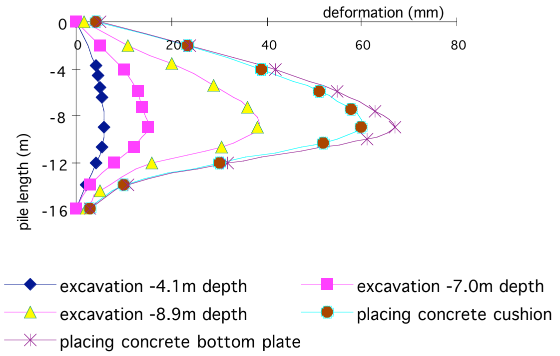


Figure 2.5 The curve of the bored pile deformation

The monitoring of the deformation along the bored piles length

The deformations along the bored pile length are see Figure 2.5. Some regularities show as:

(1) The shape of every bored pile deformation is same during the excavation stage, that is, the shape is bulgy belly, the middle is bigger, the both ends are smaller. The largest deformation value locate on -8.2m~ -9.5m from ground surface; and all less than 35mm. The result tally with the theory design regularity.

(2) It takes 7d~15d that placing concrete cushion. During the 7d~15d, due to soil can creep, the bored piles have a 15mm~25mm deformation again. The time is longer, the deformation is larger.

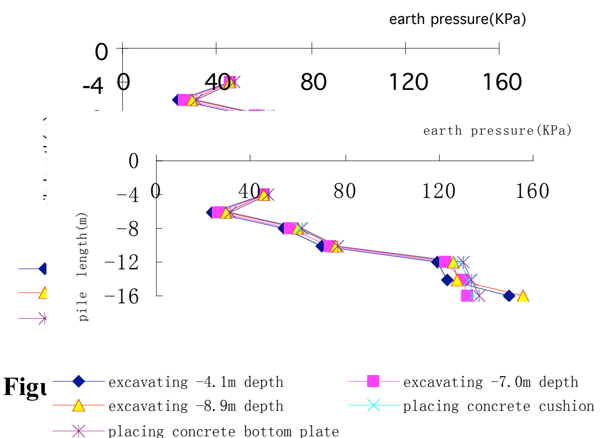
(3) It takes 16d that placing concrete bottom plate. There is a 8mm deformation during 16d. The result shows that the bottom plate play a very important role for the supporting of the bored piles.

(4) After finished the bottom plate, the bottom plate play a horizontal supporting role at -8.3m depth , then the bored piles deformation tend to become stability. At that time, the largest deformation is less than 60mm.

(5) After cutting off the ring beam, the bored piles deformation is increasingly. But the displacement increment at the top of the bored piles is only 15mm~25mm.The largest deformation is still at -8.2m~ -9.5m depth, and the deformation shape doesn't be changed.

The monitoring of the active earth pressure of bored piles

The monitoring point is set at every 2 meters along the bored pile length. The active earth pressure at the back of pit-retaining wall can't reach the limited state, due to the bored pile deformation is small. So the active earth pressure is less than the Rankine active earth pressure, see Figure 2.6, this value compare with E_0, the reduced volume at the top of bored piles is more than at the bottom of bored piles. The result is similar to the examples in the reference[1].



The monitoring of the ground surface settlement around the foundation pit

The result of the monitoring, see Figure.2.7. The settlements of points are between 30mm to 40mm.

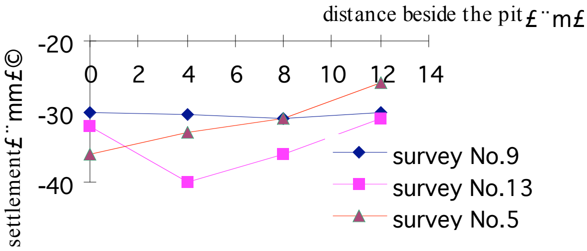


Figure 2.7 The ground surface settlement around the foundation pit

Conclusion

(1) The stress and strain in the pit-retaining structure are monitored during the whole construction process. The pit is enough safe, Plan 2 is reasonable. The anchor rods cost more than a half million RenMin Yuan, and it is saved. The economy effect is notable.
(2) The concrete cushion can prevent the soil creep. So placing concrete cushion must early set up when excavating to the bottom of the pit.
(3) The inflection point of the bored pile placement doesn't appear. The soil pressure before the bored piles is passive, and the soil pressure back of the bored piles is still active.
(4) After finished the construction of the basement, the basement becomes a horizontal supporting for the bored piles. When the ring beam is cut off, the structure is still safe.

Suggestion

(1) The construction method around No.1 and No.9 is a good way. The monitoring results show that there is a little force in the bored piles. When the condition is allowable, some plan can be design like this. It can reduce the cost. The result should be pay attention.
(2) The ring beam is a reasonable supporting structure, it make the pit-retaining wall safety and trustiness.

Reference

Dezhang Feng. The monitoring result of clayey soil pressure on the pit-retaining pile. The third Conference of Soil Mechanics & Foundation Engineering Paper Collection. Beijing, China, 1981.

A STUDY OF THE PRESENT SITUATION AND REFORM OF CONSTRUCTION SAFETY SUPERVISION IN SHENZHEN

Lu, Xuewei Shenzhen Construction Safety Supervision Center
Ji, Dexing Shenzhen Construction Safety Supervision Center

KEYWORDS

Construction safety supervision, reform, Shenzhen, China

Current Situation of Construction Safety Supervision in Shenzhen

Ever since the establishment of Shenzhen Special Economy Zone (SSEZ) in March 1979, the construction industry has made great progress and the scale of construction has been greatly expanded. As a result of such reform, a great amount of peasants get jobs on the construction sites. These labors are poorly educated, and have little ideas of safety operation and lack self-protection consciousness. During the construction boom, this causes a high accident ratio. During 1982 ~1986, statistics show that 102 persons were dead, 213 seriously injured and 509 slightly wounded in Shenzhen. Just in 1985, 41 persons were killed. Safety status in the construction industry in Shenzhen is quite serious. During the following years, about 15~20 persons lost their lives each year on construction sites.

In the early period of SSEZ, supervision of construction safety is quite insufficient. From March 1979 to December 1983, there has been only one part-time technical personnel in charge of safety for the government. From January 1984 to March 1988, there was one full-time technical personal designated by the government to be in charge of construction quality and safety. The duty is to deal with documentation and statistics, as well as to give an overall inspection about construction safety in the whole city annually. From 1988, a temporary Construction Safety Supervision Group was constituted by the government, in charge of construction safety two days every week. In 1989, *Standard of construction safety inspection* [1] was issued by the Construction Department of PRC. In order to take the standard into effect, from 1990, an activity has been taken to force the construction company to implement it, which means supervision has come from qualitative to quantitative control. From Feb. 1991 to Oct. 1994, a series of document and technical standard was issued by the municipal government. This formed the foundation of construction safety supervision.

For the development of SSEZ's economy, on the basis of the documents issued by the central government, Shenzhen Construction Safety Supervision Office was established on 28th, Nov. 1994, and began to operate formally on 1st, Jan. 1995. Up to now, district offices have been established, as well as some town offices. There are more than 150 persons serving in these offices which form a network of construction safety supervision. The staff work diligently and efficiently since the establishment of these offices, promoting the situation of construction safety to make progress continuously. In recent years, although the scale of construction investment keeps expanding, construction safety has improved year by year. From 1994 to 1997, the ratio of implementing safety standards increases by 10~15% annually, and the death ratio decreases gradually to the lowest point in 1997. In 1995, a country wide inspection revealed our city ranked second, and in 1997, the champion among total 44 cities.

From 1995, SSEZ has followed the principle "to tackle a problem not only on the surface, but also at the root", and made effort to look for new way for "3 stage supervision", "Special supervision for dangerous operations" and so on. The activities have been carried out as follows:

Firstly, "3 stage supervision". This includes the following stages. Before the construction starts, the prerequisite of construction safety should be examined; during the operation, construction safety standards should be implemented; after the construction is finished, an overall evaluation of the project will be made, which influence the check of the project before acceptance. According to the principle "to aim at safety and put prevention first", the key point of our work is precaution. We lay stress on the examination of prerequisite and implementation of safety standards, trying to eliminate the hidden dangers. At the same time, we advise the companies to eliminate these hidden dangers by spot checks, and try to help the companies to be more self-restraint.

Secondly, to lay emphasis on training and education about construction safety. In 1996, *Regulation of training and education about construction safety*[3] was in force in order to improve the workers' performance, which clarified the aim, scale and requirement of training and education, and enforcing rules about certificate of "safety operation", examination of education, and keeping record of training. From 1997, a series of textbooks for training has been compiled, among which are textbooks about worker training, electrical safety, piling machines, vertical transport equipment, and about machine disassembling and assembling. A pamphlet for training of construction safety supervision was also compiled in Guangdong province, authorized by the construction committee of Guangdong. With these textbooks, the training and education work has a plan, basis, examination and effect. To the end of 2000, 116 training classes of all kinds have been offered, and more than 6000 technical personnel trained.

Thirdly, propaganda about construction safety. From 1995, we have published newspaper about construction safety once every two months, mainly to introduce information, knowledge and advanced experience about construction safety. Every construction company can get it for free. In June 1998, a VCD about construction safety education was prepared and delivered to construction sites. Meanwhile, the competitions were organized and pictures delivered about construction safety.

Fourthly, to promote the standardization and legitimization of construction safety supervision. From 1995, according to the current situation, a series of district standards and rules have been laid down, including *Standard of construction safety inspection for special building machine in SSEZ*[2], *Standard of construction safety inspection for SSEZ*[2], *Instruction standard of construction safety inspection for SSEZ*[2] *and Supervision and safety code for climbing frame in temporary support in SSEZ*[2] etc. At the same time, *Byelaw of construction safety supervision In SSEZ*[3] was issued on 13th Feb. 1998, which has standardized supervision of construction safety and offered legal safeguard.

Fifthly, special treatment to try to reduce the ratio of serious accidents. Protection of the edge, fall accidents , and especially dangerous operations (including assembling and disassembling of vertical transport equipment, piling machines, climbing frame in temporary support etc.) have been dealt with, and the ratio of serious accidents was reduced.

Sixthly, we promote the test of safety protection staff and facilities, regulate the utility of safety protection articles on site. Every year, we help the Construction Department, the Industrial and Commercial Bureau and the Technical Supervision Bureau to inspect the construction safety protection articles and facilities, preventing the non-conformed from entering construction sites, therefore hidden dangers are eliminated. This is regarded as the daily work, which has strong influence.

Reform of Construction Safety Supervision in Shenzhen

General reform principles are: to limit the government, to entrust the authority to basic units, to supervise what should be done, to regulate the supervision, to generally optimize technical standards and regulations, to advise construction sites to achieve "civilized sites", to impel workers to join the insurance plan, to ail Vance the training plan which aims at "the person is the core", to accelerate safety culture achievement.

Measures are listed as follows:

Firstly, based on "the person is the core", the workers are supervised to improve performance. They are the participants and object of the construction safety, thus just when workers are playing a leading role to the full extent, construction safety can be ensured. Statistics suggests that 85% of accidents is caused by human beings. *Domino*'s theory confirms that humans play a leading role, and human's dangerous activities are the critical factors in the chains which cause accidents, and if this chain doesn't exist, no accidents will take place. Chairman *Jiang zemin* points out that the economy must be developed, based on the progress of science and technology and the improvement of the worker's quality. With the advance of the economy system reform and the establishment of market system, the government entrusts the companies with part of its authority, which requires the companies to be more self-restraint and improves worker's performance.

In order to accelerate the activity based on "the person is the core", the first thing is to standardize and regulate the training and education, then the problem can be sorted out, not only on the surface but also at the root. Today, some companies pay little attention to the training and education of the workers. It seems that these companies have got more economic benefit, but there are more hidden dangers in these companies, and the result is unimaginable.

Thus the general principle of construction safety supervision should be followed, and lay emphasis on the company responsibility, guiding, supervising and checking. The standard textbooks should be used with the same requirement and the same standard. Rules should be built up and records kept. The training and education plan should be carried out in the following procedure: firstly, to train the piling workers, electricians, workers whose job is to assemble and disassemble the vertical transport equipment, both part-time and full-time employers in charge of safety; then, to train 3 kinds of workers; finally, to enforce the regulations. Workers who pass no examination cannot work on the construction site.

Secondly, technical standards and regulations about construction safety should be drawn up. The supervision of construction safety started quite late in China, thus the construction of technical standards and regulations cannot catch up with the development of the construction industry. Nowadays there are only seven standards, which requires no construction safety supervision at all and, furthermore, 3 of these standards were worked out in the "Great leap" period, which need amendment in line with the development of science and technology. The relevant standards and regulations should be consummated within 2~3 years.

Thirdly, construction sites will be advised to be "civilized sites" in order to advance the level of supervision. In 1996, the Central Construction Department called on us to take part in this activity. In Sept. 1998, "civilized sites" were established, which stipulated one construction site being a "civilized site". This was a prerequisite of its safety. The measure has changed the dirty, disturbed and bad appearance of construction sites, and made this industry taking on a new look. In the future, this activity will be promoted with the best and the related supervised investment in order to make more construction sites "civilized sites".

Fourthly, a kind of injury insurance, caused by accidents, will be launched. *The construction law* [3] states that all companies in the industry must pay the insurance for injury caused by accidents, which is compulsory. Shenzhen must learn from advanced countries in this aspect and make this work conforming with the international custom.

Fifthly, the research and application of new technology will be promoted. "Science and technology is the most important productive force". The companies should be encouraged and helped to engage in the research and further application of new technology. Each year, a guideline will be worked out for the research, trying to solute relevant problems, such as the safety device of the scaffolding and the hoister, and safety device of the tower crane and the small-sized construction appliances *etc*.

Sixth, propaganda among the masses should be spread and the building of safety culture be accelerated. It's necessary to form a kind of atmosphere that everybody pays attention to safety and engages in the safety management in the construction industry by all means, and to make construction safety into the workers' conscious action. In the future, besides publications on safety, every kind of things should be exploited to educate the workers, such as pictures, pamphlets, short and simple artistic creations, exhibitions, video tape recorders, competitions and speeches through which the workers can easily learn the safety knowledge and technology.

The situation of construction safety in Shenzhen would be better and better in the future!

Reference

[1] *Standard of construction safety inspection*. The Construction Department of P. R. of China, 1989.

[2] *Standard of construction safety inspection for SSEZ*. Shenzhen Construction Safety Supervision Center, 1997.

[3] *Collection of law and regulations about construction in SSEZ.* SSEZ construction bureau, 1998.

Appendix

Year	Law and regulations
1989	Standard of construction safety inspection
1991	Contemporary regulations of construction safety punishment
1994	Qualification supervision of construction enterprise in SSEZ
1994	Contemporary regulations of civilization and environment in construction sites in SSEZ
1996	Standard of construction safety inspection for special building machine in SSEZ
1996	Contemporary regulations of construction safety training and education in SSEZ
1996	Standard of construction safety inspection for SSEZ
1996	Instruction standard of construction safety inspection for SSEZ
1996	Supervision and safety code for climbing frame in temporary support in SSEZ
1996	Supervision and safety code for pile In SSEZ
1998	Byelaw of construction safety supervision In SSEZ
1998	Regulations of construction sites civilization in SSEZ
1998	Standard of construction sites civilization in SSEZ

Table 1 Law and Regulations

No	Description
1	3 stage supervision
2	Training and education
3	Propaganda about construction safety
4	Promote the standardization and legitimization of construction safety supervision
5	Special treatment of serious accidents
6	Promote the test of safety protection staff and facilities

Table 2 The Present Situation in SSEZ

No	Context
1	The person is the core
2	Draw up the technical standards and regulations
3	Civilized construction sites
4	Injury insurance
5	Research and application of new technology
6	Safety culture

Table 3 Reform of Construction Safety Supervision in SSEZ

COMPARATIVE STUDY OF SAFETY MANAGEMENT IN HONG KONG AND ZHEJIANG PROVINCE

Ma, Chunjie Department of Construction Economy and Management, Zhejiang University, Hangzhou, P.R. China
Lin, Detian Department of Construction Economy and Management, Zhejiang University, Hangzhou, P.R. China

KEYWORDS

Safety management, construction, site

Introduction

During the last 10 years, with the accelerated pace in economic reformation, the building industry in China has developed very fast. The amount of investment, the scale of buildings developed and the building labours increase every year. Due to its characteristics, such as complexities, difficulty in management and the huge number of people involved in it, the building industry is more dangerous than other industries. In turn, it leads to the high incidence of accidents. Thus, it is necessary to implement safety management in the building industry.

Though the injury and death rate in the China building industry has gone down in recent years, it is still very high and unacceptable. Therefore, it is essential for the China construction industry to learn from other country/area's experiences in safety management.

Hong Kong (HK) has pretty much the same culture background, living habits, traditions as mainland China. So the experiences from building industry of HONG KONG will definitely be useful to the development of building industry in the mainland.

Instruction of Safety Management System in Hong Kong and Zhejiang

Safety management system in Hong Kong

The HONG KONG government began to introduce safety management system via Airport Core Program in 1991. After development and improvement for 10 years, now HONG KONG has established an effective safety management system. The various systems and schemes are elaborated as follows:
Factories and Industrial Undertakings (Safety Management) Regulation
To ensure that the contractors have set up a safety management system, the HONG KONG government requires them to establish a management system. The key elements of the system are:

- Safety policy
- Safety organization
- Safety and health training
- Safety and health inspection
- Personal protective equipment
- Evaluation, selection and control of sub-contractors
- Process control program
- Safety committees
- Safety promotion
- Emergency preparedness
- Job Accident/incident investigation hazard analysis
- Health assurance program

Pay for Safety Scheme (PFSS)
To effectively carry out daily safety management missions, contractors must pay for the expenditure of preparing safety plans, holding safety meetings, and employing safety officer etc. The cost of safety

management is pre-priced, which is fixed at 2% of the estimated contract sums.

Independent Safety Audit Scheme (ISAS)
According to the scheme, independent safety auditors carry out safety audits at quarterly intervals. The audit reports highlight the strength and weakness of the contractors' safety management system. The score and comments are also included. If the contractor can achieve 70% of the scores, they can attain the pre-priced payment. If the score is less than 60%, they will be given an adverse report.

Safety Promotion and Safety Award Scheme
The purpose of safety promotion is to enhance the safety performance of contractors and the awareness of all building workers. The award scheme aims to encourage contractors to maintain a healthy and safe environment to workers.

Monitor System
Government will monitor and assess the performance of contractors by using both active system such as PFSS, ISAS etc, and reactive system, such as the monitoring of accident frequency rates, record of site safety convictions, etc.

Regulation Action against Contractors with Poor Site Safety Record
A "carrot and stick" approach is adopted to manage site safety. Contractors with good performance are rewarded while contractors with poor performance will be punished. The regulation actions include the issue of warning letters and voluntary suspension from tendering.

Safety management in Hangzhou, Zhejiang Province, PRC

A standard safety regulation, *Civilized Construction Safety Standard Site Management Regulation*, which require the contractor to set up a safe, healthy and neat construction site, is established in the ZheJiang(ZJ) province. The regulation consists of 4 parts:

1. General rules

2. Safety management
- General rules of construction company
- Professional training
- Safety inspection
- Hazard control program
- Safety board
- Arrangement on site
- Roster management on special kind of work

3. Detailed requirement on construction facilities
- falsework
- construction electricity
- derrick
- tower crane
- middle and small types of construction facilities
- safety net, safety belt, safety helmet
- protection of holes

4. Setting up a neat construction site

The regulation mentioned above is just a guideline. The company must comply with this regulation, and can formulate its own safety policy and safety plan according to its own conditions.

The officials from the government in ZHEJIANG inspect and assess the construction site safety performance by using a "score list system", which includes 9 parts:
1. safety management
2. falsework
3. safety helmet, belt, net and holes
4. construction electricity

5. derrick
6. town crane
7. middle and small types of construction facilities
8. physical site conditions
9. summary

Except for this "score list system", the accident rate is another criterion for scoring. There are three kinds of results, i.e. excellent, pass, or failure. The safety supervision department, a department in the government, is responsible for this inspection.

<u>Study of Safety Plans in Hong Kong and Zhejiang</u>

Having discussed the government-level regulation, we now study the company-level regulation both in Zhejiang and Hong Kong.

Two safety plans, one in Hong Kong and the other in the city of Hang Zhou, which is the capital of Zhejiang province, and their safety management are studied and compared.

Plan A— From a large-scale Housing Authority project site in the north-western part of the New Territories in Hong Kong, with the plan prepared by a well known Hong Kong building contractor.

Plan B— From a sizable agriculture pesticide factory project in No.5th road of XiaSha in Hang Zhou, with the plan prepared by a reputable construction company in China.

(Scores range from 1 to 5)

	Safety policy	**Safety organization**	**Safety committee**	**Safety training And promotion**	**Safety inspection**
Plan A	Contained the company safety policy statement (5)	Outlined the structure of the organization, described individual safety responsibilities, and presented an organizational chart (5)	Described the members and functions of the safety committee (3)	Set forth the schedule for safety training; specified individual activities to promote safety; described the safety newsletter, and the safety bulletin board (5)	Described the procedures of the safety inspection (3)
Plan B	Contained the company safety policy statement (5)	Outlined the structure of the organization, described individual safety responsibilities, and presented an organizational chat (5)	Described the members and functions of the safety committee; presented the standard form of meeting minutes (5)	Set forth training objectives, course content; described the safety bulletin board and facilities (4)	Indicated the formation, content, method and frequency of safety inspection (5)

	Risk assessment and hazard analysis	Accident investigation	Hazard control program	Emergency procedure	Health assurance program
Plan A	Indicated the procedure of risk assessment and job hazard analysis (5)	Described procedures for recording and investigating accidents and compiling statistics (3)	Described precautionary safety measures for each major site operation (3)	Presented organizational chart for emergencies; described accident reporting procedures and facilities; outlined procedures for typhoons, fires, and evacuation (4)	Described procedures for monitoring and controlling noise, dust, and chemical substance (3)
Plan B	Outlined the risk element of some kinds of works (4)	Described procedures for reporting accidents and dangerous conditions; outlined procedures for investigations and compiling statistics (4)	Described safety procedures for each site operation; indicated the relevant legal ordinances and regulations (5)	Presented the emergency faulty; described the makeup of the emergency team and the duties of each member; outlined emergency and procedures (4)	Outlined methods for the handling of hazardous materials and the use of safety equipment and controlling noise, dust, and chemical substance (5)

	Personal protective equipment (PPE)	Evaluation selection, and control of subcontractor	Safety audits	Total scores
Plan A	Listed all the commonly used PPE along with related safety requirements (3)	Described procedures for evaluating, selecting and controlling subcontractor; outlined safety penalties and the award scheme (3)	Indicated that safety audits of both safety management and physical site conditions should be carried out at least every three months (3)	(48)
Plan B	Listed all the commonly used PPE along with relevant statutory requirement and safety standards; indicated the requirements for PPE use (5)	———— (0)	———— (0)	(51)

Besides the content discussed above, the plan B has its own special safety system. For example, safety license management system, safety technology management system, construction safety requirement, safety performance award and penalty regulations, etc.

Having discussed the safety regulation and system in HONG KONG and ZHEJIANG, we can see that both of them have thorough regulations, which detail all aspects of safety management. Frankly speaking, in the company-level, the safety manual of ZHEJIANG is more detailed than that of HONG KONG. But, in the government-level, it is not the case. There is an effect of the system to guarantee the regulations to be carried out in HONG KONG but not in ZHEJIANG. And this is the key point.

The contractors are always concerned with cost and profit. To carry out safety management, they think, with no doubt, will increase their cost, which will in turn, decrease their profit, and waste their time. Therefore, without efficacious supervision system, the contractors are not willing to execute the safety management. Even though some of them follow the safety rules, they just do so as a kind of formality, which will not be of any use at all and may lead to poor safety performance.

To tackle this problem, a supervision system must be established. The ZHEJIANG government can learn from HONG KONG experiences, and set up a sequence of schemes, similar to PFSS and ISAS, which is suitable for use in ZHEJIANG.

Conclusion

What is really needed is a list of actions and procedures to be followed by all parties in the same manner to secure safety on sites. We strongly recommend that the ZHEJIANG government to adopt the methods below:

1. To ensure it is suitable for realistic situations, the government should update the safety regulations from time to time.

2. The government should set up a new system to encourage contractors to execute the safety management.
   - The profit can be based on the safety performance. Safety performance and quantity of work are two foundations of getting pre-priced payment. Supervisors not only are in charge of the cost, process, work period and quality, but also take care of the safety performance on construction sites. So, a safety supervisor should be employed if necessary.
   - The policy must enforce the functions of the safety supervision department. The department must inspect the sites periodically to ensure the contractors have complied with the regulations. The performance of contractors will be a reference criterion in future tendering. A contractor with good performance in safety will be awarded financially and he will have more chance of wining the future bids.

3. The government should provide professional training to enhance the workers' awareness of safety and prepare plans for preventing accidents and disasters. The government should also conduct examination for the workers.

4. The workers' bonus should be linked to their safety performance. The longer they work safely, the more bonus they can earn. It will encourage the workers to work under the safety regulations.

5. The government should offer professional safety certificates to competent safety personnel in different specialization areas.

6. The fines from unsafe sites could be used to fund a safety center. The main activities of this center include:
   - Participate in technical investigation of accidents to identify causes and take steps to avoid them in the future;
   - Create an accident databank with reasons, results, and methods of accident prevention;
   - Explain safety principles and their importance in every workplace;
   - Participate in international safety conferences and organize safety courses and provide training sessions for workers, engineers and managers at all levels of responsibility;
   - Conduct regional and state surveys about safety matters in all economic sectors and propose recommendations to improve safe working conditions;
   - Facilitate sharing of information and coordination among insurance companies.

References

[1]* S.L. Tang, S.W. Poon, S.M. Ahmed, & Francis K.W. Wong, *Modern Construction Project Management*, Dragon Vision Publisher, 1998.

[2] Lam Hon, "Safety Management System in Public Works Contracts", *Proceedings of Safety*

management in the Construction Industry—Asia Experience, 2000.

[3] 马纯杰、魏成勇、郑叔民，《建筑工程项目管理》，浙江大学出版社，2000.

[4] 胡建文，《香港工程建设和建筑业管理》，海天出版社，1999.

[5] Syed M. Ahmed, Jack Chu Kwan, Fox Young Wei Ming & Derrick Chong Pui Ho, "Site Safety Management in Hong Kong", *Journal of Management in Engineering*, 2000.

SABRE
Construction Site Safety Hazard Assessment System

SABRE - A Users Guide

January 2002

Prepared by; Tony McKernan, Kieron Joy, and Mutie Baidas

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Tool Guide January 2002

Contents

1) Introduction to Hazard Assessment

The Construction Industry has one of the worst safety records for an industry not only in the UK but also across the world.

Safety is a very visible area of failure

Although great improvements have been made across the industry since the introduction of CDM regulations we still have an average of over:

- 2 workers killed every week,
- 1 member of the general public killed each month.
- If you worked in the construction industry in the last 20 years you have a 1 : 600 risk of death
- All our major recent history construction projects have accidents on site that result in deaths, Channel Tunnel etc.

Despite the introduction of CDM induction courses, rigorous method statements and intense Health and Safety campaigns across our industry, accidents continue to occur at an alarming and unacceptable rate.

For every construction site it is estimated that there is at least 10 or more non-reportable accidents occurring per month, although the industry does not have regulations and audits to confirm such figures.

Every accident on site, reportable or not, has a direct and indirect effect on productivity and efficiency of site. Every accident costs the industry money, time and loss of faith by the workforce with regards to their well being and safety on site.

Hazard Assessment - The Benefits

- an industry with an improved safety record (less deaths)and a higher safety awareness culture
- independently monitored projects and company safety scorecards demonstrating the industry's progress towards objectives and targets
- clients will be able to differentiate between the best and the rest, providing a rational basis for selection and to reward excellence
- "zero accidents culture" will be encouraged
- A better and safer working site environment that encourages new recruits to the industry

2) Aim of SABRE

There is a need to implement a process on site that pro-actively eliminates the circumstances and situations that may result in an accident.

There is also a need for an industry wide Site Safety Hazard Assessment methodology and tool to enable the supply chain on site to report potential hazards and prevent accidents from happening.

This system not only focuses efforts to eliminate safety hazards but it also encourages the team on daily basis to be extra vigilant on hazard spotting knowing that an inspection is due every week and that continued poor performance will be recorded.

The tool allows issues to be highlighted and scored for discussion with the site team to learn from behaviour affecting the score and dissemination to workforce and management alike. To raise the profile of safety and hazard assessment.

The scoring system will encourage improvement from unacceptable to acceptable levels, as well as acceptable to well managed, and well managed to excellent. Through recording issues affecting scores, the team can learn about good performance for helping improvement as well as poor performance and reasons why.

It aims to help to address the need within Rethinking Construction of:

- Reductions of the number of accidents by 20% per year
- Developing industry wide tools by which the construction companies can demonstrate continuous improvement and progress towards the target of reducing accidents by 20% per annum.
- Underpinning improvement by evidence of objective independent data by which clients can make selections based on added value and reward excellence.
- Improving working environments on sites.

By going beyond CDM into a more pro-active safety culture on site through encouragement to improve.

The tool is similar to Brae's CALIBRE system, which maps activities on site with a view to improving efficiency. As with CALIBRE, the Hazard Assessment system would involve recording scores using a hand held computer and gathering feedback from operatives on their views of safety issues. These views and results can then be published in prominent places within the site, like staff canteen noticeboards, to raise everybody's awareness of Safety performance.

The system will only work if operatives and management identify and discuss hazards they see on site. A strong recommendation from the steering group, was to create a tool which through the process of generating data, the assessors communicate to the workforce the assessment scores and the reasons for the scores.

The tool can be used by anyone with basic safety awareness and user friendliness is a key consideration. The ability to complete an assessment and speedily produce charts is seen to be a very powerful tool.

The tool also aims provide a simple 'paperless' process for the site to use regularly and continually.

This aims to change a culture of safety being the responsibility of a nominated safety officer and perhaps, of a regional rep that visits once a month to review site conditions.

3) How to use the Tool

The tool is based upon a simple methodology, which combines on site observational assessment of a number of relevant hazard criteria, such as plant and machinery or scaffolding, with a very simple scoring system that can be related to areas in the work place.

3.1) Preparation

The first stage of an Assessment is to select criteria from the predetermined list of Hazard Assessment categories provided in SABRE. It is unlikely that all the criteria will be used in an assessment. It is also not necessary to use the same criteria for all parts of the site. It should be noted that the assessor should aim as far as possible for some consistency between assessments to help better comparison.
The assessor should also pre-determine logical functional zones or work areas on the site. For ease of reference functional zones should match the commonly used names for site working areas. It will be necessary to establish this system at the first assessment and retain it for all subsequent assessments.

3.2) Assessment

Using the handheld computer the assessor can now undertake the Hazard Assessment for each category in each functional zone.
The assessor will score each of the questions against the simple scoring category. The assessor should aim to identify with the scores selected where excellence is being achieved, or where improvement can be made.

Simple notes should be made by the assessor of scores given and factors affecting the score to provide feedback and learning as appropriate.

3.3) Results and Feedback

Following an assessment the data is imported into the Safety Assessment software from the handheld computer and results will be immediately published in simple graphical form.
Assessors should be encouraged when practicable to obtain feedback from the workforce to their views on appropriate scores. These views should be recorded and either published with the results or discussed with relevant people as appropriate.

To maintain the confidence of the workforce every effort should be made to communicate the conclusion of discussions involving their feedback. Credit for excellence should be encouraged using site notice boards, or using the formal site management hierarchy. Credit should be communicated as a Team achievement as it is unlikely to be one individual or supplier who can be singled out for praise.
Conversely, poor performance should be dealt with through pro-active support from the entire team to achieve improvement and not criticism in the public domain.

Individual failure is a Team failure.

The Hazard Assessment can then be used to demonstrate where excellence is being achieved as well as provide confirmation of compliance with minimum safety requirements and identifying for the construction team where poor levels of compliance are occurring.
It will also be possible by comparing Hazard Assessments on a periodic basis, to follow the performance of a site over the duration of a project. This will enable the construction team to demonstrate that Safety and Hazard Management is a continuous process.

4) The Assessment Tool - Categories and Questions

4.1) The Categories

The tool has been developed to be as generic as possible to allow its implementation across all types of construction projects. This means that not all categories of assessment may be relevant for every site.

The assessment system may also be used to focus on particular areas of safety i.e. Excavations, Scaffolding, General Housekeeping. This flexibility will allow the construction team to select relevant areas for assessment and to be scored against these areas only.

Therefore, prior to an assessment it will be necessary to identify the relevant categories to be observed.

Results will only then be compared against these categories and the charts will be produced in this way as well.
The assessment categories are:

SABRE Category	
Category_ID	**Category_Name**
1	COSHH
2	Cranes & Lifting Equipment
3	Electrical Work
4	Emergencies
5	Excavations
6	Fire
7	Hoists
8	Housekeeping
9	Ladders
10	Manual Handling
11	Noise
12	Personal Protective Equipment (PPE)
13	Plant & Machinery
14	Powered Access Equipment
15	Public Protection
16	Roof Work
17	Scaffolding
18	Welfare

Within each category there exists a number of core questions for the assessor to use, which like the main categories can be used or not dependant upon their relevance to the project.

Assessors will again need to be encouraged to be as consistent as possible with each assessment for better comparison of results.

4.2) The Questions

Questions have as far as possible been selected and worded to be observational to avoid the need to refer to files or documents.
(The notable exception to this is Category Emergencies)

This has been done to make the tool as simple as possible and reduce the time needed to complete an assessment. The assessor is encouraged to choose a score for the question at the time of the assessment to provide an objective view of the issue being marked. Simple notes should be kept for any high or low scores and should be discussed in feedback sessions.

Quick and Easy Assessment without the Paperwork

Questions have also been selected to deal with relevant issues within categories but not to be exhaustive on each subject. This again is deliberate to encourage use of the tool regularly to produce assessments that identify quickly and easily good practice and areas for improvement.
If the assessments are completed more and often then hazards can be managed and improved more effectively.
To further help the assessor SABRE is provided with the CIRIA SITE SAFETY Handbook special publication 130, which will provide legislation and best practice requirements for the categories to be assessed. It will be of particular help for technical categories of questions.

In addition to this a quick guide to scoring is included at the back of the manual to provide instruction for many of the questions. The Site Safety Handbook and quick guide will be a useful reference prior to using the tool for the first time.

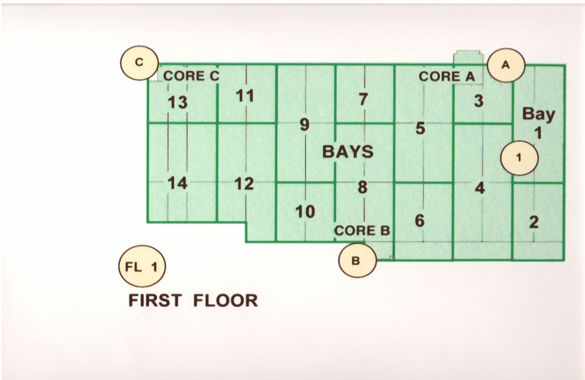
5) Functional Zones / Working Areas or Suppliers

It has been recognised that it can be very difficult to make an accurate and fair observation about a whole site and that some system of assessing individual work areas or zones or indeed individual suppliers is required.

This function will also help to fairly assess a whole site and avoid having to poorly mark an assessment because of an individual operative or item of plant, or specific work area, which is not meeting the standards required. An additional feature of this will allow the construction team to focus in very accurately on an area, which may well be under performing.

To achieve this does require the assessor to clearly allocate work areas and zones and suppliers before the assessment begins to avoid confusing the assessment. This does not require lengthy analysis and review of the project beforehand. It will merely require the assessor to have an appreciation of the functional zones of a project and allocating numbers or names in a logical way.

For example, an office construction can be organised around floors (1,2,3,4…), or bays cores or gridlines if necessary..



Major civils projects can be organised around the areas of work, abutments (1,2,3.), retaining structures (6,7,8, 9.) carriageway, chainages (possibly 0 -100m, 1, 100m - 200m, 2, etc.)
Items of major plant may also be allocated ID no's if appropriate.
Suppliers can be separated as major trade supplies, groundwork, joinery, electrical etc or by supplier name
.

6) The Scoring System

Score %	Meaning	
100%	**Excellent**	Very high level of working practices above and beyond normal
75%	**Well Managed**	Relatively good safety compliance, demonstrating better than normal practices
50%	**Acceptable**	Compliance to safety - Opportunity for improvement
25%	**Unacceptable**	Very little compliance - Needs immediate attention

The scoring system aims to achieve 3 main objectives:

- Be simple to apply, by having only 4 categories of score.
- Encourage improvement through the identification of levels of achievement, where an acceptable score indicates compliance but may present opportunities for improvement.
- Is a simple visual presentation of achievement that quickly identifies strengths and weaknesses.

The assessor should be able to instinctively score categories in this way, removing as far as possible subjective review being necessary.

Many assessments may only achieve an acceptable rating, which allows the team to seek opportunities for achieving improvement to Well Managed or Excellent scores. This may be done through developing initiatives to demonstrate better working practices or tighter control to improve the workplace and operations.

High and low scores should always be accompanied by details of the factors influencing the assessment. This is particularly important for explaining why a low score was given as well as collecting details of good and excellent practices for sharing within the project and with other projects.

7) How to Produce an Assessment

SABRE on site data collection has been developed to be used on any pocket PC that supports windows CE applications. In particular the data collection software has been developed on the iPAC Pocket PC and this guide will refer specifically to this hardware. Nevertheless, many of the features and functions will be similar for all pockets PC's and this guide should still apply.

As a consequence any user will need to familiarise themselves with the pocket PC and some of its basic functions. This will inevitably require a little bit of time to get used to but this should be minimal with most individuals' who are PC aware.

7.1) Installing and Finding SABRE

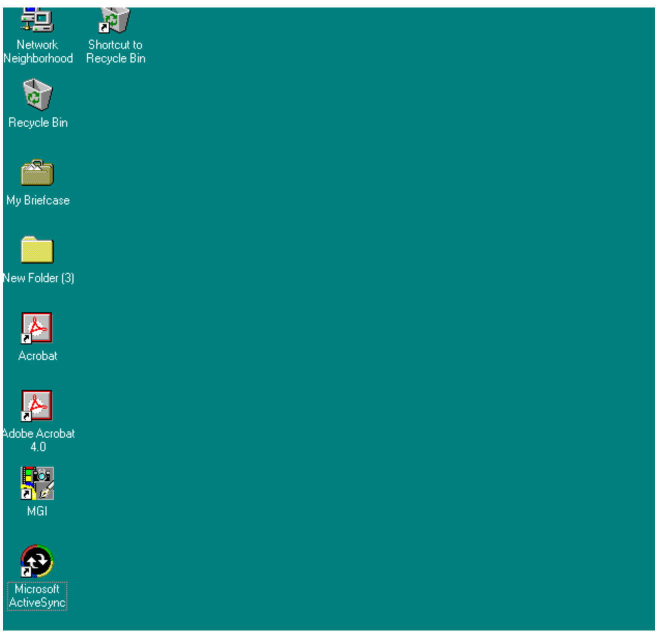
To install SABRE onto the pocket PC the following procedure needs to be followed.

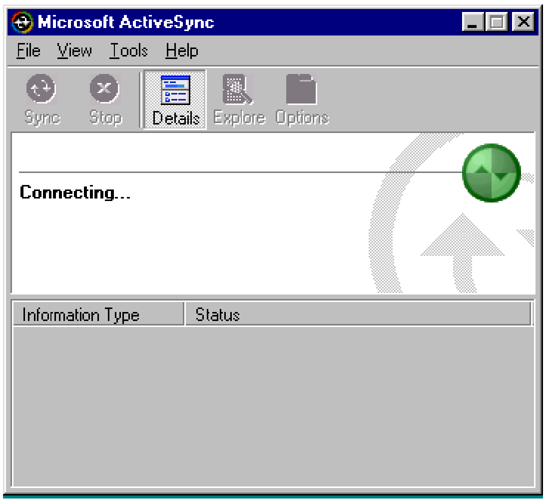
A folder called SABRE will now be installed onto your computers C:/ Drive using the path name C:/Sabre.
This folder contains Sabre Handheld and PC Analysis software.

To install SABRE to the handheld open the mobile device software and ensure that **Microsoft ActiveSync** is installed and running.

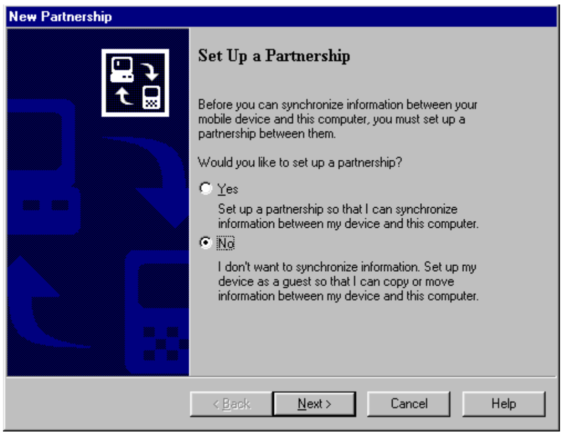
To down load ActiveSync Click

http://www.microsoft.com/mobile/pocketpc/downloads/activesync/as-dl.asp?submit1=I+Accept+%3E%3E

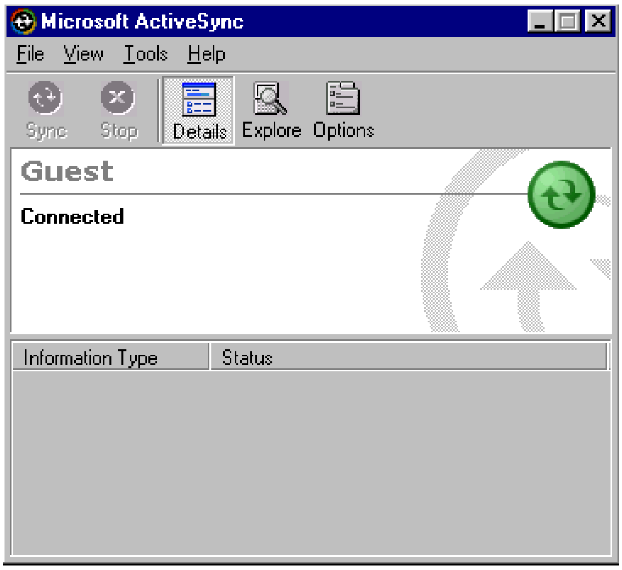




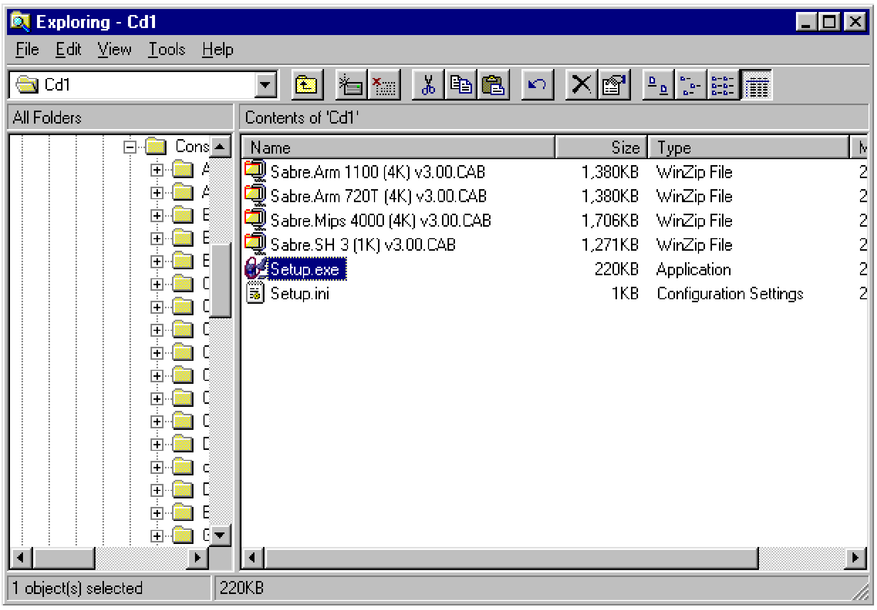
This window will appear inducting that Microsoft ActiveSync is connecting.



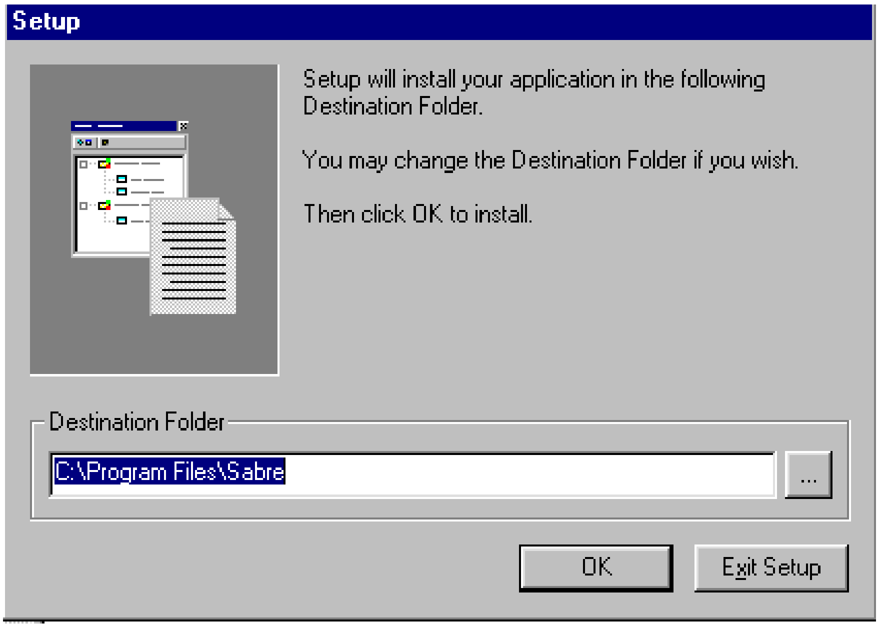
Select No button and go to next



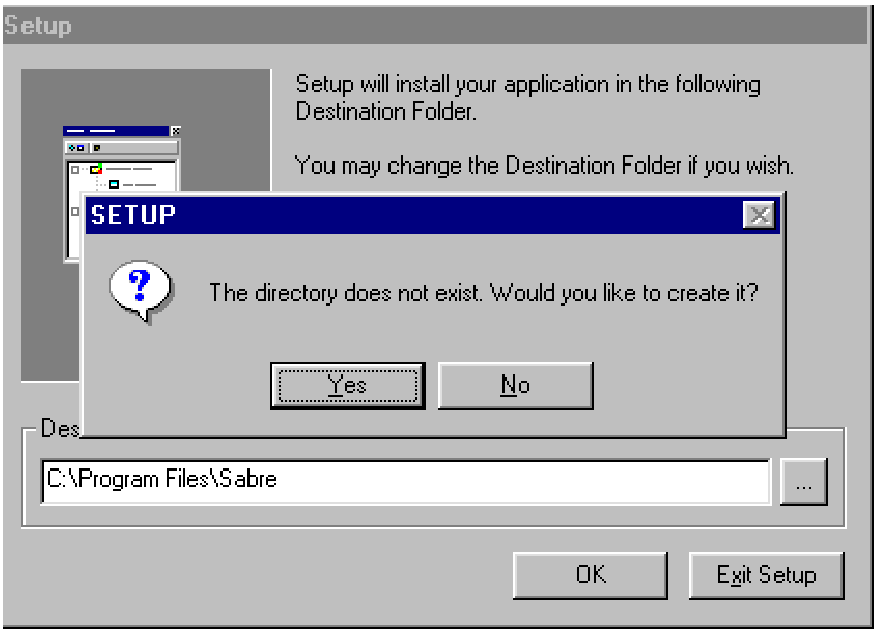
This window will appear inducting that the iPAC Pocket PC now is connected. Minimise this window.



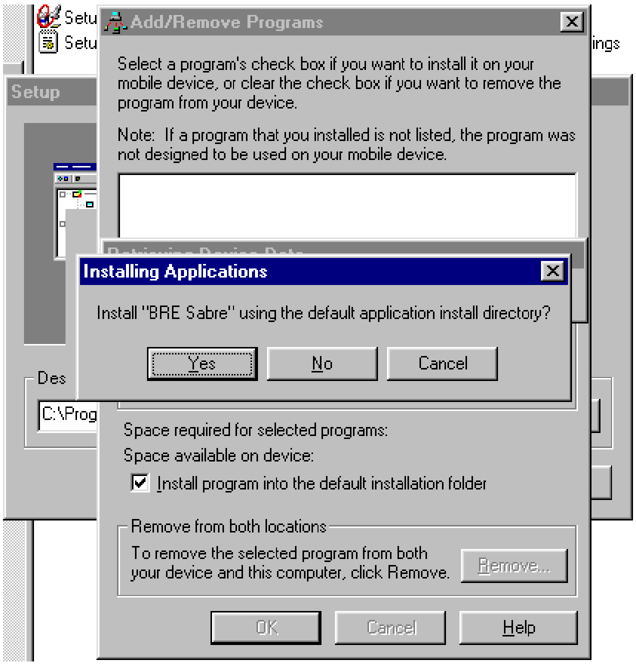
Using windows explorer Go to the Sabre folder in your hard drive or sabre CD supplied open\Installation V3\CD1\Setup.exe and double click Setup.exe to install SABRE.



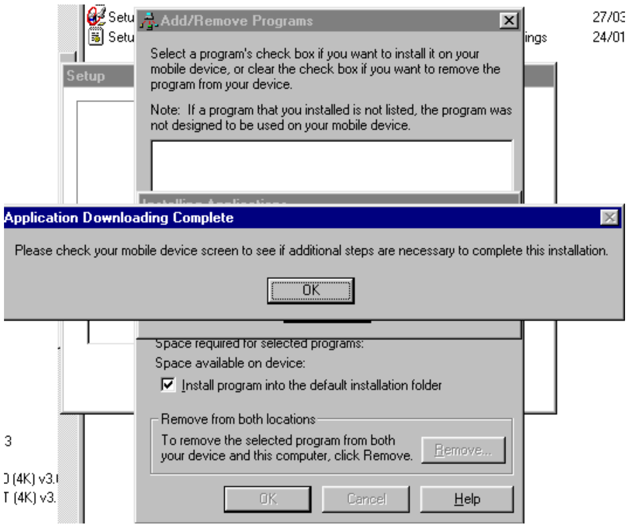
Click Ok to start installing after checking the destination of you Sabre folder



Click Yes
.



Click Yes

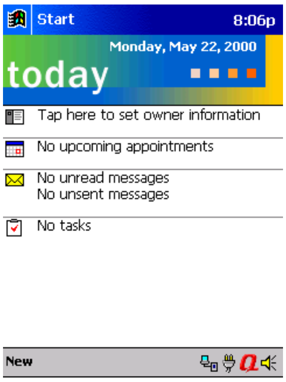


Click OK, also click Yes To All in your handheld.

Having installed SABRE onto your iPAC Pocket PC handheld, the file can now be opened and used for assessment

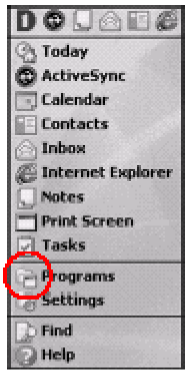
7.2) Opening Sabre in your iPAC Pocket PC Handheld.

You can open SABRE from the start menu drop menu or from the programms. If you want open SABRE from the start menu you have to add SABRE shortcut the menu, by going into setting then Personal, then Menu and select SABRE and click OK.



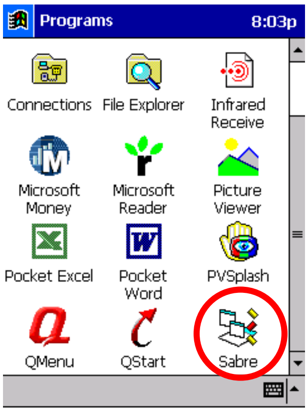
Tap start for the drop down menu

Becouse SABRE is a programme you have to open programme window.



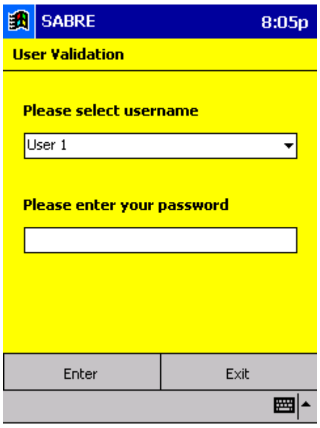
Tap Programme to open SABRE

.

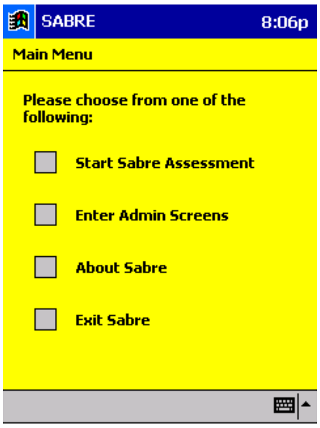


Tab SABRE to open

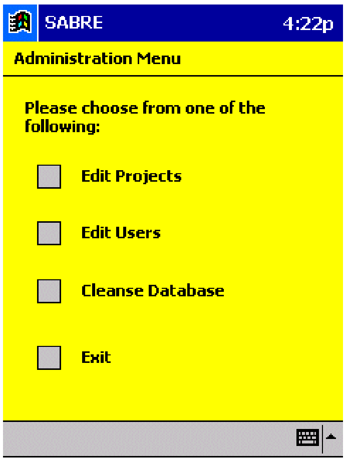
Tap the screen again



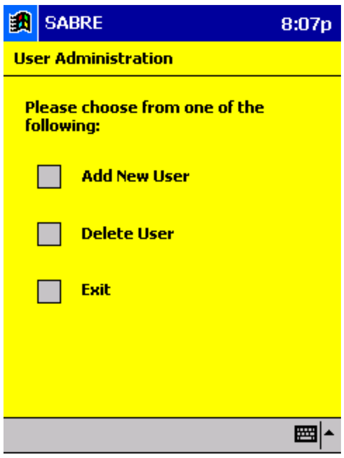
This screen will appear, because you are a new user tap Enter



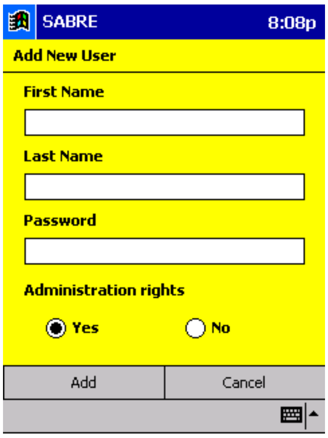
Select Enter Admin Screens to log on as a new user



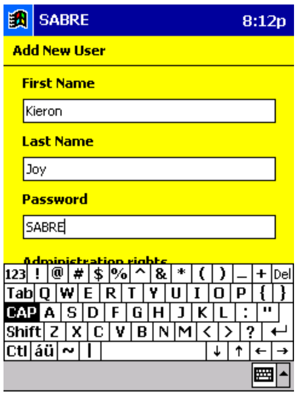
Select Edit Users



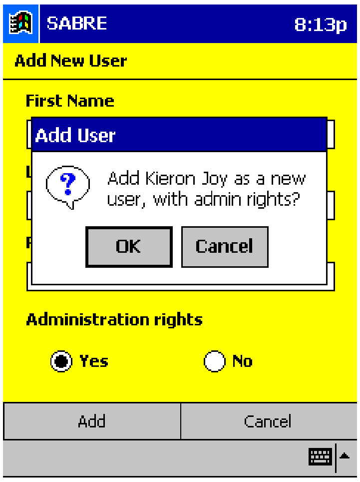
Select Add New User



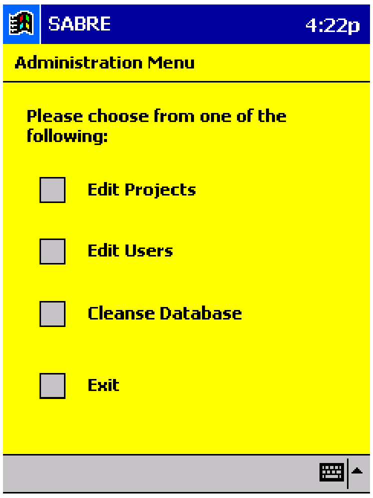
This screen will appear. To fill in the boxes tap the keyboard or writing with the stylus and using character recogniser



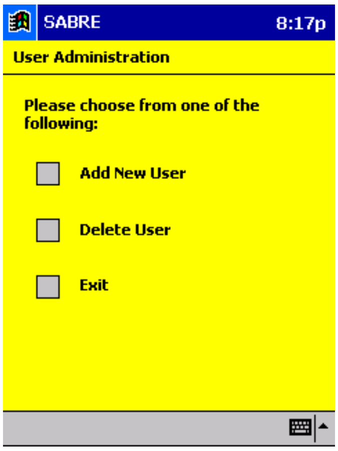
After filling in the information tap the keyboard to close the keyboard, select yes and tap Add



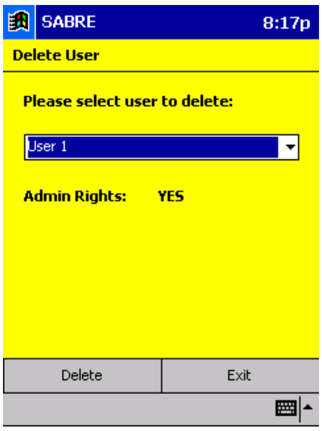
Tap OK



This screen will appear, select Edit users to delete User 1 if you want

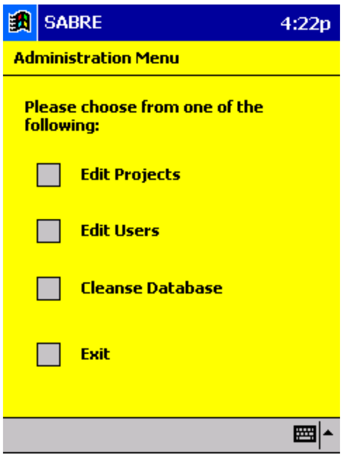


Select Delete User

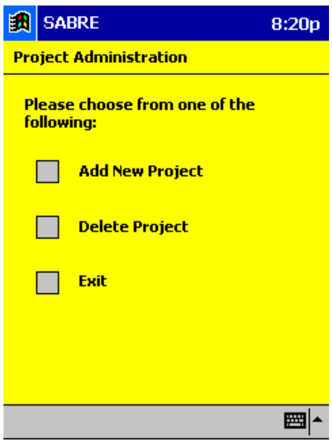


Tap Delete

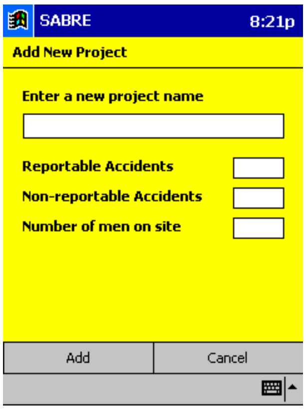
To enter project and assessment details



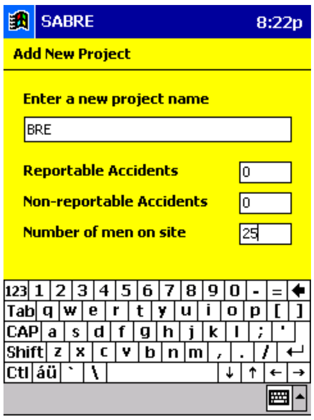
Select Edit Project



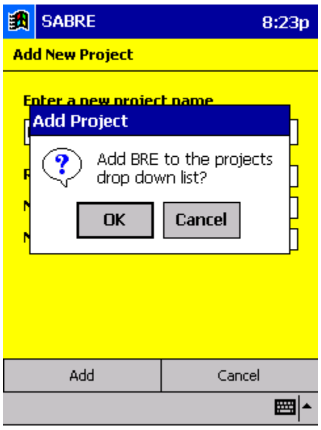
Select ADD New Project



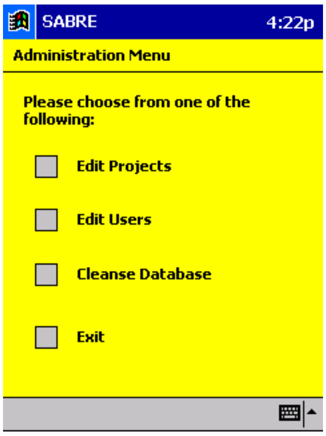
Tap the keyboard to fill in the boxes, please remember that even if you do not have any reportable or non-accidents fill in the two boxes with 0



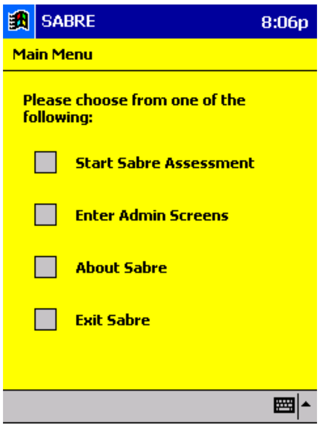
Tap the keyboard after entering the information



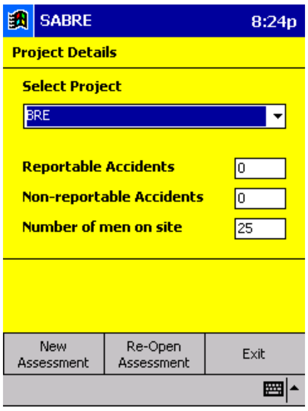
Click OK



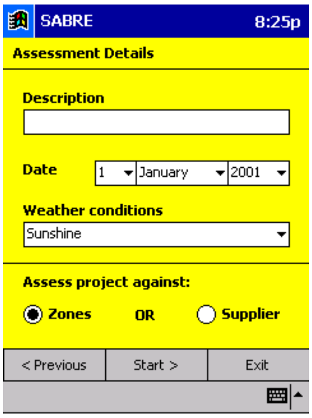
Click Exit



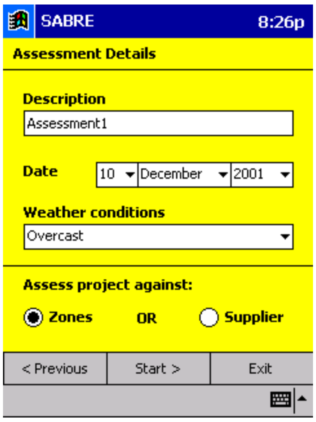
Select Start Sabre Assessment



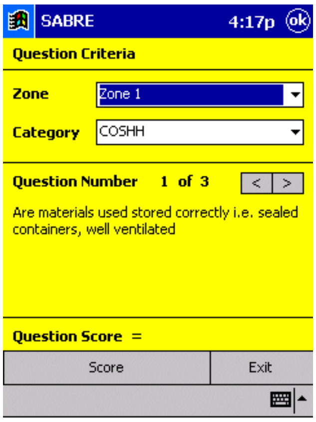
Tap New Assessment



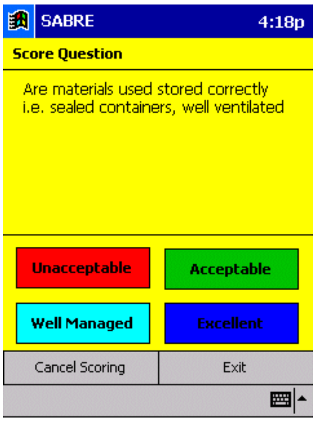
Fill in Description, Date, Weather conditions and Zone or Supplier



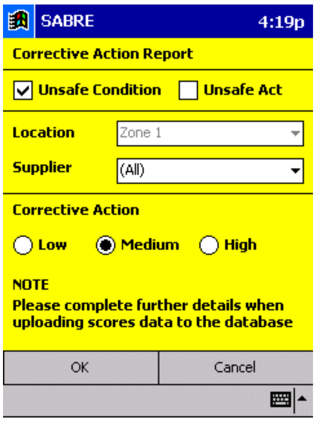
Tap Start



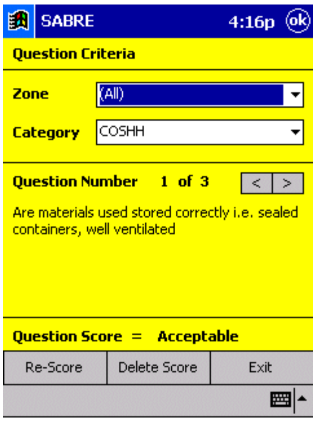
Select from the drop menu Zone, Category, and QuestionNumber, read the question and Tab Score



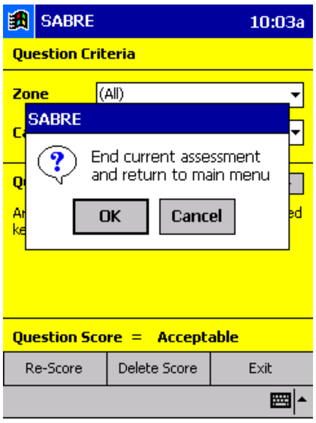
Tap the relevant score



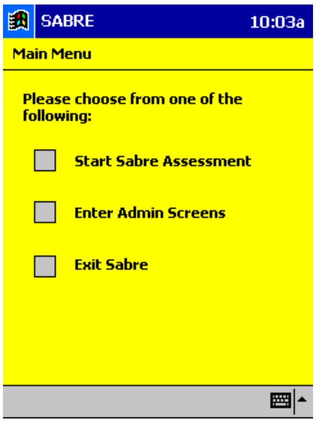
If you score Unaceptale this menu will appear, you have to fill in the boxes



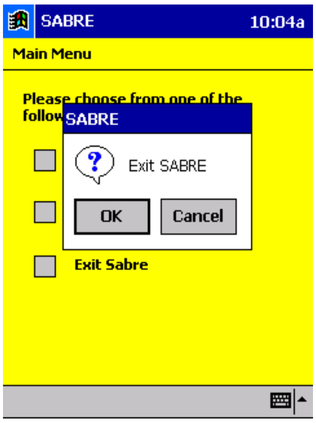
Now you have the option to Re-Score or tap the scroll bar to go to the next question.
If you have finished, tap Exit to come out of SABRE software



Tap OK



Tap Exit Sabre

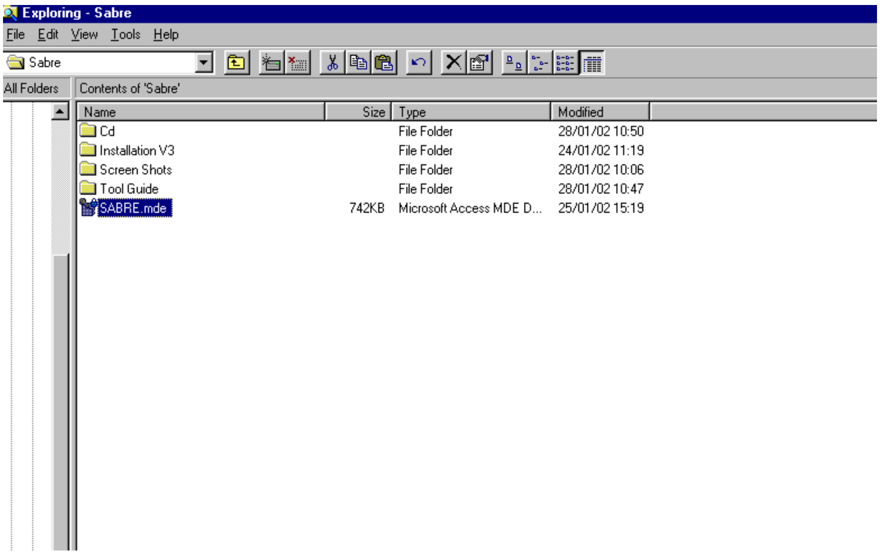

SABRE
10:04a
Main Menu
Please choose from one of the
follow
SABRE
Exit SABRE
OK
Cancel
Exit Sabre

Tap OK

8) Analysing the Database using SABRE Data Analysis Tool

8.1) Downloading SABRE Database

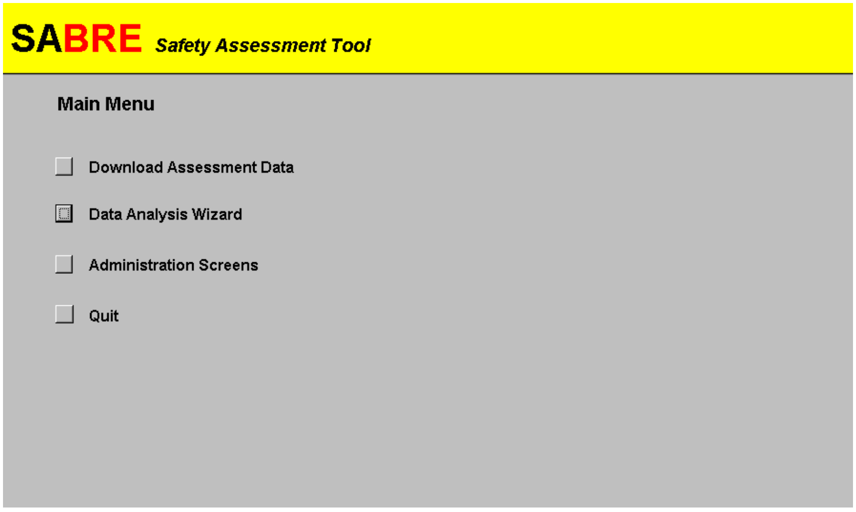
Downloading SABRE database is simple, just copy the database from your CD to your desktop or other chosen destination.



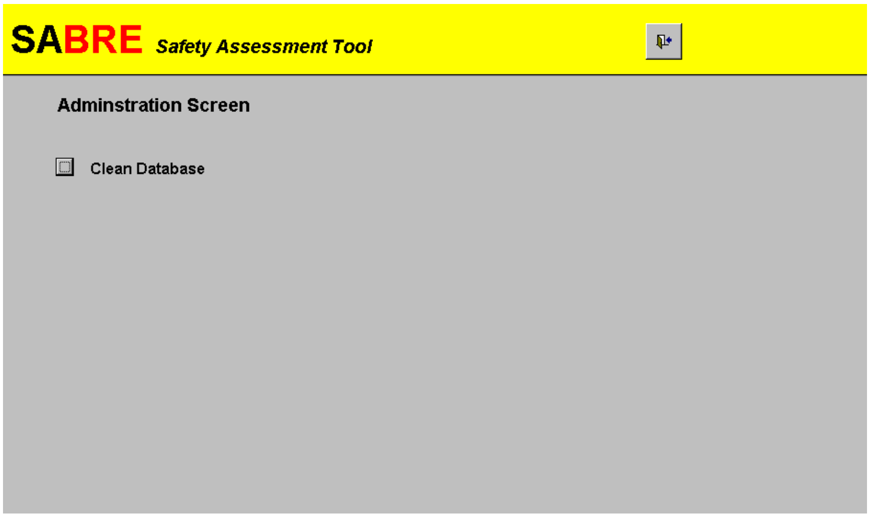
Copy SABRE.mde to your destination then open the database from the directory folder were you have installed it

8.2) Clean Data

Before importing any database from handheld make sure you have a clean version of SABRE Data Analysis Tool by



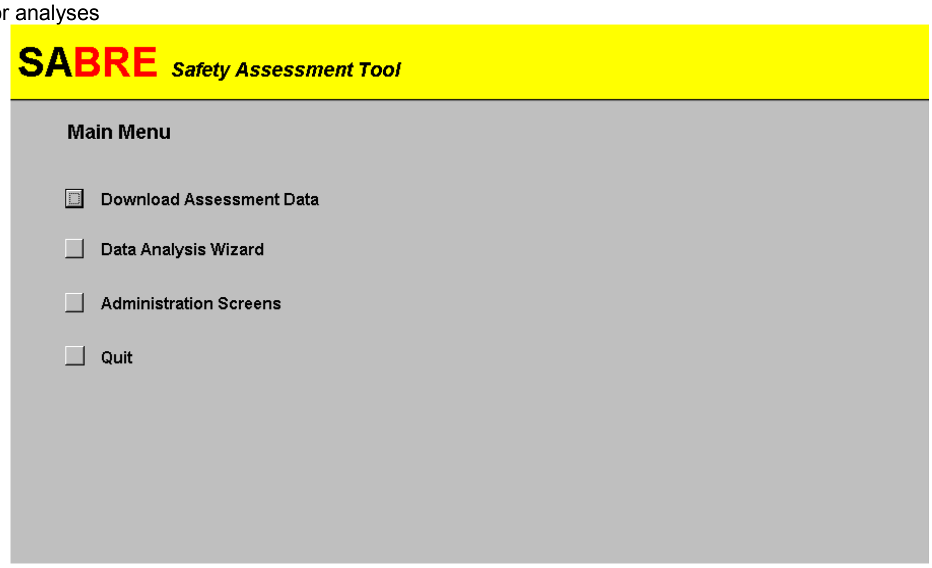
selecting **Administration Screens**



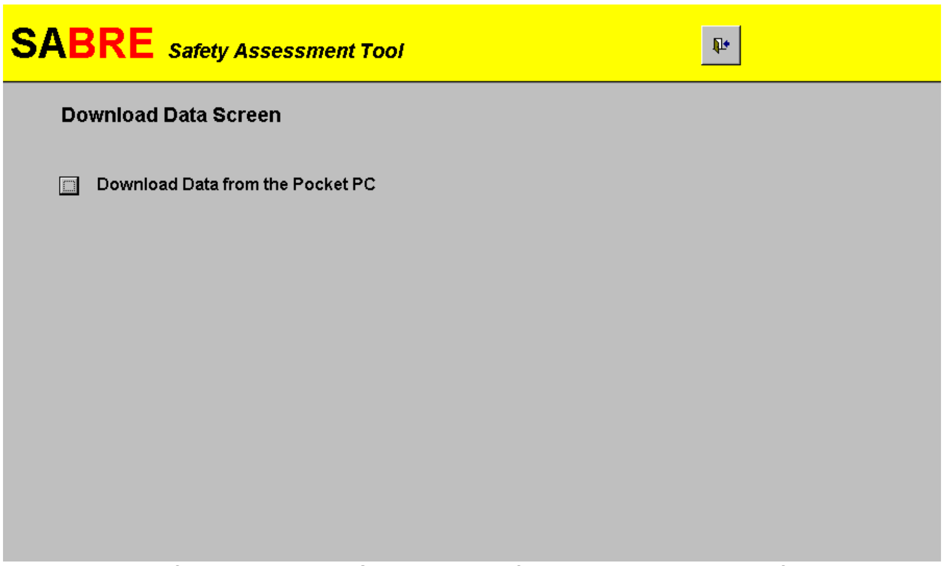
then click on **Clean Database,** to clean any previous data inside the tool.
When you first use the database it will be empty, you may wish to ensure that by following the above instructions. When you start using the database regularly do not clean the database, as you will lose the assessments previously downloaded.

8.3) Download Assessment Data

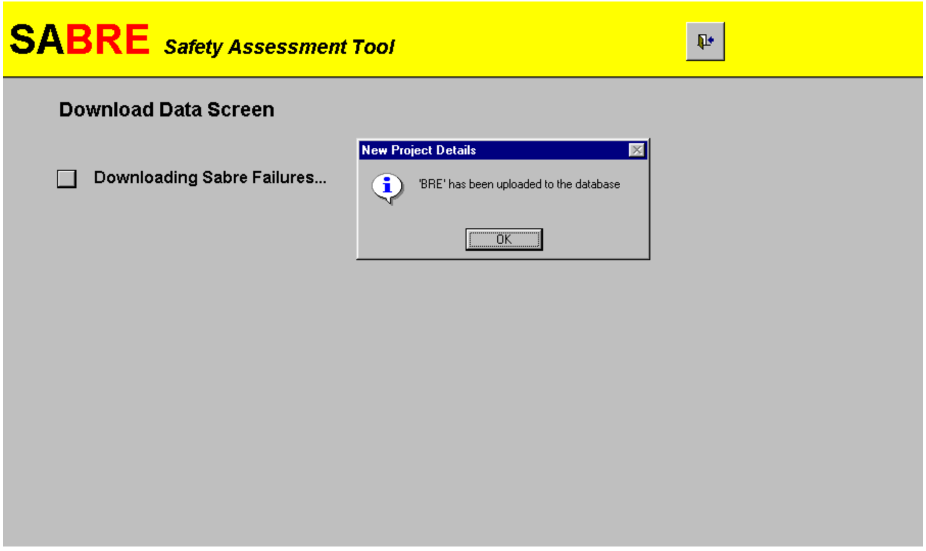
After completing an assessment or a number of assessments the data needs to be transferred from the handheld to the database for analyses



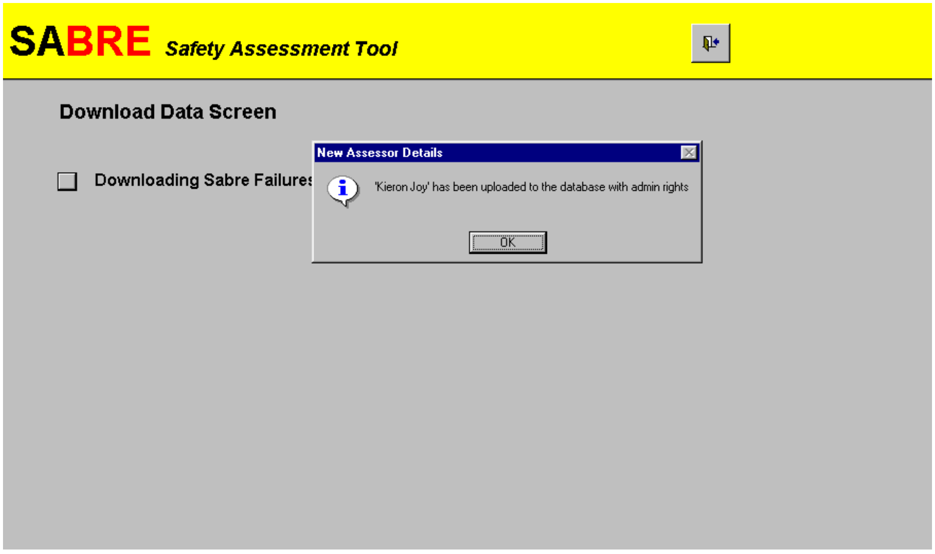
To do this Click on the **Download Assessment Data** button to import data from the handheld.



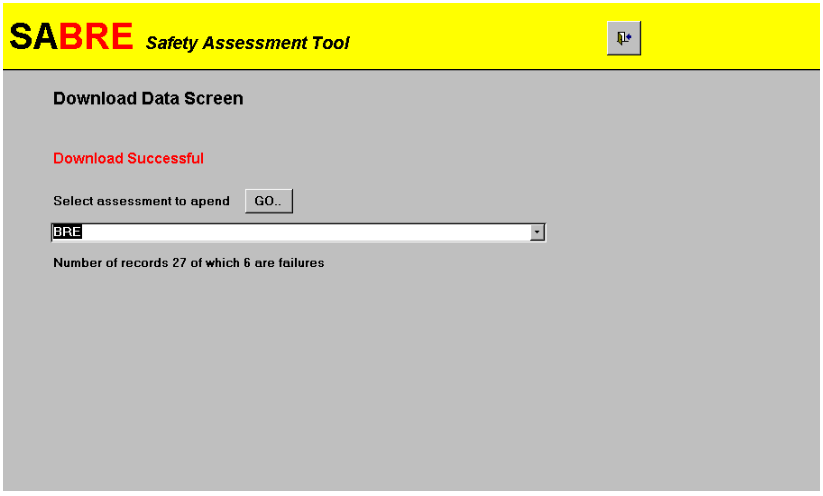
Click on the **Download Data from the Pocket PC** to import data from the handheld and wait for the downloading process to commence



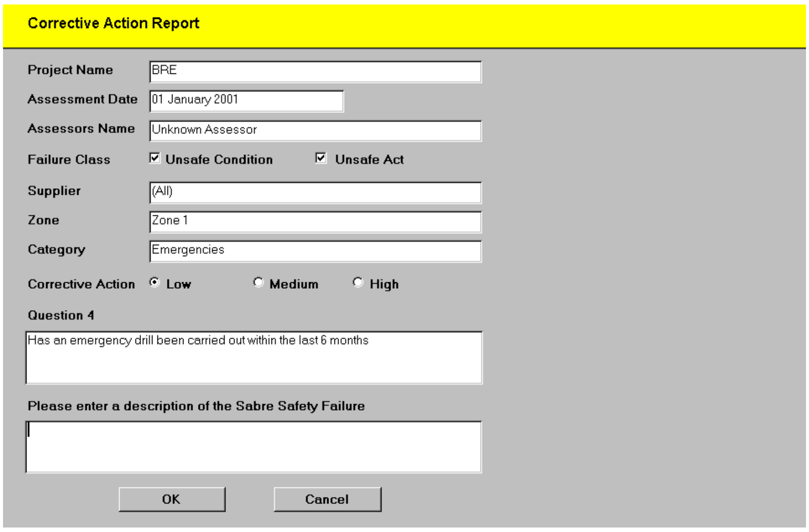
This message will apper, If a new project details have been installed from the handheld, Click OK to accept details



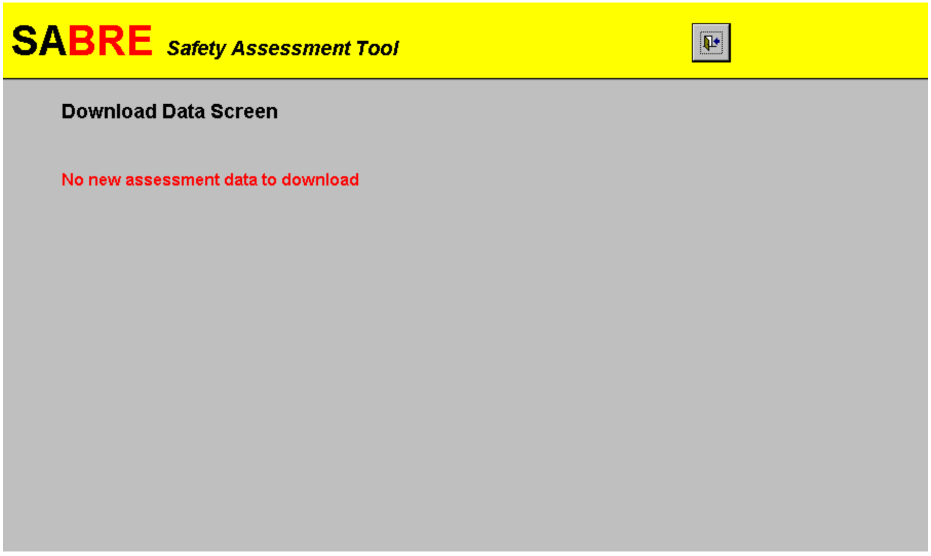
This message will appear if new asser details have been installed on the handheld. Click OK to accept details



From this screen you will see the project details downloaded in the dropdown menu and number failure entrys, select the project from the drop menue and Click **OK** to install the reasons into the database. This allows you to ignore projects incorrectly installed or select only projects wish to install in this database, select the assessment to apend and Click OK

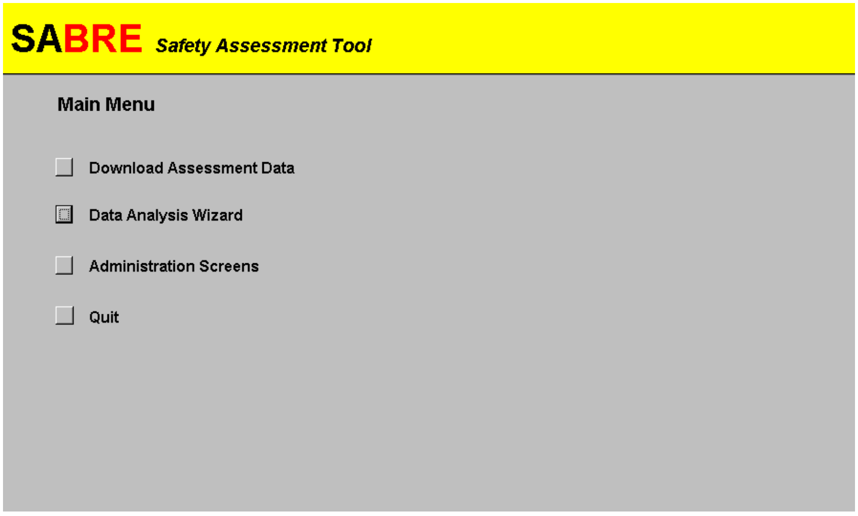


Any corrective action recorded during assessment are presented to enter a description of SABRE safety failure in the descripartion box. When you have entered the failure Click OK to procced, all corrective actions reports are required to be completed to end the assessment downloaded. The same procedure will be followed for any future assessments you wish to download

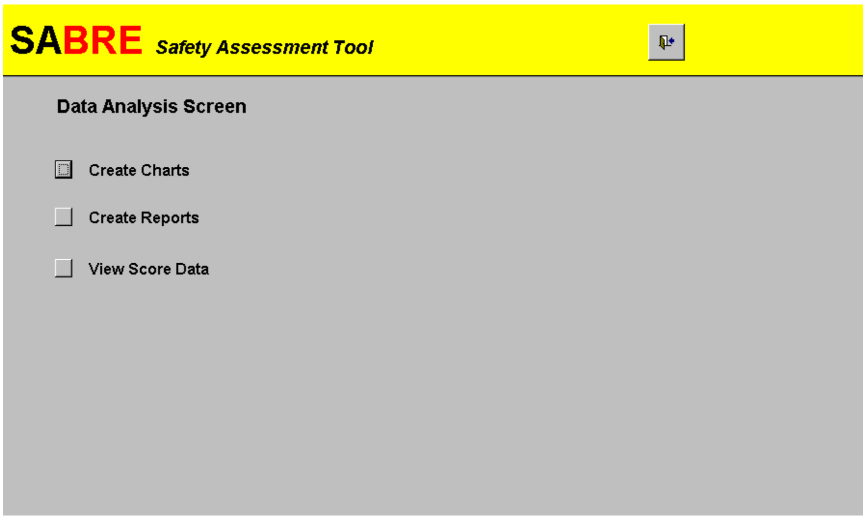


This screen will appear once all corrective action report are entered, Click **Exit** to get to the Main Menu to produce assessmernt charts

8.4) Producing assessment charts using Data Analysis Wizard

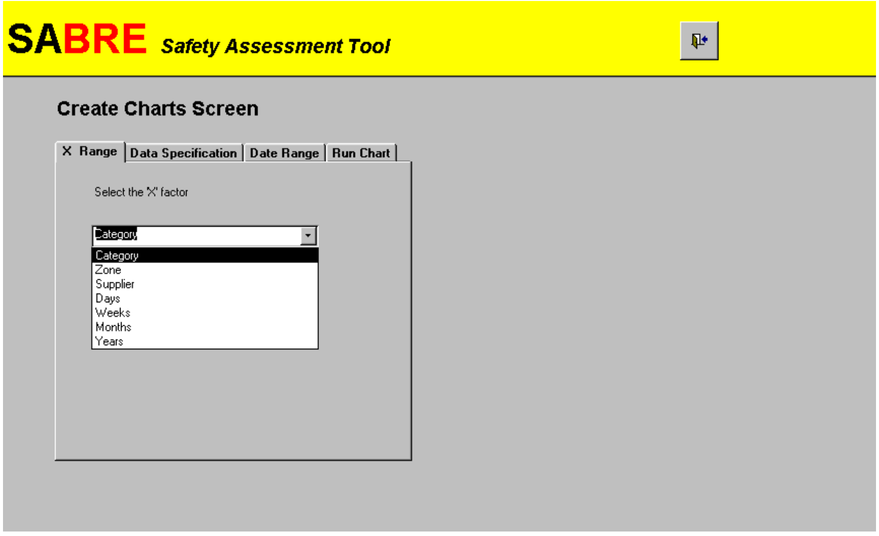


Click **Data Analysis Wizard** to get into the Data Analysis Screen

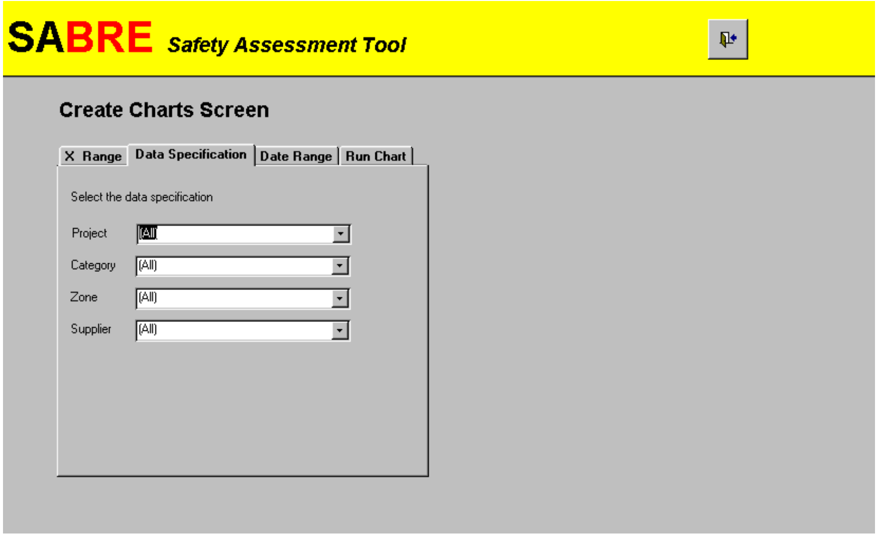


Click on **Create Charts** to start producing charts. For each assessment or a group of assessments, Click on Create Reports to produce corrective Action Reports for each assessment or group of assessments, Click on View Score Data to see scores for each assessment

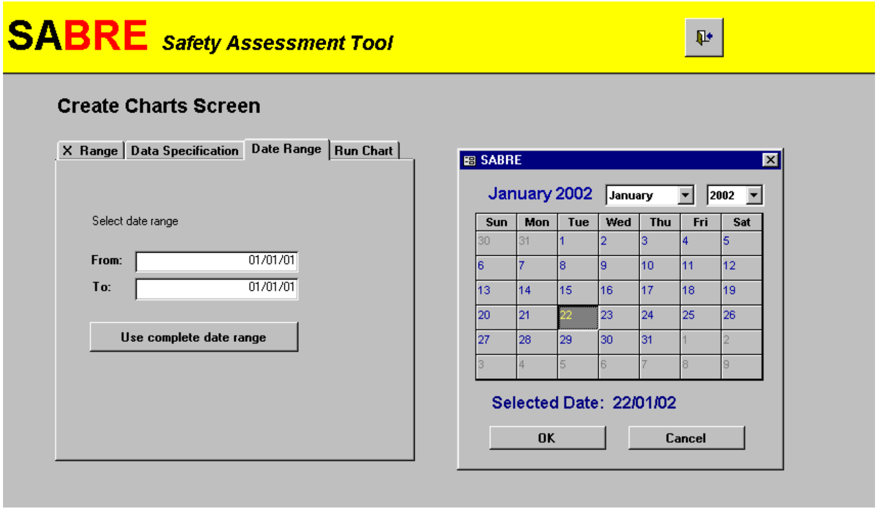
8.5) Producing a chart for an assessment or group of assessments



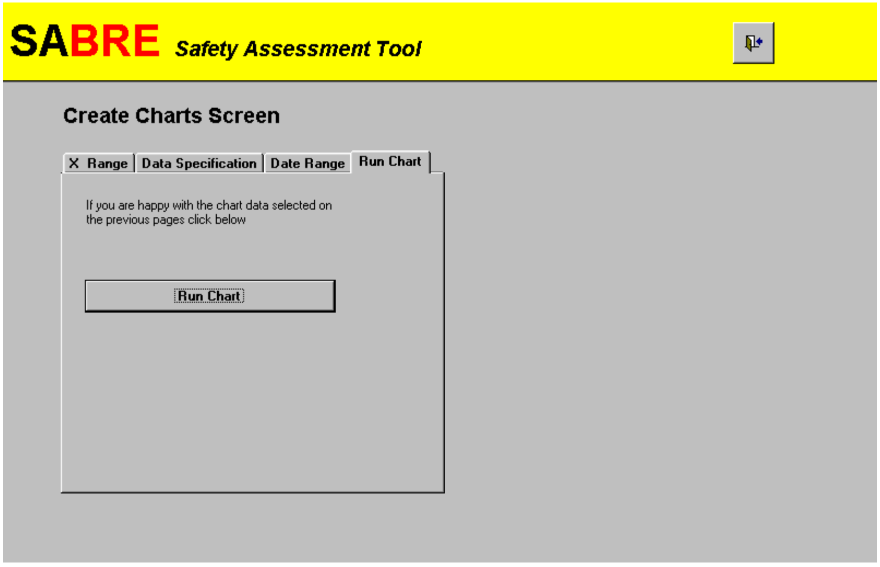
To produce or run a chart select from the drop down menu in the X Range Category, Zone, supplier etc, then move to Data Specification, Data Range and Run Chart.



Select from the drop menues project, category, zone and supplier then move to Data Range..

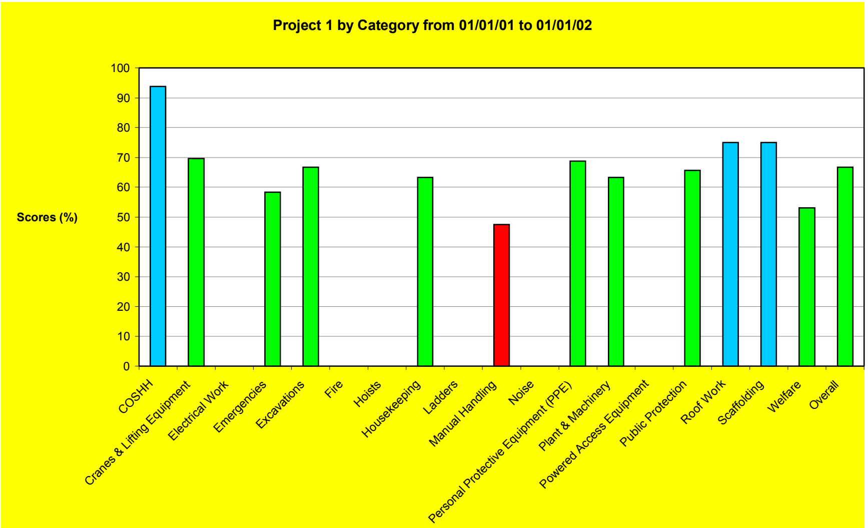


Select data range from and to, select data from the calander. Then move to Run Chart.

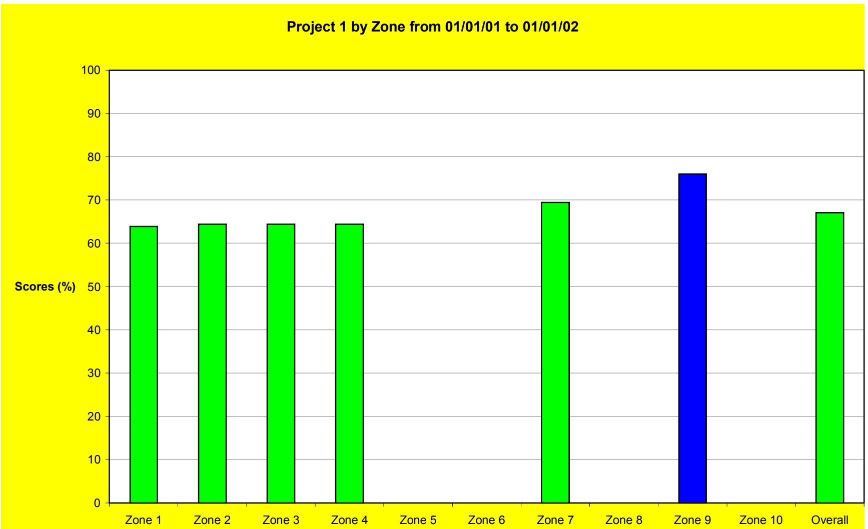


Click **Run Chart** nto produce a chart.

Some of charts which can be produced from SABRE tool.



By Category all Zone

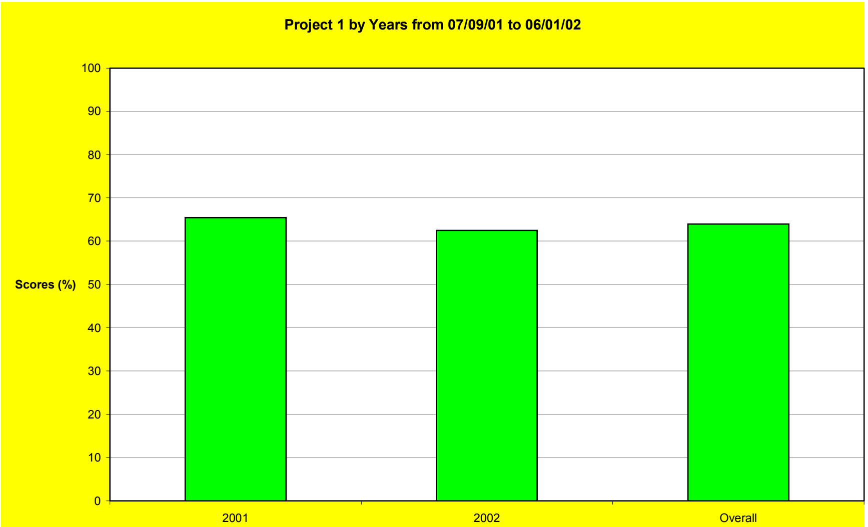


All Categories by Zone

SABRE can produce performance per day, week, month, or year for one project or a number of projects

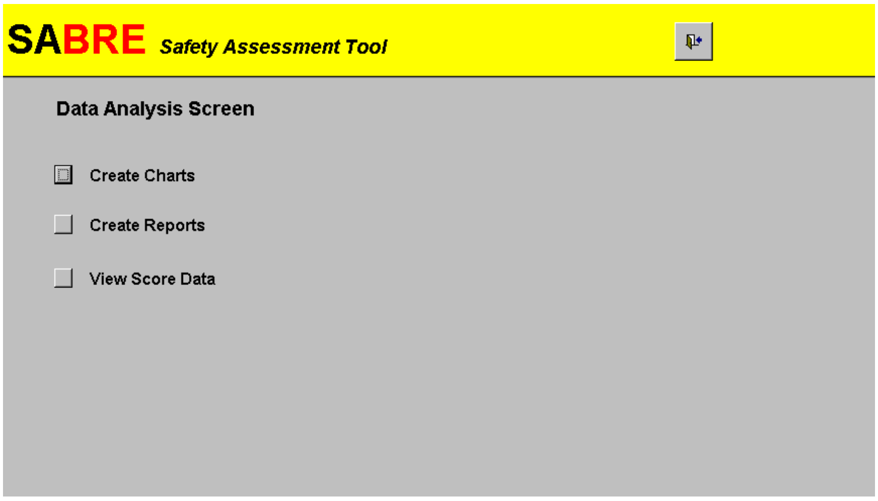
By Week

By Month

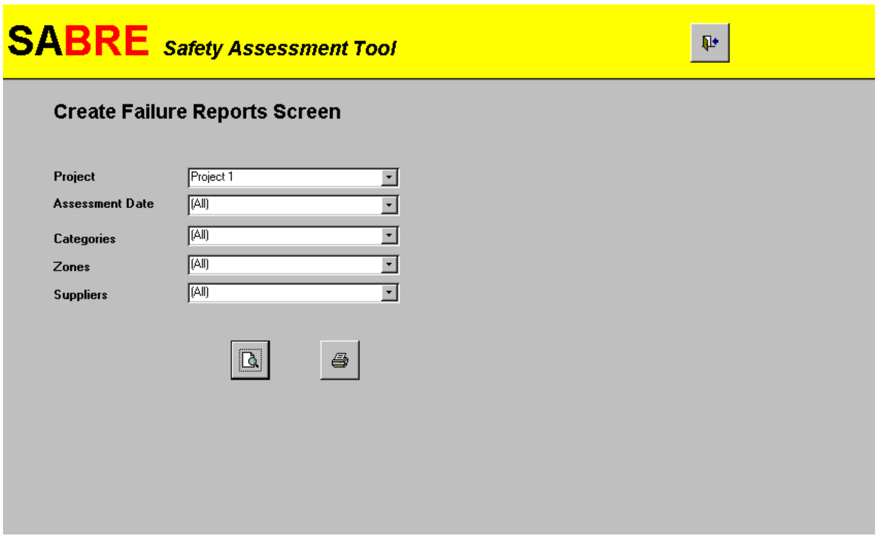

Project 1 by Years from 07/09/01 to 06/01/02
Scores (%)
100
90
80
70
60
50
40
30
20
10
0
2001
2002
Overall

By Year

8.6) Create corrective action reports for an assessment



To create failure report Click **Create Reports**



Select project, Assessemnt Date, etc and click view

Sabre Failure Report

Project **Project 1**

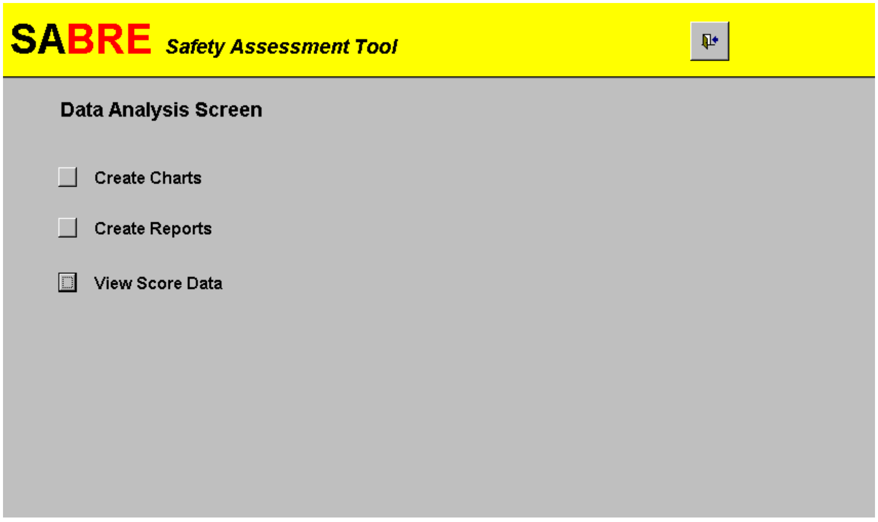
Assessment Date 01/01/01

Zone	Zone 1
Supplier	(All)
Category	Manual Handling
Question	Are operatives using good manual handling techniques
Risk Description	High
Failure Description	Many items has to be downloaded manually

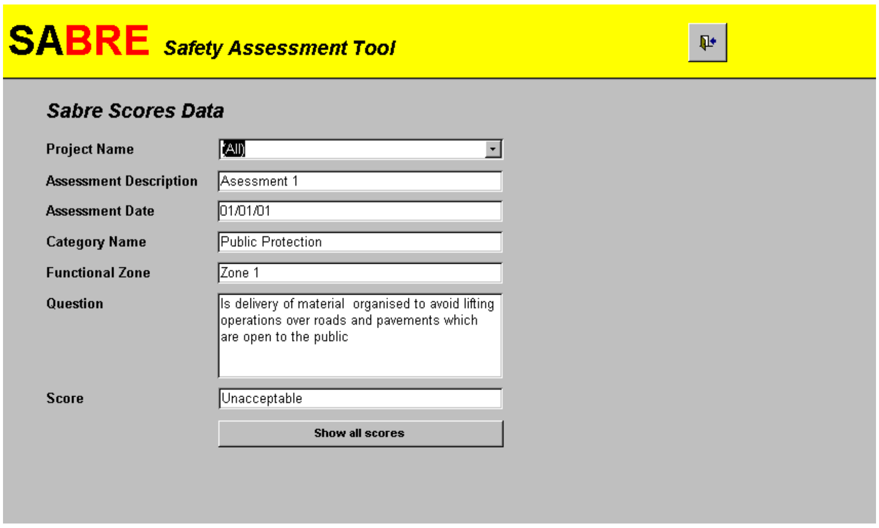
21 January 2002 Page 1 of 6

A typical Failure Report sheet with failure Descripation. This report can be printed for issing for the responsible party for their action.

8.7) View Score Data



To view scores Click **View Score Data**



You can view all scores or failures only

9) Quick guide to Compaq iPAQ Pocket PC H 3700 Series

9.1) Know your device

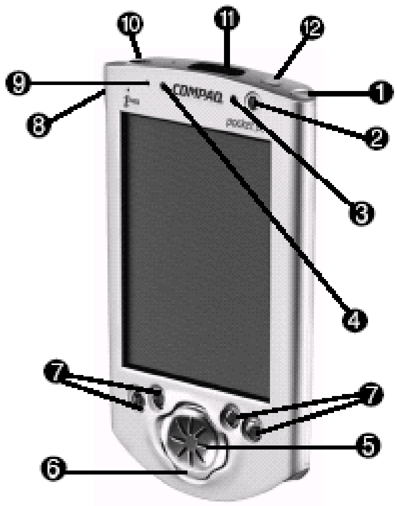
This section is designed to help you get started using Pocket PC devices.

Tool Guide January 2002

Quick guide to Compaq iPAQ Pocket PC H 3700 Series

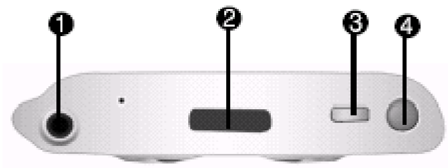
The illustrations below introduce you to the various buttons, connectors, ports and other features of your iPAC Pocket PC.

Front Panel



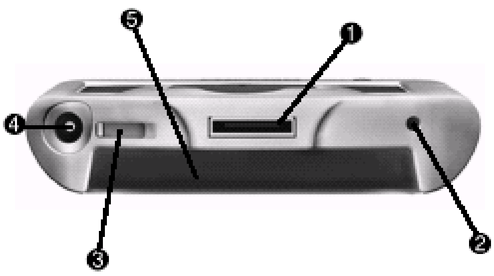
1 Stylus: tap, draw, or write
2 Power Button
3 Power Indicator: alarm charge light
4 Light sensor: adjusts backlight
5 Speaker
6 iPAQ Navigation/Action Button 5: scroll through a list, open a selected item
7 Programmable Application Buttons 1-4 (left to right): navigate to applications, default: button 1 is Calendar, button 2 is Contacts, button 3 is Inbox, and button 4 is iPAQ Task
8 Record Button
9 Microphone
10 Stereo Headphone Jack
11 Infrared Port: exchange information with other Windows-powered devices
12 Stylus Release Button: eject the stylus

Top Panel



1 Stereo Headphone Jack
2 Infrared Port: exchange information with other Windows-powered devices
3 Stylus Release Button: eject the stylus
4 Stylus: tap, draw, or write

Bottom Panel



1 Communications Port: connect to cradle, USB, or serial cable.
2 Reset Button: reset with stylus
3 On/Off Switch: clear all information
4 DC Jack: connect to external power
5 iPAQ Expansion Pack Connector: connect to an optional Expansion Pack

BRE

9.2) Caring for your iPAC

When treated properly, your iPAC Pocket PC will be a reliable desktop PC companion. Below some of these tips to ensure long and trouble-free use:

- **Clean the screen**. Touching the screen with your hands will leave a trace of natural oil that may make it difficult to read the screen. To clean the screen Use a small amount of glass cleaner sprayed on a soft cloth. Please try to avoid spraying direct to the screen. Also make sure to turn off the iPAC Pocket PC before cleaning.
- **Do not drop your iPAC Pocket PC**. Dropping the iPAC Pocket PC can cause damage to delicate components such as the display and the internal parts. Please note that accidental damage is not covered under the iPAC Pocket PC express warranty.
- **Avoid radiated interference**. Radiated interference from other electronic equipment may affect appearance of the display of your iPAC Pocket PC.
- **Avoid high temperatures**. Your iPAC Pocket PC is designed to operate at temperatures between 0 to 40 °C (32 to 104 °F). Operating outside this range may damage the unit or result in loses of data.

9.3) Using your iPAC Pocket PC for the first time

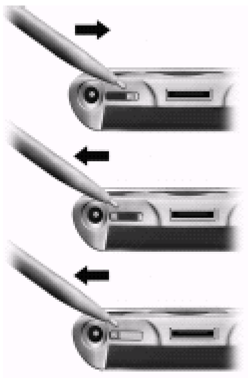
The following steps explain how to use your iPAC Pocket PC.

Set up your Compaq iPAQ Pocket PC by first turning on the battery. Then charge it with the AC adapter or the cradle. Use the cradle to synchronize your Compaq iPAQ Pocket PC with your computer.

CAUTION: For synchronization to work properly, install Microsoft ActiveSync 3.5 before you first connect your Compaq iPAQ Pocket PC to your computer. Because your Compaq iPAQ Pocket PC uses some power to maintain RAM and the clock, you need to recharge the battery regularly. Keep the Compaq iPAQ Pocket PC connected to the cradle or the AC adapter while you are at your desk. The best policy is to keep the Compaq iPAQ Pocket PC connected to your computer when working at your desk and carry your AC adapter with you when travelling.
Charge your Compaq iPAQ Pocket PC for three hours before you first use it.

CAUTION: Some of the applications on your Compaq iPAQ Pocket PC are held in RAM memory, you will need to reinstall those applications if the battery completely discharges.

Turn on the battery
Before you charge your Compaq iPAQ Pocket PC, turn on the battery
1. With the stylus, open the On/Off door at the bottom of your Compaq iPAQ Pocket PC
2. Move the On/Off switch to the on position at the left
3. Close the On/Off door



9.4) Charge with the AC adapter
Charge your Compaq iPAQ Pocket PC with the AC adapter. Use the AC adapter to charge your optional expansion pack, if you have purchased one. For more information about expansion packs, see Expanding Functionality with Expansion Packs.
Charge your Compaq iPAQ Pocket PC for three hours before you first use it. The standard adapter works in any household outlet. You can also purchase one that works in your car's cigarette lighter or a 12-volt power outlet.

CAUTION: Use only Compaq recommended AC adapters.
1. Locate the AC adapter
2. Plug the AC adapter into an outlet
3. Insert the DC adapter plug into the bottom of your Compaq iPAQ Pocket PC

Charge with the cradle

Charge your Compaq iPAQ Pocket PC with the cradle. Use the cradle to • synchronize with your computer • recharge the battery of an optional expansion pack, if you have purchased one (for example, recharge the battery of the Dual-slot PC Card Expansion Pack) Charge your Compaq iPAQ Pocket PC for three hours before you first use it.

CAUTION: For synchronization to work properly, install Microsoft ActiveSync 3.5 before you first connect your Compaq iPAQ Pocket PC to your computer.

1. Install Microsoft ActiveSync 3.5 Insert the Compaq iPAQ Pocket PC Companion CD-ROM Follow the instructions in the installation wizard For more help, click on the Microsoft ActiveSync 3.5 Help button during installation
2. Locate the cradle
3. Insert the AC adapter plug into the DC jack on the back of the cradle
4. Attach either the USB or serial cable to your computer Getting Acquainted If you have a Microsoft Windows NT 4.0 operating system on your computer, you must use a serial cable
5. Slide the bottom of your Compaq iPAQ Pocket PC into the cradle and push firmly The charge light blinks when your Compaq iPAQ Pocket PC is recharging the battery The charge light is solid (non-blinking) when the battery is fully charged. Microsoft ActiveSync 3.5 opens on your computer and recognises your Compaq iPAQ Pocket PC

9.5) Set Up Synchronisation

Synchronising allows you to share information between your Compaq iPAQ Pocket PC and your computer or your server. Please note that you should set up synchronization when you first connect your Compaq iPAQ Pocket PC to your computer.

Synchronize with your computer

CAUTION: For synchronization to work properly, install Microsoft ActiveSync 3.5 before your Compaq iPAQ Pocket PC is connected to your computer for the first time.

During installation,
• Create partnerships, which allow you to synchronize information with multiple computers • select the information to synchronize with your Compaq iPAQ Pocket PC, for example, Contacts, Calendar, Inbox, Tasks, Favourites, Files, Notes, and AvantGo
1. Insert the Compaq iPAQ Pocket PC Companion CD-ROM
2. Follow the instructions in the installation wizard
For more help, click on the Microsoft ActiveSync 3.5 Help button during installation
3. The information you select will automatically synchronize when your installation is complete

Synchronize information

Synchronizing allows you to share information between your Compaq iPAQ Pocket PC and your computer. Please note that you should have set up synchronization when you first connected your Compaq iPAQ Pocket PC to your computer. By default, Microsoft ActiveSync 3.5 continuously synchronizes with information on your computer automatically. Manually synchronize information with your Compaq iPAQ Pocket PC at any time you are connected to your computer.
1. Insert your Compaq iPAQ Pocket PC into the cradle or cable
2. From your computer, open Microsoft ActiveSync 3.5
From the Start menu, click Programs and click Microsoft ActiveSync 3.53. Click Sync

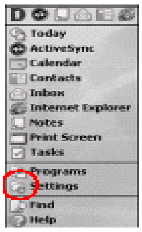
9.6) Turn on the screen

When you turn on the screen of your Compaq iPAQ Pocket PC for the first time, you are guided through Welcome screens. Follow the instructions to

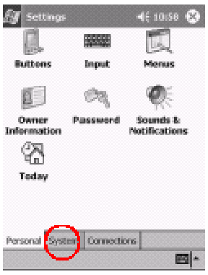
• realign your screen
• learn about the stylus
• learn about the pop-up menus
• select your time zone
1. Press the Power button to turn on the screen
2. Follow the instructions on the Welcome screens

9.7) Change the backlight settings

1. From the Start menu, tap Settings *Getting Acquainted*



2. Tap System



3. Tap Backlight
4. Select the backlight settings

9.8) Enter Information

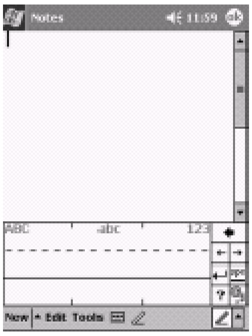
Enter letters, symbols, and numbers on the Compaq iPAQ Pocket PC screen by
• tapping the Keyboard
• writing with the stylus and using the Letter Recogniser to create text
• writing with the stylus and using the Block Recogniser to create text
Tap the Keyboard, write with the stylus and the Letter Recogniser, write with the stylus and the Transcriber, and write with the stylus and the Block Recogniser in any application.

Type with the on-screen Keyboard

Enter typed text directly on the screen by tapping letters, numbers, and symbols on the Keyboard.
Hint: To see the symbols, tap the 123 or Shift key.

Write with the stylus and the Letter Recogniser

Write letters, numbers, and symbols on the screen using the stylus and the Letter Recogniser. Create words and sentences by writing in upper case (ABC), lower case (abc), and symbols (123) in specific areas.



1. From any application, tap the up arrow next to the Input Panel button
2. Tap Letter Recogniser to see a writing area
3. Write a letter or symbol between the dashed line and baseline for the Letter Recogniser to work effectively
Write a letter between the hatchmarks labelled ABC to type text in upper case
Write a letter between the hatchmarks labelled abc to type text in lower case
Write a number or symbol between the hatchmarks labelled 123 to type symbols
4. What you write on the screen will be converted to text

10) Appendix

A1) Questions List

A2) FAQ

Category_ID	Question_Number	Question_Text
COSHH	1	Are materials used stored correctly i.e. sealed containers, well ventilated
COSHH	2	Are those using them are wearing PPE i.e. gloves, masks, eye protection
COSHH	3	Are workers and others who are not protected kept away from exposure
Cranes & Lifting	1	Is the lifting equipment on a firm level base
Cranes & Lifting Equipment	2	Are safety clearance goal posts provided if the lifting equipment is travelling under power cables
Cranes & Lifting Equipment	3	Is 600mm clearance provided between lifting equipment and any obstruction
Cranes & Lifting Equipment	4	Is lifting equipment working in close proximity to others prevented from making contact
Cranes & Lifting Equipment	5	Is the lifting equipment a safe distance from excavations e.g. slopes underground services softground obstruction etc
Cranes & Lifting Equipment	6	Is a banksman present
Cranes & Lifting Equipment	7	Is the banksman able to communicate clearly with the machine operator.i.e. handsignals/radio.
Electrical Work	1	Are portable electric appliances labelled to indicate they have been P A tested within the last 3 months
Electrical Work	2	Where mains voltage has to be used, are trip devices (e.g. residual current devices - RCD's) provided for all equipment
Electrical Work	3	Are cables and plugs free from damage
Electrical Work	4	Are leads and cables protected from damage
Electrical Work	5	Are all connections to the system properly made with suitable plugs
Electrical Work	6	Is lighting properly fitted in working order and protected
Electrical Work	7	Are panels being commissioned clearly signed
Emergencies	1	Have emergency procedures been adequately developed and included in the site indications
Emergencies	2	Are suitable emergency routes and exits provided, signed and kept clear
Emergencies	3	Is there an adequate means of raising the alarm and does it work
Emergencies	4	Has an emergency drill been carried out within the last 6 months
Emergencies	5	Do all employees receive site induction which include details of site layout, site rules and emergency procedures
Emergencies	6	Are access routes for emergency service vehicles maintained
Excavations	1	Have underground services been located before excavation
Excavations	2	Is excavation safe by having sides battered to a safe angle, or providing structural supports e.g. trench sheets and struts, drag boxes, sheet piling or proprietary systems
Excavations	3	Is there safe access to the excavation
Excavations	4	Are there guard rails or other equivalent protection to stop people falling in
Excavations	5	Are properly secured stop blocks provided to prevent tipping vehicles falling in
Excavations	6	Are materials, spoil or plant kept away from the edge of the excavation in order to reduce the likelihood of a collapse of the side?

Category_ID	Question_Number	Question_Text
Fire	1	Are extinguishers red except for a band of colour indicating the extinguisher's content
Fire	2	Are there proper storage areas for flammable liquids and gases (e.g. LPG and acetylene) with proper signage and out of direct sunlight
Fire	3	In the hot area of work e.g. burning and welding, cleared before use from any combustible materials beyond area of splash and spatter or provide flame proof protection
Fire	4	Is smoking banned in areas where gases or flammable liquids are stored and used
Fire	5	Are gas cylinders and associated equipment in good condition
Fire	6	Is flammable and combustible waste removed regularly
Fire	7	Are the right number and type of fire extinguishers available and accessible?
Fire	8	Are there adequate means of raising the alarm
Hoists	1	Is the hoist protected by a substantial enclosure to prevent someone from being struck by any moving part of the hoist or falling down the hoistway
Hoists	2	Are gates provided at all landings, including ground level
Hoists	3	Are the gates kept shut except when the platform is at the landing
Hoists	4	Are the controls arranged so that the hoist can be operated from one position only
Hoists	5	Is the hoist's safe working load clearly marked
Hoists	6	If the hoist is for materials only, is there a warning notice on the platform or cage to stop people riding on it
Hoists	7	Are barriers erected to prevent access beneath inclined hoists
Housekeeping	1	Can everyone reach their place of work safely, e.g. are roads, gangways, passageways, passenger hoists, staircases, ladders and scaffolds in good condition
Housekeeping	2	Are there guard rails or equivalent protection to stop falls from open edges on scaffolds, mobile elevating work platforms, buildings, gangways, etc
Housekeeping	3	Are holes and openings securely guarded, with edge protection or provided with fixed, clearly marked covers to prevent falls
Housekeeping	4	Are Structures stable, adequately braced and not overloaded
Housekeeping	5	Are all working areas and walkways level and free from obstructions such as stored material and waste
Housekeeping	6	Is the site tidy, and are materials stored safely
Housekeeping	7	Are there proper arrangements for collecting and disposing of waste materials
Housekeeping	8	Is eating and drinking at workplace discouraged and can the facilities be reached safely from work place
Housekeeping	9	Is the work adequately lit. Is sufficient additional lighting provided when work is carried on after dark or inside buildings
Ladders	1	Are ladders secure against slipping or falling
Ladders	2	Is a second person standing at the foot to prevent slipping if ladder not tied.
Ladders	3	Do ladders extend approximately 1m above the landing place or is an adequate alternative handheld available
Ladders	4	Can tools and materials be carried up and down so that one hand is kept free to grip the ladder
Ladders	5	Is a ladder stay or similar device used to avoid placing ladder against fragile support
Ladders	6	Are ladders placed in a safe place away from moving vehicles, overhead cranes or electricity lines
Ladders	7	Do ladders have level and firm footings
Ladders	8	Are ladders at a slope of I out for every 4 up (except vertical ladders)
Ladders	9	Is a suitable rest platform provided in ladder more than 9m in length
Ladders	10	Are ladders stored properly

Category_ID	Question_Number	Question_Text
Manual Handling	1	Are working areas where manual handling is taking place clear of tripping and slipping hazards
Manual Handling	2	Where possible are lifting accessories used to reduce the need for manual handling
Manual Handling	3	Are operatives using good manual handling techniques
Manual Handling	4	Is the working area free from obstructions
Manual Handling	5	Is lighting adequate for manual handling activities
Noise	1	Is noisy plant or machinery fitted with silencers
Noise	2	Are barriers erected to reduce the spread of noise
Noise	3	Are people not involved in the work kept away
Noise	4	Is suitable hearing protection provided and worn by workers in noisy areas
Noise	5	Is work carried out within specified hours to avoid nuisance
Noise	6	Are areas in which noisy operations exist clearly signed
Personal Protective Equipment (PPE)	1	Are operatives wearing PPE e.g. hearing protection, eye protection, hand protection, foot protection etc.
Personal Protective Equipment (PPE)	2	Is the equipment in good condition and worn by all who need it
Personal Protective Equipment (PPE)	3	Is the wearing of PPE properly encouraged - signage, posters
Personal Protective Equipment (PPE)	4	Is high visibility clothing required and worn.
Plant & Machinery	1	Are all dangerous parts guarded, e.g. exposed gears, chain drives, projecting engine shafts
Plant & Machinery	2	Are guards secured and in good repair
Plant & Machinery	3	Are there separate routes for pedestrians and where plant practicable
Plant & Machinery	4	Has plant that requires it got amber rotating lights, reversing siren and are they in use
Plant & Machinery	5	Is the reversing area controlled by a banksman and are non-essential personnel excluded
Plant & Machinery	6	Are blocks and scotches provided when tipping into or running alongside excavations
Plant & Machinery	7	Are loads secure
Plant & Machinery	8	Is plant parked on level ground, in neutral with the parking brake applied
Plant & Machinery	9	Are public roads kept clean
Plant & Machinery	10	Are operatives wearing high visibility clothing around mobile plant
Plant & Machinery	11	Is adequate lighting provided to vehicle routes

Category_ID	Question_Number	Question_Text
Powered Access Equipment	1	Is fixed equipment, e.g. mast climbers, rigidly connected to the structure against which it is operating
Powered Access Equipment	2	Does the working platform have adequate guard rails and toe boards or other barriers to prevent people and materials falling off
Powered Access Equipment	3	Have precautions been taken to prevent people being struck by the moving platform, projections from the building or falling materials, e.g. barrier or fence around the base
Powered Access Equipment	4	Is the power supply isolated and the equipment secured at the end of the working day
Public Protection	1	Are the public adequately protected from the work by fencing or other suitable barriers.
Public Protection	2	Are warning signs displayed to discourage children from site
Public Protection	3	Is delivery of material organised to avoid lifting operations over roads and pavements which are open to the public
Public Protection	4	Is there means of securing the site preventing public areas during the working day and all other times.
Roof Work	1	Are there barriers and other edge protection to stop people or materials falling from roofs e.g. netting
Roof Work	2	Are precautions taken to stop people falling from the leading edge of the roof or from fragile or partially fixed sheets which could give way I.e. harnesses.
Roof Work	3	Are suitable barriers, guard rails or covers, etc provided where people pass or work near fragile material such as asbestos cement sheets and rooflights
Roof Work	4	Are people excluded from the area below the roof work If this is not possible, have additional precautions been taken to stop debris falling onto them
Roof Work	5	Are roofing materials secured to prevent displacement
Roof Work	6	Is protective clothing and safety equipment worn e g safety harnesses
Scaffolding	1	Is there safe access to the scaffold.
Scaffolding	2	Are all uprights provided with base plates (and, where necessary, timber sole boards) or prevented in some other way from slipping or sinking
Scaffolding	3	Are all the uprights, ledgers, braces and struts in position
Scaffolding	4	Are there effective barriers or warning notices in place to stop people using an incomplete scaffold (e.g. where working platforms are not fully boarded)
Scaffolding	5	Are there adequate ties
Scaffolding	6	Are materials, stacked above the toe board prevented from falling I.e. brickguards
Scaffolding	7	Are there adequate guard rails and toe boards or an equivalent standard of protection at every edge from which a person could fall 2 m or more
Scaffolding	8	Is the upper guard rail positioned at a height of at least 910 mm above the work platform
Scaffolding	9	Are intermediate guard rails in place to ensure that there is no unprotected gap of more than 470 mm between the toe board and upper guard rail?
Scaffolding	10	Are structures stable, adequately braced and not overloaded
Scaffolding	11	Are the working platforms fully boarded and are the boards arranged to avoid tipping or tripping
Welfare	1	Have suitable and sufficient numbers of toilets been provided and are they kept clean
Welfare	2	Are there clean wash basins, warm water, soap and towels

Category_ID	Question_Number	Question_Text
Welfare	3	Is suitable clothing provided for those who have to work in wet, dirty or otherwise adverse conditions
Welfare	4	Are there facilities for changing, drying and storing clothes and are they clean and tidy
Welfare	5	Is drinking water provided
Welfare	6	Is there a site hut or other accommodation where workers can sit, make tea and prepare food and is it clean and tidy
Welfare	7	Are there adequate first aid facilities
Welfare	8	Are welfare facilities easily and safely accessible to all who need to use them
Welfare	9	Have arrangement been made to separate smokers from non-smokers

Frequently Asked Questions

Q 1: My battery terminated and the SABRE Icon does not appear on the program menu?

Reinstall SABRE as described in Section 7.1.
Caution: Because iPAC battery uses some power to maintain RAM and the clock, you need to recharge the battery regularly. Keep the IPAC Pocket PC connected to the cradle or the AC adapter while you are at your desk. The best policy is to keep the IPAC connected to your computer when working at your desk and carry you're your AC adapter with you when travelling

Q 2: I know batteries eventually run out or take fewer charges as time goes on. Is there anything I can do to prolong the life of my device's built-in batteries?

To ensure long battery life over time, back up your unit then allow it to completely run down. After the unit is almost fully out of power leave it to charge for 18-24 hours. This will help your battery life remain near new levels for a much longer periods of time.

Q 3: Downloading isn't working?

Is the serial or USB cable connected to the handheld and PC/laptop and is ActiveSync running and a connection established (see Section 7.1 and Section 9.5)

Q 4: I have downloaded my assessments but the database does not show them in drop down menu

Have you recently lost SABRE due to battery failure and reinstalled, if so see Section 7.1 to reinstall SABRE
Use one database per handheld

Q 5: Where is the Compaq iPAC Pocket PC manual?

The manual is included on the CD in Adobe Acrobat format. If you have Adobe Acrobat reader installed on your computer then just open the file by double clicking the following file: D:\Manual\CP Navman_UK.pdf (where D is the drive letter of your CD-ROM drive).
If you do not have the Adobe Acrobat reader installed on your computer, then you will need to download the free reader from the website, which you can find inside the CD

Q 6: Can I use SABRE Software on different type of handheld?

You can use SABRE on any handheld which operate by Pocket PC, but you can not use in different operating system like palm or others, because the software is on VBA. But Hewlett-Packard Jornada, and Casio EM-5—Blue.

Q 7: Which processors (ARM, SH3, MIPS) are on which devices?

a. ARM
   Cassio E-200, all Compaq iPAQ 3600, 3700, and 3800 series, HP Jornada 560, 700, and 800 Series
b. SH3
   Cassio A10/A11, A20 series, Compaq Companion, HP Jornada 430, 520, 540, 680, and 690 Series
c. MIPS
   Cassio E-100, E-115, E-125, E-500, Compaq Aero devices, HP Jornada 560, 700, and 800 Series

Q 8: How can I adjust the volume of my reminders, program sounds, etc?

d. Open the "Start Menu"
e. Tap on "Settings"
f. Tap on "Sounds & Reminders"
g. Adjust appropriately.

Q 9: I have a lot of documents I need to store on my device. Is there anyway to squeeze more memory space out of my device?

If all you really need is plain text, then save your Word document as a plain text document. You'll save several hundred bytes even on a very small file!

Q 10: Any other ways to conserve memory space?
Use solid colour or no backgrounds to free up about 20k of RAM.
Adjust the RAM by right clicking on My Computer. Click on the memory tab then moves the slider bar to the left for more program memory, and to the right for more storage memory.

Q 11: Where can I find the close button or an exit menu option on my Pocket PC applications?

Well, there aren't any. The Pocket PC operating system does a good job of automatically closing down applications, so you can just keep starting the ones you need. If you really want to shut them down however, there is a neat trick - bring up the pop-up keyboard panel and type "CTRL" and "Q". This will cause most programs to quit. Alternatively, use one of the many utilities programs available. (If you have an iPAQ, the Q utility program provided has a "Close All Apps" option.)

Q 12: My Start Menu suddenly moved to the centre of the screen?

What's the deal? Don't worry, this happens when you have added (or installed) more than eight programs to the menu, and is done on purpose so the scroll buttons don't obscure details on the screen. To move it back to the left, you can remove programs from the menu by tapping Start, Settings, and Menus. Then deselect the ones you don't need.

Q 13: I use my Pocket PC device to compose reports while on the road. I'd really like to use symbols like I do in Microsoft Word, like I do on my laptop. Is there a way to add symbols to Pocket Word?

All you need to do is copy the Symbols True Type font file (symbol.ttf) from your desktop PC (\windows\fonts) to the "Font" directory on your device. The symbols should be available as one of the selectable fonts.

Q 14: Looking for a quick way to switch the backlight on and off of your iPAQ?

Simply press and hold the power button, and the backlight will toggle. If you find that you are accidentally pressing the voice-recorder button while the device is in your pocket or bag, use Start/Settings/Buttons control panel to re-assign the function to something more harmless, such as displaying the Today screen.

Download ActiveSync 3.1

Thank you for registering. Please choose the version of ActiveSync 3.1 you would like to download below.

Please review the System Requirements before downloading.

If you are running Internet Explorer 4.0 or later

1. Download the ActiveSync setup software (3.3 MB) to your PC (choose language below).
2. Select **Run this program from its current location** and click **OK**.
3. Follow the instructions on the screen.

Download Now

All other browsers

1. Download the ActiveSync setup software (3.9 MB) to your PC (choose language below).
2. Select **Save this program to disk** and click **OK**.
3. Store the ActiveSync download file to a new empty folder, creating the new folder and opening it as necessary. Remember the location of the new folder. Click **Save**.
4. Go to the location where you saved the ActiveSync download file on your computer and double-click the file to unpack all the ActiveSync setup files.
5. Double-click the **Setup.exe** file and follow the instructions on the screen.

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THE USE OF PROJECT MANAGEMENT TECHNIQUES IN THE IMPLEMENTATION OF SAFETY AND HEALTH STANDARDS IN CONSTRUCTION PROJECTS

Murray, Malcolm School of Construction Economics and Management, University of the Witwatersrand, South Africa

Introduction

The construction industry continues to be the industry in the majority of countries with the highest indices of accidents leading to deaths and temporary or permanent disabilities. Governments in developed countries attempt to address this by implementing legislation which punishes infracting companies or persons, by the application of fines (New Civil Engineer International 2000a) and even prison sentences (Engineering News Record 2001a). A complementary approach is to exhort the construction industry to improve its safety record (Engineering News Record, 2001b).

In developing countries, appropriate legislation quite often exists but it is often not applied in the case of infraction of laws, probably because construction workers are often migrant, low-paid, are not afforded union-protection and are held in low esteem by the society in which they live. Another factor which influences attitudes to safety and health is cost: a worker from a developing country who earns US$100 an hour and who dies in an accident at age 25 would be assessed for future loss of future earnings of US$80.000, a US worker at least 20 times that amount.

At the same time, in the corporate world, in the author's experience issues of safety and health are rarely really seriously addressed by owners, engineers and contractors during the construction planning and execution processes. The general approach seems to be top-down where head-office inspectors visit and monitor sites or provide guidelines. Two examples of this are the approaches taken by AMEC (AMEC, 2000) and Skanska (Särkilahti, 2001). A more suitable approach would be the bottom-up one where construction site managers automatically implement safety and health planning in their day-to-day activities. For this to happen, these areas would probably need to receive additional exposure in undergraduate construction management courses.
In the following the construction planning processes will be examined and the application of the Project Management Body of Knowledge (PMBOK) processes and areas of knowledge, suitably adapted to include issues of safety, health and environment and social issues, will be described. The application of PMBOK processes would include applying risk management techniques to the analysis of safety and health and to do this it would be necessary to develop registers of indicators which would alert management to the need for risk analysis. A project Plan of Action or Business Plan including the above processes would assist Safety and Health officials and others in evaluating a contractor's approach to safety and health matters.

The Construction Planning Process

Call for tenders

Once an owner has decided to go ahead with a construction project, after carrying out feasibility studies, he instructs his representative to prepare tender documents. These, among other things, may include specifications which give guidance to the tendering contractors on the quality of the finished product expected from the contractor eventually chosen to carry out the project. Sometimes the Bill of Quantities includes items to be priced dealing with environment or health and safety matters: the contractor may be required to establish on site a first-aid station, for example. In some countries, local legislation may require that sites employing more than 200 workers would require a medical doctor and a safety engineer in attendance; in the author's experience rarely does the tender documentation emphasise the need to comply with this type of legislation or indeed, safety and health issues in general; if they are mentioned it is in a token fashion.

Tender preparation

During the tender preparation process contractors usually focus on planning and scheduling (or programming) to achieve a competitive price, given that contract awards are still frequently based on lowest-price criteria. The contractor will usually examine the specifications with care to ensure that his tender includes sufficient money to produce a product to the required quality. Sums will be included in the preliminary and general sections of the budget to cover such safety and health requirements as a first aid station and safety equipment for the workers.

Construction planning

On award of the contract the tender plan is usually detailed and developed into a construction plan, or Programme of Action, which is used as a guide during actual construction.

The Project Management Body of Knowledge (PMBOK), which has been progressively developed since the 1970's, includes the basic planning processes described above but has also developed complementary processes which will be described in the next section.

The PMBOK Processes and Knowledge Areas

Processes

The 2000 edition of the Project Management Body of Knowledge (PMBOK, 2000) describes the five groups of processes which are followed during the carrying out of a project; these comprise the initiation, planning, execution, control and closing process groups. Figure 1 provides an indication of the groups and of the linkages between them.

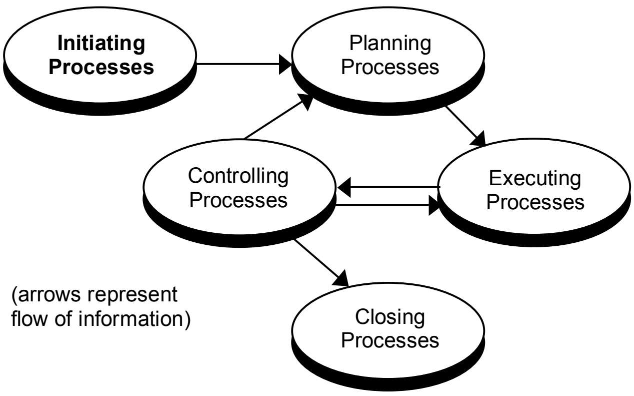

Figure 1 Process Groups and their links
Source: PMBOK 2000

These processes would be followed during each phase of a number of phases of which a project could consist.

Areas of knowledge

The carrying out of the processes involves the application of so-called areas of knowledge which comprise the management of project: integration, scope, time, cost, quality, human resources, procurement, communications and risk. The areas of knowledge are given equal weighting by PMBOK, as it has been developed as a guide and is not industry-specific. In the author's experience, however, in the construction industry the following priority ranking is often given to the management of the areas, as mentioned earlier:

1. scope, time and cost
2. procurement
3. human resources
4. quality
5. integration and communication
6. risk

The reason for this is probably because construction managers mainly have an engineering background and are more concerned with numerical, measurable issues than with human-related matters. It will not escape notice that, with the exception of risk management, the above listing shows a gradation of priority from 'hard' to 'soft' management topics.

In PMBOK 2000, compliance with health and safety regulations is listed under project human resources management, together with other topics concerned with dealing with people. This area comprises the following major processes: organisational planning, staff acquisition and team development. Project Quality Management, however, is considered to be an area of knowledge in its own right, consisting of quality planning, assurance and control. Similarly, project risk management is also considered to be another knowledge area and consists of the following major processes: risk management planning, risk identification, qualitative analysis, quantitative analysis, response planning and monitoring and control.

Generic framework

Finally, it should be remembered that the Project Management Body of Knowledge is only a guide, or generic framework, which can and should be adapted for use in a variety of project scenarios, which include the development of products such as software, of the implementation of information and communication technology (ICT) in industry, and the carrying out of projects in the aerospace, aeronautical and construction industries. Evidently the application of PMBOK should be tailored to meet the particular needs and peculiarities of each industry. Its application in the construction industry will be discussed in the next section.

Application of PMBOK to the International Construction Industry

International construction industry

As is known the construction industry differs from other industries in a number of ways, although it does share the characteristic of being project-based with an increasing number of areas of industry and commerce.

The larger companies of the construction industry work internationally and may work in an ever-changing number of countries which are often of the type characterised as 'developing', possessing diverse cultures, populations with different levels of education and safety and health legislation of varying quality. (Murray and Zagaretos 2001)

The traditional way of carrying out business in a developing countries was for the contractor to mobilise, carry out the contract and, unless they obtained further work, to demobilise. Responsible contractors complied with local legislation but there was no overwhelming pressure for them to do so.

However, society now increasingly expects that businesses act in an ethical manner towards their shareholders and towards the society in which they operate. This means that contractors, whether they are operating in their home country or abroad, can and should be expected to manage environmental and social issues in a responsible manner. The social issues, of course, include the management of the safety and health of their workforce. Environmental issues include the responsible management of the contractor's operations to prevent pollution of water, ground and air in the region in which they are working, as well as to ensure the protection of flora and fauna.

Finally, it is expected that the contractor interacts with local communities in such a way that they benefit from the presence of the intruders (by being given, for example, employment preference and training) and are not adversely affected by the presence of the contractor, culturally or socially. An example of this negative impact would be the spread of HIV/Aids by migrant workers.

An example of how companies working internationally are being held to their social responsibilities is the ruling handed down by the House of Lords in July 2000 holding that a group of South African asbestosis and mesothelioma sufferers could sue Cape plc, a British company which had previously worked in South Africa through a subsidiary, in England, for compensation as a result of exposure to asbestos and related products arising from Cape plc's earlier operations in South Africa. (Stein 2001)

Companies will also be held to their safety responsibilities and their financial consequences (New Civil Engineer International 2000b).

It is becoming increasingly clear that, as globalisation develops, construction companies will be obliged to carry out their business following first-world criteria, independently of whichever part of the developing world they are working.

Extension of Areas of Knowledge

It would therefore make sense to have the areas of knowledge of the PMBOK, when applied to the construction industry, extended to include items dealing with the issues described above. A revised list of knowledge items would consists of the management, throughout the duration of the project, of:

- integration
- scope of work
- time i.e. planning and scheduling (or programming)
- costs and budgets
- quality
- human resources
- procurement
- safety
- health
- community impacts
- environmental impacts
- risk
- communication

Table 1 shows the mapping of the project management processes to the process groups and knowledge areas, adapted for use by international contractors. The added areas of knowledge are shaded.

Process Groups / Knowledge Area	Initiating	Planning	Executing	Controlling	Closing
Project Integration Management		Project Plan Development	Project Plan Execution	Integrated Change Control	
Project Scope Management	Initiation	Scope Planning Scope Definition		Scope Verification Scope Change Control	
Project Time Management		Activity Definition Activity Sequencing Activity Duration Estimating Schedule Development		Schedule Control	
Project Cost Management		Resource Planning Cost Estimating Cost Budgeting		Cost Control	
Project Quality Management		Quality Planning	Quality Assurance	Quality Control	
Project Human Resource Management		Organisational Planning Staff Acquisition	Team Development		
Project Procurement Management		Procurement Planning Solicitation Planning	Solicitation Source Selection Contract Administration		Contract Closure
Project Safety Management		Safety Management Planning Safety Risk Identification Safety Risk Response	Safety Plan Execution	Safety Risk Monitoring and Control	
Project Health Management		Health Management Planning Health Risk Identification Health Risk Response	Health Plan Execution	Health Risk Monitoring and Control	
Project Community Management		Community Management Planning Community Impact Identification Community Impact Response	Community Management Plan Execution	Community Impact Monitoring and Control	
Project Environment Management		Environment Management Planning Environment Impact Identification Environment Impact Response	Environment Management Plan Execution	Environment Impact Monitoring and Control	
Project Risk Management		Risk Management Planning Risk Identification Qualitative Risk Analysis Quantitative Risk Analysis Risk Response Planning		Risk Monitoring and Control	
Project Communications Management		Communication Planning	Information Distribution	Performance Reporting	Administrative Closure

Table 1 Mapping of Project Management processes to the Process Groups and Knowledge Areas, revised for use by international construction contractors.
Source: Adapted from PMBOK 2000

The management of the environment and community issues would be carried out by using techniques similar to those used for Environmental Impact Assessments which involve identification of impacts and their subsequent mitigation and control.

Similarly, safety and health issues would be managed by identifying the areas of risk, planning for risk mitigation and then controlling operations to make sure that the safety and health plans are executed correctly. Areas of risk would be identified by examining safety and health indicators which are discussed in the next section.

Safety and Health Indicators

It is well known that there are areas of operation where safety risks or health risks can be inherently high. In the area of safety, for example, trenching or the use of tower cranes should immediately lead to preventative safety planning and operation monitoring to guarantee that accidents do not happen. These mitigative activities should include, in the case of tower cranes, examination of erection procedures, operations procedures, training of operators and signallers and monitoring of operations by a qualified and experienced construction engineer (who may not necessarily be the safety engineer).

In the health management area, winning of a contract in sub-Saharan Africa would immediately alert the responsible contractor to the need to plan for, monitor and control HIV/Aids, TB and malarial infections (Murray and Appiah-Baiden, 2002).

Using published information, lists of safety and health indicators can be drawn up. In the case of safety, operations or activities would be classified on a scale of 1 to 5, one indicating a fairly safe operation, five a dangerous operation. In the case of health, countries or regions of countries would be classified using a similar scale, the level of health danger would be indicated, and the source of that danger identified. Operations of danger to health would be similarly classified. For example, the existence, or possible existence, of asbestos in a building being renovated would merit an indicator of 5.

Engineering News Record has published the top ten causes of deaths in the US construction industry in 1999 (Engineering News Record 2001c). Table 2 lists the causes; in 1999 23,8% are fall-related and 15,3% are due to being run-over by equipment or a vehicle.

	INCIDENT TYPE	**1991-98 [% of total]**	**1999 [% of total]**
1	Fall from/through roof	11.2	10.6
2	Non-operator run over by equipment	7.8	9.2
3	Fall from structure	7.6	8.1
4	Run over by highway vehicle	3.8	6.1
5	Operator crushed by equipment	5.2	5.8
6	Lifting operation accident	5.4	5.4
7	Equipment contacts power source	8.4	5.2
8	Fall from scaffold	2.9	5.1
9	Collapse of structure	4.3	5.0
10	Shock from equipment/tools	4.1	4.7

Table 2 Top 10 causes of death in1999
Source: ENR/OSHA

Table 3, from the same source, lists numbers of construction fatalities, again in the USA. In 2000 58 % of fatal accidents happened to people working for speciality trades contractors, which tend to be smaller organisations.

	1995-1999 Average	**1999**	**2000**	**2000 %**
Total Construction Fatalities	1,115	1,191	1,154	100
General Building Contractors	190	183	175	15
Heavy Contractors	260	280	284	25
Speciality Trades Contractors	652	710	672	58
Unidentified	13	18	23	2

Table 3 Construction fatalities
Source: ENR/U.S. Dept. of Labour, Bureau of Labour Statistics

Transport engineers use a similar technique of using safety indicators; one system is to assign a danger index to accident black-spots which is based on the number of crashes resulting in claims by insurance company policy-holders (Engineering News Record 2001d).

Following the identification of, and the indication of, the level of safety and health risks, a risk evaluation exercise would be carried out where monetary values would be assigned to the costs and benefits of not complying, or complying, with risk mitigation activities. Chapter 11 of PMBOK 2000 deals with risk management in general and outlines suitable procedures to follow.

Conclusions and Recommendations

Given the continuing high rate of accidents in the construction industry and the high risk of workers contracting ailments and diseases, especially in developing countries, it is recommended that safety and health management should be accorded the same level of importance as given to the more usually considered areas of time and cost management. Indicators can be developed to alert construction managers to the existence of dangerous or unhealthy operations on a contract-by-contract basis. Risk management procedures could then be applied to the identified risky operations or unhealthy operations. A similar approach could be taken to the management of the social impact and environmental impact of construction operations on an existing society or environment. All of the above would be included in the contracts' Plan of Action or Business Plan. The presence, or otherwise, of a competent Business Plan, developed at contract level, would help Health and Safety inspectors and others in evaluating the degree of attention and care given by site management to safety, health and other issues.

Further research could be carried out in developing safety and health indicators which classify unsafe construction activities and unhealthy operations in developed and developing countries respectively.

References

AMEC, 2000, www.amec.com: Safety, Health and Environment.

Engineering News Record, 2001a, Contractors face criminal charges in workers' deaths. *Engineering News Record*, USA, August 27, 2001. p. 7.

Engineering News Record, 2001b, Summit tackles work zone safety. *Engineering News Record*, USA, July 23 2001, p. 10.

Engineering News Record, 2001c, Construction leads in deaths despite lower fatality rate. *Engineering News Record*, USA, August 27, 2001. p. 12.

Engineering News Record, 2001d, State Farm (insurance company) pinpoints nation's most dangerous intersections. *Engineering News Record*, USA, July 9, 2001. p. 20.

Murray, M., 2001, The influence of cultural differences on the performance of international contractors. *Proceeding of the Seventeenth Annual Conference of ARCOM, Association of Researchers in Construction Management* (University of Salford, UK), Vol.1, pp. 101–110.

Murray. M, and Appiah-Baiden. J, 2002, The influence of the HIV/Aids pandemic on the construction industry in sub-Saharan Africa. *CIB W65 Symposium on Construction Innovation and Global Competitiveness*, USA, September 2002 (paper submitted).

New Civil Engineer International, 2000a, Heathrow Express report slates poor risk management. *New Civil Engineer International*, London, August 2000. p. 5.

New Civil Engineer International, 2000b, Construction backs calls for EU-wide fine enforcement. New Civil Engineer International, London, March 2000. p. 5.

PMBOK 2000, A Guide to the Project Management Body of Knowledge, 2000 ed., (Project Management Institute, USA).

Särkilahti, 2001, Skanska OY's Integrated Management System. *Proceedings of the International Conference on Costs and Benefits Related to Quality and Safety and Health in Construction*, Barcelona, Spain, 2001-12-01.

Stein, R., 2001, Cape plc to cough up and pay. *M.Sc Environmental Law Course, Part B*. University of the Witwatersrand, South Africa.

INDOOR AIR QUALITY PROBLEMS IN BUILDINGS IN THE UNITED STATES

O'Neal-Coble, Leslie Holland & Knight LLP, Orlando, Florida, U.S.A.

Introduction

In recent years indoor air quality (IAQ) problems leading to the so-called "sick building syndrome" have fed considerable litigation. Personal injury claims, which utilize remedies under insurance disability and workers' compensation laws, or the Occupational Safety and Hazard Act, as well as property damage, constructive eviction, and design and construction defect claims may relate to IAQ problems.

The World Health Organization estimates that nearly thirty per cent of all new and remodeled buildings worldwide may be afflicted with indoor air quality problems.[i] This and studies performed by the U.S. Environmental Protection Agency rank IAQ concerns among the top environmental risks to public health.[ii] Not surprisingly, commentators expect IAQ litigation to proliferate.[iii] Perhaps eight per cent of commercial buildings in the U.S. fall short of compliance with engineering standards for acceptable indoor air according to the National Energy Management Institute.[iv]

This paper will generally outline the various types of IAQ problems related to buildings, and address some of the practical and legal problems stemming from IAQ issues.

Sources of IAQ problems

The two primary sources of IAQ-related problems are biological contamination and chemical contamination. Biological contamination can result from microbial bacterial or fungal growth or both, on building materials, carpets, furniture and the like or contaminated central air handling systems, for example, and is usually caused by persistent excessive moisture. In the context of building construction, excess moisture may result from one or more of the following: improper drying in during construction; improper design, construction or maintenance of the building envelope or improper design, construction or maintenance of the heating, ventilation and air conditioning (HVAC) system, poor material selection, or construction mistakes.[v]

Chemical contamination may result from releases of organic compounds fumes or gases emitted from plastics, fibers, coatings, or chemicals used in building components or furnishings, office operations or building cleaning. Volatile organic compounds (VOCs) have been identified as possible sources of indoor air quality problems. New buildings typically have higher concentrations of VOCs because of releases from construction materials, building elements, and new furnishings; however, VOCs can also be emitted by bacteria or fungi.[vi]

Buildings may have both biological and chemical contamination. IAQ problems often have multiple causes, which make their diagnosis and solutions more difficult.

Consequences of IAQ Problems

Either type of contamination may trigger occupant complaints of health effects. Symptoms of IAQ-related complaints include breathlessness, dry cough, bronchial asthma, chest tightness, rashes, itching, eye irritation, drowsiness, dizziness, to more serious effects such as Legionnaire's disease or cancer.[vii]

One study indicated that as many as twenty percent of all office buildings in the United States had IAQ problems or were "sick."[viii] Indoor air quality problems have become one of the principal environmental problems in the United States in this decade.

The increased public awareness and concern with IAQ issues has resulted in building occupants demanding compensation for adverse health effects and "building teams" pointing fingers over economic damages. Most IAQ lawsuits contain accusations of a sick building injury by occupants. Building owners, faced with costly solutions to these problems, also make claims against all who had anything to do with the design, construction, or maintenance of the building, using a variety of legal theories. Owners, landlords, tenants, designers, and contractor, should understand the legal aspects of these claims.

Medical Aspects of Indoor Air Quality

Although full coverage of the medical aspects of indoor air quality is beyond the scope of this presentation, certain medical issues are important for the legal practitioner. Over the last ten years there has been an increase in lawsuits over indoor air quality. Several of these suits have resulted in multimillion dollar verdicts for remediation, reconstruction, and relocation costs.[ix] The issues causing these verdicts are the risks to health caused by the presence of contaminants in indoor air. Those individuals affected by these contaminants may be workers who are present in the building during their work day or they may be temporary occupants. One aspect of indoor air quality problems is that the symptoms tend to occur when the person is in the building yet moderate or disappear after the person leaves the building. Another problem is the difficulty with establishing the cause of the symptoms. Some of the contaminants affecting indoor air quality are: mold, environmental tobacco smoke, volatile organic compounds (VOCs), dust, dust mites, bacteria, and just about any matter than can affect human comfort or health.[x]

Two common terms used in discussing indoor air quality include "sick building syndrome" which generally means a broad range of symptoms which have no identifiable cause, and "building related illness" which means that a unique set of symptoms have been linked to an identifiable cause.[xi] Some of the health effects that may be linked to exposure to indoor air chemical, biological, and physical agents are listed in the following table:

Allergic bronchopulmonary mycosis (ABPM)	Infection
Allergic bronchopulmonary aspergillosis (ABPA)	Infectious disease
Allergy	Influenza
Asthma	Inhalation fever
Bronchitis	Legionnaires' disease
Building-related illness (BRI)	Opportunistic fungal infection
Building-related symptom (BRS)	Organic dust toxic syndrome (ODTS)
Common cold	Pneumonia
Conjunctivitis	Pontiac fever
Cryptococcosis	Primary amebic meningoencephalitis (PAM)
Dermatitis	Rhinitis (coryza)
Granulomatous amebic encephalitis (GAF)	Sick building syndrome
Hantavirus pulmonary syndrome (HPS)	Sinusitis
Histoplasmosis	Sore throat
Humidifier fever	Toxic effect
Hypersensitivity disease (allergy)	Tuberculosis (TB)
Hypersensitivity pneumonitis (HP) (extrinsic allergic alveolitis)	

[xii]

Source ACGIH, Bioaerosols, Assessment and Control (1999)

Although the link between a particular illness and the indoor air contaminant may be clear in some cases, (i.e. Legionnaires disease is clearly caused by a bacteria, Legionella pneumophila); in many cases neither science or the medical profession has established a definitive link between the contaminant and the disease.[xiii] Despite this lack of a direct causal link to disease, the risk of such a link is so great that it cannot be ignored and may not be necessary to establish liability.

One additional risk factor with indoor air quality is that of psychogenic effects of indoor air contaminants. Once an individual complains about health concerns due to indoor air, other occupants may begin to experience similar symptom or believe they are suffering similar symptoms. This reaction has several names, the most common is "Mass Psychogenic Illness." The symptoms may exist but have no physical sign nor laboratory findings of disease.[xiv]

Regardless of the source of the complaints, building owners/managers, contractors, subcontractors and designers should not ignore them. Complaints related to hot/cold temperatures, excess humidity, unusual odors (chemical or musty) or health complaints of headaches, sinus problems, lethargy, shortness of breath, and similar types of health issues must be taken seriously. There may be a pattern to these complaints that indicate a problem with indoor air quality. If a pattern is shown or the complaints exceed a minimum number, the building owner/operator should hire qualified experts to investigate. The options for investigation will depend on the nature and severity of the symptoms. They may range from isolating the specific area to a large scale epidemiological survey and evacuation of the building. Indoor air quality problems can be extremely difficult to pinpoint due to the multiple factors involved. For example, if the evidence indicates that mold is the potential source of the symptoms there are a number of ways to test for and remediate the mold with conflicting theories on the best method.[xv] The remedy will depend on the type of mold present and the extent of contamination.[xvi] This remediation may range from cleaning a limited area with bleach to fullscale containment with decontamination suits, similar to that involved in asbestos abatement.[xvii] There are only limited standards available for the removal of mold contaminated building materials, with the City of New York Health Department and ACGIH being the most recent to provide such standards.

One critical aspect of investigating indoor air quality problems is to keep the building occupants informed of the status and results of the investigation. In fact, if the contaminants are toxigenic fungi, occupants may have to be informed under the Hazardous Communication Standard.[xviii]

Theories of Liability in IAQ Cases

Design and construction claims

When confronted with a "sick building" most owners look to the original designer and constructor to recover the cost of repair on the basis that the owner did not contract for a "sick building," the owner did not cause the problems, and the owner should not be required to finance correcting the problems.

There are numerous legal theories available to building owners in pursuing such claims: breach of contract; breach of express warranty; breach of implied (both common law and statutory) warranty; breach of warranty of fitness for a particular purpose; common law indemnity; negligence; and strict liability. Each of these theories has certain benefits and limitations, which are generally discussed below.

Contract claims

Breach of contract claims require proof of a written or an oral contract, failure to perform some aspect of the contract, and damages resulting from the failure to perform, subject to any contractual damage limitations. Since owners usually have contracts with the architect and with the general contractor or construction manager they typically make breach of contract claims against those parties for IAQ-related problems.

Contract theories, obviously, are limited to defendants with contractual relationships. This may reduce the number of possible defendants and the possible sources of funds to pay settlements or judgments. The lack of contractual privity may be overcome by direct beneficiary or third party beneficiary arguments.[xix] Additional limitations in some contracts are notice requirements for claims and some contracts expressly limit the recoverable damages.

If the general contractor provided a performance bond, the owner may be able to make a bond claim in addition to the construction contract claim. However, if the IAQ problems do not arise until after the building is completed, there is a split of authority as to whether such latent defects are covered under the surety bond.[xx]

As with warranty claims, an owner considering a surety bond claim should carefully review the bond for notice requirements and should comply with such requirements as soon as possible.

Warranty claims

Many construction contracts contain express warranties for the overall building. Subcontractors and manufacturers often warrant specific building components as well. These warranties may provide additional bases for owners' claims. However, warranties may be so limited both in scope and in time as to have little value. Owners considering claims on written warranties should carefully review them for notice provisions and time limits. Notice letters should be sent as soon as possible.

Many states have created implied warranties of fitness for residential construction. Although such implied warranties have generally not been applied to commercial construction, some courts have questioned why there should be such a distinction in the legal remedies available to purchasers of different types of property.[xxi] Perhaps commercial owners will be able to make such claims in the future; at present, their viability is questionable.

Negligence claims

Negligence claims require proof of four elements: (1) defendant owed plaintiff a duty to act in some way; (2) defendant did not perform its duty; (3) defendant's failure to perform its duty caused plaintiff to suffer some injury; (4) the injury resulted in the plaintiff suffering a loss.

Claimants may be able to recover greater damages under a negligence theory than under a contract theory. Until recently, it was common to find both theories pursued in the same case. In the past few years, the "economic loss rule" has been used to defeat negligence claims for purely economic damages (that is, damages other than for personal injuries and property damage). The economic loss rule may prevent recovery on a negligence theory where the damage is to the "product" itself.[xxii] Some courts have held that a building is a single product, so the owner could not recover for damages to one building component caused by another building component.[xxiii] In this analysis, one court has stated that, "one must look to the product purchased by the plaintiff, not the product sold by the defendant."[xxiv]

Application of the economic loss rule may prevent an owner from pursuing claims from a responsible third party manufacturer, supplier, or subcontractor to recover the cost to remediate and reconstruct the building.

Some jurisdictions have allowed plaintiffs to bring actions based on negligence for indoor pollution claims, finding asbestos contamination sufficient to invoke the property damage exception to the economic loss rule.[xxv] However, this rule remains a significant bar to negligence claims in these cases.

Strict liability

Strict liability theory holds a defendant strictly liable for a defective product without proof of negligence, without an intent to guarantee, without privity of contract, and without consideration of contractual liability disclaimers.[xxvi] This theory is widely used in products liability cases. The policy considerations underlying such cases are that a seller who places unreasonably dangerous products in the stream of commerce should be liable for physical harm its products cause. Applying these policy considerations to buildings is difficult because buildings are not usually thought of as products. The courts which have held that a building may be a "product" for strict liability purposes have considered mobile homes or mass produced homes, not occasional sales of homes.[xxvii] Some courts have found that portions of structures, such as defective precast panels or facing tiles, may be considered products.[xxviii] A Georgia court declined to apply the doctrine of strict liability to an owner's claim against a homebuilder because the builder was not involved in the manufacture of personal property.[xxix]

Courts have reached differing conclusions regarding whether strict liability can apply to economic losses alone, without physical injury.[xxx] Some courts have held where there is a risk or death or personal injury, tort remedies are available.[xxxi]

Strict liability theory may not apply to architects and engineers unless it can be shown that the design or the system was standardized or mass marketed.[xxxii]

Other theories

Some plaintiffs have argued that health effects caused by a sick building caused or contributed to their "disability" under the Americans With Disabilities Act.[xxxiii] A federal court in Colorado reversed an insurance company's denial of long-term disability benefits. In this case of a sick building injury, the plaintiff relied on insurance and disability law for a remedy. The plaintiff used a federal statute, ERISA, to enforce her rights under the terms of a long-term disability insurance plan.[xxxiv] Additionally, as workers compensation laws are broadened, IAQ litigation could include more worker compensation claims.

Damages

As noted elsewhere in this paper, anyone involved with the ownership, management, construction, design, or maintenance of a building may become involved in a lawsuit over indoor air quality. Depending on the degree and source of the indoor air quality problem, the damages can range from minor cleanup costs to total evacuation and reconstruction of the buildings. The damages may not be directly linked to a disease. For example, in establishing damages for remediation of a building due to the presence of toxigenic mold, it may not be necessary to prove that the mold caused the health effects, rather it may only be necessary to prove that it was reasonable to incur the remediation, relocation, and reconstruction costs.[xxxv]

Reasonable remediation damages can range widely from the mere costs of the bleach for a simple mold problem, or the cost of a ventilation fan if the problems are due to volatile organic compounds, or million dollar containment costs. The issue will be whether the cost of the remediation is reasonably necessary. If the building has to be evacuated (either partially or totally), the cost of temporary facilities, moving costs, and related damages may also be recovered. Plus, the costs to reconstruct the building may be recoverable. The actual cost incurred in reconstructing the building may be reduced to the present value at the time of the original construction, if the damages are assessed several years after original construction. In addition, if upgrades are required due changes in the law, i.e. installation of handicapped facilities that were not required in the original construction, these costs may also be recoverable.

Collection Problems in Indoor Air Quality Cases

Having a viable legal theory is only one step in recovering costs related to repairing or remediating an IAQ problem. Finding sources of funds to pay judgments or settlements can be a challenge for all parties. As IAQ claims increase, the insurance industry seeks cost containment through provisions such as pollution exclusion clauses.

Design professional insurance

Assuming that the design professional has insurance, the question remains the amount and extent of the coverage. Surprisingly, design professionals on large projects frequently have relatively low coverage limits, sometimes $1 million or less. In addition, many owners are unhappy to find that the insurance policy is written so that the cost of litigating the dispute reduces the amount of coverage. This is called a declining balance policy. With this type of policy, it is possible that there will be little or no insurance left after a trial or an appeal.

In addition, to limit their exposure some insurers include pollution exclusion clauses in their policies, such as the following:

It is hereby understood and agreed that such insurance as is afforded by this policy does not apply to any claim based upon, arising out of or in any way involving the discharge, dispersal, release or escape of smoke, vapors, soot, fumes, acids, alkalis, toxic chemicals, liquids or gases, waste materials or other irritants, contaminants or pollutants.

Pollution exclusion clauses exclude from coverage emissions that may be the cause of IAQ problems. Since the mid-1980s, insurers have attempted to avoid the costs of environmental pollution by the use of pollution exclusion clauses, and have placed IAQ claims under the same exclusionary blanket as "traditional" environmental pollution sources in order to avoid payment on these claims. Court decisions are mixed as to whether insurance companies can use these clauses to refuse coverage of IAQ-related claims.[xxxvi]

Another concern with design professional's liability insurance is whether the policy is a "claims made" or an "occurrence" policy. "Claims made" policies cover only those claims made during the policy period, regardless of when they arose. "Occurrence" policies cover claims which arose during the policy period, regardless of when they are made. It is not uncommon for owners to require design professionals to have errors and omissions coverage during a project, only to find that the coverage has been dropped by the time the claim arises, leaving the owner with no "deep pocket."

Contractor's commercial general liability insurance

Commercial general liability insurance generally does not cover the cost to repair or to replace defective work or the material itself, but covers consequential damages arising from defective work. Consequential damages may include loss of use of the building, damages to furniture and fixtures and even the cost to repair other portions of the work. General contractor's CGL policies may cover defective work performed by subcontractors, but not work the general contractor performed itself.

The owner, the general contractor and the subcontractors should carefully examine the CGL policy and its exclusions. From the owner's standpoint, the CGL insurance may be a good source for paying a settlement or a judgment. From the general contractor's and subcontractor's standpoint, the CGL carrier may help pay costs to defend a lawsuit.

Personal Injury Claims

Duty to abate

The owner, the contractor and the designers may share in the duty to abate known hazards. If the indoor air quality problem is of such magnitude that there is a health threat or risk of physical harm to the occupants, the owner or employer may have no other choice than to abate the hazard.

There are a number of cases finding a duty to abate in situations involving toxic chemical spills[xxxvii], formaldehyde foam insulation [xxxviii], and asbestos[xxxix], so it is not unlikely a court could reach a similar finding in an indoor air quality case.

Theories of liability in personal injury claims

Personal injury claimants generally use negligence or strict liability theories for their claims. The economic loss rule does not apply to personal injury claims.

The most difficult hurdle in personal injury suits is proving causation. The plaintiff must show that contaminants in the building caused his or her symptoms. "Scientific cause and effect relationships are generally hard to prove and precise diagnosis of certain diseases is possible only with an autopsy."[xl] It is difficult to discover which of many possible agents caused illness and to identify the precise cause of that agent. "Proving causation becomes particularly difficult because a sick building may contain a multiplicity of suspect contaminant. Accordingly, individual contaminants might not be conclusively or exclusively linked to the alleged harm."[xli] Also, occupational diseases may take a long time to arise, making it difficult to determine at what point the worker contracted the disease.

Despite these difficulties, some plaintiffs have been successful in obtaining large verdicts for IAQ-related injuries. In the “Waterside Mall” case, five plaintiffs were awarded just under $1 million for injuries allegedly caused by exposure to various airborne toxins.

Conclusion

Indoor air quality problems present substantial risk to building owners, design professionals, contractors, subcontractors, and their insurers. When faced with such claims, the parties are better served by focusing on the solution rather than on affixing blame. Because litigating these cases is extremely expensive, parties should look for creative alternative dispute mechanisms to try to resolve the case if possible.

Endnotes

Sources:

Godish, Thad: Sick Buildings, Definition, Diagnosis and Mitigation. (1995).

ACGIH, Bioaerosols, Assessment and Control (1999).

SMACNA (Sheet Metal and Air Conditioning Contractors National Association, Inc.), Indoor Air Quality, Second Edition (1993).

United States Environmental Protection Agency, Building Air Quality (1991)ORL1 #709997 v1.

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[i] U.S. Environmental Protection Agency, Air & Radiation Pub. No. ANR-445-W, Indoor Air Facts No. 4 (revised): Sick Building Syndrome 1 (April 1991).

[ii] U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, “Why should you be concerned about the quality of the air that you breathe?” (last modified June 8, 1999) <http.//www.epa.gov/iaq/>.

[iii] Cross, Frank B., Legal Responses to Indoor Air Pollution, 169 (1990); Geisler, Robert, “The Fungusamoungus: Sick Building Survival Guide,” 8 St. Thomas L. Rev. 511, 513 (1996)

[iv] Kelly, Thomas J., “Measuring the ROI of IAQ”, Buildings (March 1999) at 2.

[v] Icard, Thomas. and Wright, W. Cary, “Sick Building Syndrome and Building-Related Illness Claims: Defining the Practical and Legal Issues,” 14 The Construction Lawyer 1 (1994); Post, Nadine M., “Containing Noxious Mold”, Engineering News-Record (May 1999) at 32.

[vi] Heady, Gene, “Stuck Inside These Four Walls: Recognition of Sick Building Syndrome Has Laid the Foundation to Raise Toxic Tort Litigation to New Heights,” 26 Texas Tech. L. Rev. 1041, 1048 (1995)

[vii] Icard and Wright, supra, note v.

[viii] Katz, Robert W., “How to Prove a Sick Building Case,” Trial (Sept. 1991) at 58.

[ix] Centex-Rooney Construction Co., Inc., St. Paul Ins. V. Martin County, Florida, 706 So. 2d 20 (Fla. 4th DCA 1997).

[x] Godish, 37-42, 93-203.

[xi] Sick Buildings-Godish at 1.

[xii] Source ACGIH, Bioaerosols, Assessment and Control (1999), pp. 3-3 through 3-5.

[xiii] ACGIH, 3-5.

[xiv] Sick Buildings Godish, 31-34.

[xv] ACGIH, 15-1 – 15-7.

[xvi] Id.

[xvii] Id. and Godish, 333.

[xviii] Godish at 333.

[xix] In re Masonite Corp. Hardboard Siding Products Liability Litigation, 21 F. Supp. 2d 593 (E.D. La. 1998).

[xx] Florida Bd. of Regents v. Fidelity & Deposit Co. of Maryland, 416 So. 2d 30 (Fla. 5th DCA 1992) (surety not liable for.latent defects); School Board of Pinellas County v. St. Paul Fire & Marine Ins. Co., 449 So. 2d 872 (Fla. 2d DCA), review denied, 458 So. 2d 274 (Fla. 1984) (surety liable for latent defects).

[xxi] Florida Eastern Properties, Inc. v. Southeast Commercial Developers, Inc., 479 So. 2d 793 (Fla. 5th DCA 1985).

[xxii] In re Masonite Corp. Hardboard Siding Products Liability Litigation, 21 F. Supp. 2d 593 (E.D. La. 1998).

[xxiii] Casa Clara Condominium Ass'n., Inc. v. Charley Toppinso & Sons, Inc., 620 So. 2d 1244 (Fla. 1993).

[xxiv] Id. at 1246.

[xxv] Northridge Co. v. W.R. Grace & Co., 471 N.W. 2d 179 (Wis. 1991); 80 South Eighth Street Ltd. Partnership v. Carey-Canada, Inc., 486 N.W.2d 393 (Minn. 1992).

[xxvi] Reisman, David, "Strict Liability and Sick Building Syndrome: Defining a Building as a Product Under Restatement (Second) of Torts, Section 402A," 10 J. Nat. Resources & Envtl. L. 35 (1995).

[xxvii] Blagg v. Fred Hunt Co., Inc., 612 S.W.2d 321 (Ark. 1981); Kaneko v. Hilo Coast Processing, 656 P.2d 343 (Haw. 1982) (holding that buildings may be products); Oliver v. Superior Ct., 259 Cal. Rptr. 160 (Cal.Ct. App. 1989) (holding strict liability not applicable to occasional sales).

[xxviii] Chicago Bd. of Educ. v. A,C, & S, Inc., 525 N.E. 2d 950 (Ill. App. Ct. 1988); Trustees of Columbia v. Mitchell/Giurgola Assoc., 109 A.D.2d 449 (N. Y. App. Div 1985); but see Casa Clara Condominium Ass'n, Inc. v. Charley Toppino & Sons, Inc.,620 So. 2d 1244 (Fla. 1993).

[xxix] Seely v. Loyd H. Johnson Construction Co., Inc., 470 S.E.2d 283 (1996); See Golden, Brian M., "Strict Liability Applied to the Homebuilder: A Defect in the Law of Defective Products," 14 The Construction Lawyer 11 (October 1994).

[xxx] School Dist. of City of Independence, Missouri v. United States Gypsum Company, 750 S.W. 2d 442 (Mo. App. 1988).

[xxxi] United States Gypsum Co. v. Mayor of Baltimore, 647 A.2d 405 (Md. 1994); Council of Co-Owners Atlantis Condominium, Inc. v. Whiting-Turner Contracting Co., 517 A.2d 336 (Md. 1986).

[xxxii] Sime v. Tvenge Assoc. Architects & Planners, 488 N.W. 2d 606 (N.D. 1992).

[xxxiii] Keck v. New York State Office of Alcoholism and Substance Abuse Services, 10 F. Supp. 2d 194 (N.D.N.Y. 1998); Patrick v. Southern Co. Services, 910 F. Supp. 566 (N.D. Ala. 1996).

[xxxiv] Clausen v. Standard Insurance Co., 961 F. Supp. 1446 (D. Col. 1997).

[xxxv] Centex-Rooney Construction Co., Inc., St. Paul Ins. V. Martin County, Florida, 706 So. 2d 20 (Fla. 4th DCA 1997).

[xxxvi] Donaldson v. Urban Land Interests, Inc., 564 N.W. 2d 728 (Wis. 1997); Terramatrix, Inc. v. United States Fire Insurance Co., 939 P. 2d 483 (Colo. Ct. App. 197); Evanston Ins. Co. v. Treister, 794 F. Supp. 560 (D.V.I. 1992).

[xxxvii] Indiana Harbor Belt Railroad Co. v. American Cyanamid Co., 662 F.Sup..635 (N.D. Ill 19870, app. dismd. 860 F.2d 1441 (7th Cir. 1987).

[xxxviii] Shooshanian v. Wagner, 672 P.2d 455 (Alaska 1983).

[xxxix] Roseville Plaza Ltd. v. United States Gypsum Co., 811 F.Supp. 1200 (E.D. Mich. 1992).

[xl] Gastel, Ruth, "Occupational Disease: Insurance Issues," Ins. Info. Inst. Rep., (June 1994).

[xli] Heady, supra, note 4 .

A COMPARATIVE STUDY OF SAFETY IN CULTURE THE CONSTRUCTION INDUSTRY OF BRITAIN AND THE CARIBBEAN: SUMMARY OF THE FINDINGS

Peckitt, Steven J. St. Dunstan's House, U.K.
Glendon, A.I. Griffith University, Australia
Booth, R.T. Aston University, U.K.

Introduction

In most societies, the construction of structures is integral to human activity providing, *inter alia*, places for shelter, business, religious ceremonies and learning. The construction industry produces the built environment, creates employment and generates wealth. Small businesses specialist in one of numerous different construction related activities, dominate the industry resulting in a competitive, complex, dynamic and fragmented industry. The construction industry is commonly considered to be dangerous, difficult and dirty, and is one of the most hazardous land-based industrial activities, producing numerous serious accidents and cases of ill health to workers and members of the public.

The concept of safety culture is concerned with managing health and safety risks. The Advisory Committee on the Safety of Nuclear Installations (ACSNI) study group on human factors, provided one of the most quoted definitions of safety culture: *the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and proficiency of, an organisation's health and safety management* (HSC, 1993).

Geller (1994) proposes the concept of *Total Safety Culture*, identifying *personal* (knowledge, skills, abilities, motivation, personality); *behavioural* (compliance, coaching, recognition, communication); and *environmental* (equipment, tools, machines, housekeeping, environment, engineering) factors as key aspects of safety culture. One of the most simple and general, but useful, definitions of safety culture is: *aspects of culture that affect safety* (Waring, 1992).

The aim of this research project[1] was to examine health and safety risk management in the construction industry in two different parts of the world in order to gain a better understanding of factors that significantly impact upon the safety culture of this industry. This paper briefly describes some key findings from this study, highlighting significant attitudes, behaviours and situations that were found to impact upon the safety culture of the construction industry in Britain and in seven anglophone Caribbean countries in the last decade of the twentieth century. It examines the following specific issues:

1) standards of construction site health and safety;
2) construction worker attitudes to health and safety related issues;
3) construction companies health and safety management practices;
4) societal factors that impact upon the safety culture of the construction industry, including legislation and societal values.

Methodology

Cooper (1993), Geller (1994) and Cameron (1997) advocate the use of Bandura's (1977) *Social Learning* theory for the analysis of safety culture. Bandura's theory can be used to model of safety culture, where safety culture is represented the dynamic reciprocal relationship between group members' perceptions and attitudes towards safety (cognition); their job related actions (behaviour); and the effectiveness of health and safety

[1] This research was supported by Aston University and the Health and Safety Executive. The views expressed are those of the authors and do not necessary represent the views of the HSE.

management systems (environment/situation) (Cooper and Phillips, 1995). The focus of this model can be extended from organisations to the industry level by viewing safety management practices as behaviours and the influence of external influences, including legislation, economics, history and climate as situational factors (Figure 1). This reciprocal model recognises that the strength of each element may be different in any given situation. Describing a safety culture as good/positive or poor/negative equates with the possession of characteristics identified as being effective or ineffective for controlling occupational risks to health and safety in their operating environment.

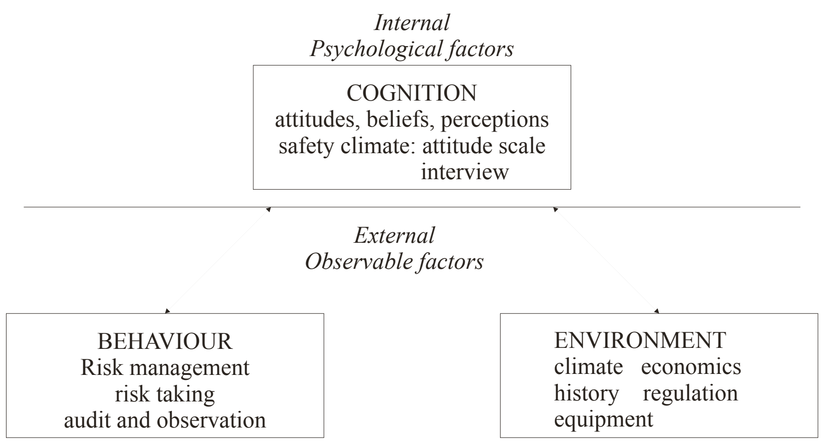

Figure 1 Reciprocally determined model of safety culture
(after Bandura, 1977 and Cooper, 1993)

Combinations of psychological and ethnographic methods have been deemed to be the most appropriate tools for examining safety culture (Schein, 1990; Guest, *et al.* 1994). An organisation's safety management system, the prevailing safety climate and daily goal directed safety behaviour can be evaluated making it possible to assess safety culture in a meaningful way (Cameron, 1997). Attitudes can be measured using a safety climate tool, while work behaviours and situational factors can be assessed by a variety of techniques including audit, literature review, direct observation and questioning (see Appendix 1 for a summary the tools used for data collection). This triangulation of information sources provides a check against observer bias and provides verification of the emergent conclusions (Bryman, 1988).

Cognition

Safety climate scales developed by Leather (1987, 1988) and Phillips, *et al.* (1994) to examine workers' attitudes to safety related issues in the British construction industry are incorporated into this study. In addition, an eleven-item interview schedule was developed by the first author to examine factors that Hinze (1981) found to influence accident rates on sites in the USA, including: size of working groups; inter-worker relations; and nature of deadlines.

Site Behaviours and Practices

A construction site safety audit tool, developed and validated by Cooper, *et al.* (1991), was used to measure aspects of construction site safety in the Caribbean. The results from the original British study are used as comparative data with the Caribbean audit scores (see Table 1). In addition to audit and general site observations, site safety management arrangements were explored during Caribbean head office and site interviews.

Situation

The characteristics of the industry, regulatory frameworks, and other relevant societal factors were examined through interview, literature review and observation. In the Anglophone Caribbean, 59 sites were audited and interviews were conducted with 153 site workers, 61 managers and directors, and government inspectors and heads of representative bodies. In Britain, site safety standards and safety management auditing was undertaken on three major contracts of the Jubilee Line Extension Project (JLEP)[2]. Ninety-four British construction workers employed on the JLEP, provided responses to the safety climate scales.

Results

Construction site safety

The results of site safety auditing highlight similarities and distinct cultural differences between the two construction industry cultures. The Caribbean Region scored an average site safety score of 57%, compared with an average score of 77% for British sites (Table 1).

Audit Category	British Sample* n = 27	Caribbean Sample n = 57
Housekeeping	77	78
Scaffolding	79	45
Access	81	71
Personal Protective Equipment (PPE)	71	33
Mean Score	**77**	**57**
*The combined pre-intervention baseline scores from the site audits conducted by UMIST researchers for HSE (Duff, *et al.* 1993; Robertson, *et al.* 1999) provide a comparable sample of British construction sites.		

Table 1 Mean Site Audit Results (% Safe) for British and Caribbean sites

The two samples achieved almost identical average scores for the Housekeeping category of the audit, while the Caribbean sites produced a marginally lower average score for the Access category and significantly lower scores than the British sample on the Scaffold and PPE categories. Housekeeping was good in both samples, but methods for gaining access to heights and the provision of PPE and scaffolding are areas of cultural difference.

Wooden scaffolding predominates in the Caribbean, while metal scaffolding is the norm in Britain. Edge protection and complete boarding to working platforms are rare in the Caribbean, but are recognised standards in the British construction industry. These results correspond with findings of Rowlinson and Linguard (1996), who, using the same measure in Hong Kong where bamboo scaffolding is common, found that the scaffolding category emerges as the most culturally influenced category on the UMIST site auditing tool and the hardest area in which to achieve behavioural change. Personal protective equipment provision was variable, but generally poor in the Caribbean. Workers readily wore protective equipment, i.e., hard hats, goggles, gloves, and facemasks, when the contractor provided them. Ladders are custom made out of wood on sites in the Caribbean, but factory manufactured from wood or metal in Britain. Compared with Britain, hazardous chemicals were not as common on Caribbean construction sites due primarily to climatic and economic imperatives that result in the use of different construction designs, materials, finishes, systems of work and techniques. The Caribbean was more labour intensive with relatively low levels of mechanisation when compared with Britain, and where used, plant was often poorly guarded and maintained.

[2] not reported in this paper

Safety Climate

The results of the analysis of the attitudinal data provided by construction workers in Britain and the Caribbean indicates that there is broad correspondence on the key dimensions of each safety climate. Factor analysis of the data determined that the principal factor is the interaction between managers and workers. The other factors identified include workers' perceptions of risk, work experience, sense of rushing and safety communications, corresponding with the findings of Dedobbleer and Beland (1991).

In addition to the shared aspects of safety climate, the two samples demonstrate significant differences. Caribbean workers responded less positively to safety climate items relating to management behaviours in comparison with their British counterparts, but were more positive with respect to the items relating to the foreman's and their own actions with respect to safety, than was the British sample. Compared with the Caribbean sample, the British sample recorded higher scores on items relating to feeling rushed and that there was a significant chance of them having an accident. Caribbean workers scored higher than the British sample on the items relating to risk perception**,** sense of individual control over safety, communications and relations with their work-mates, and enjoyment of working on site. Less than a quarter of British workers stated that they discuss personal problems with their colleagues, less than a half stated that they enjoyed their work, while two-thirds responded that they experienced impossible deadlines and that they had to rush to finish off work.

Safety management practices

The majority of small construction companies that dominate the industry worldwide tend to have slim management structures, with little bureaucracy and no formal safety management systems. Risk assessments, safety policies, safety committees and documented safety management systems were virtually absent in the Caribbean. Directors and project managers were often unaware of their duties under health and safety legislation, including reporting accidents. Caribbean directors stated that they did not take occupational health and safety legislation or international standards into consideration when tendering for works, or price for safety items in their tender bids. There was a general absence of formal health and safety training specific to the construction industry in the Caribbean and there was no equivalent of the BritishConstruction Industry Training Board (CITB).

In Britain the effectiveness of contractors' safety management systems varies both with size and activity (Birchall and Finlayson, 1996). Civil engineering contractors tend to have more sophisticated and effective safety management systems than do the commercial building and housing contractors. The medium and small construction contractors, who dominate the British construction industry, only rarely have effective safety management systems. In particular, the risk assessment process, communication of information and employee involvement is poor in many organisations. Health and safety training for managers, supervisors and workers is often lacking, despite the existence of national training organisations. Construction managers in Britain commonly view safety as a cost that conflicts with production and therefore take little direct interest in it and ignore safe systems of work when they feel strong programme and financial pressures (Leather, 1987).

Site managers with experience of working in both the Caribbean and Britain stated that they had to carry out a far greater degree of control of day-to-day site activities in the Caribbean due to the lack of engineers, skilled tradesmen and supervisors. Directors, managers and foremen stated that there were good relations on site between workers and site managers, stressing the importance of open communications and the need to consult with workers. Site relations tended to be more paternalistic on Caribbean sites, with less emphasis on efficiency and speed. Both foremen and managers across the Caribbean stated that you had to get the respect of the workers in order to get them to work hard and that workers do not like pressure and will walk off the job if shouted at or pressed to work faster or harder.

Industry characteristics

The stereotypical image of the British construction industry is that it is a dirty, noisy, dangerous, inconveniencing activity undertaken by hard living men, employed by unscrupulous contractors. There is little job security, little training and generally low academic entry requirements to the industry. The pressures of tight work schedules are compounded by bonus payment systems and "pay when paid" clauses. Sharp practices of many small builders, some of which border on fraud, perpetuate the image of the dishonest and incompetent cowboy builder frequently portrayed in British television dramas and documentaries.

Latham (1994) describes the British construction industry as litigious with conflict, adversarial attitudes, fragmented organisation and a lack of trust resulting in over 1000 writs being issued each year. Competitive tendering, programme pressures and the use of penalty clauses all set up pressures that conflict with safety management. Time and cost pressures result in risks being ignored and the law being broken with the consent of supervisors and managers. The requirement for high-speed project completion often results in poor planning, a cost premium and an increased risk of accidents and mistakes occurring. Competitive tendering limits the amount of influence that builders have on designs, the degree of innovation and investment in new technologies and prevents collaboration between architects, engineers and builders (Atkin, *et al.* 1995). The fragmented relationships between clients, consultants, designers, contractors and subcontractors in the construction industry in both regions results in difficulties such as inadequate planning, disputes, nepotism, poor communications and time delays. Caribbean projects frequently experience delays due to client indecision, poor design briefs, design changes, materials supply problems and late payment (Lewis & Atherley, 1996). Adversarial relationships, attitudes of the work force, inefficient bureaucracies, lack of finance, low pay and motivation, low productivity, political interference, poor infrastructure, and skills and materials shortages are common problems facing the construction industry in the Caribbean (Lewis and Mugishagwe, 1996). However, compared with Britain there is not the same degree of adversity, 'cut-throat' competition, imposition of unreasonable deadlines, or litigation in the Caribbean. Only one of the Caribbean companies studied had been to court over a contractual dispute. Project managers in the Caribbean who had experience of both cultures stressed the slower pace of work compared with British industry. In the Caribbean there was a lower level of pressure on the workers and a slower pace of working. Bonus schemes, tight time schedules, penalty clauses and litigation were all uncommon in the Caribbean. Construction managers with experience of both cultures stated that works of similar size would take approximately twice as long in the Caribbean generally, compared with Britain.

Societal factors

The nature of occupational health and safety regulation and the impact of societal culture were examined and compared. Occupational health and safety legislation applicable to construction in the Caribbean varies from country to country, is proscriptive and rarely enforced. Only Jamaica and Guyana had comprehensive construction specific regulations, while Trinidad and Tobago have a set of regulations relating specifically to earthworks. Inspectors are rarely provided with legal powers of prohibition and prosecution, or with adequate technical equipment, and means of transport. On the whole they are underpaid, handicapped by bureaucracy and excessive delays in judicial proceedings and the low level of legal penalties for violations. The regulatory system for occupational health and safety in Britain is extensive and complex. The Health and Safety Executive (HSE) is the organisation responsible for health and safety in the British construction industry. HSE inspectors have powers of immediate prohibition, improvement and prosecution. Regulations forming a comprehensive regulatory framework cover the whole construction process. In the mid-1990s an average of 100 inspectors was devoted to inspect the construction industry. HSE construction inspectors annually carried out around 30,000 inspections, representing approximately a quarter of all HSE inspections, issued around a half of all HSE prohibition notices and conducted a third of HSE prosecutions (HSC, 1996).

African-Caribbean people dominate the manual trades in the construction industry of the Caribbean region. When describing the important factors that impact upon construction site safety in the Caribbean, African-Caribbean workers stressed the values of freedom, love of life (*joie de vivre*), social aspects of work and the willingness to take time to do things. Caribbean workers scored items relating to interactions with fellow workers, communications on site and enjoyment of work higher than did British workers. A prevalent attitude expressed by Caribbean workers was that British people live to work whereas Caribbean people work to live. British culture, biased towards individualism and low power distance, places emphasis on the legal system, democratic power, technology and the work ethic (Hofstede, 1980). British workers scored higher the items related to rushing and risk-taking, highlighting differences in the perception of pressure and time. The common British cultural symbol of the fierce and determined Bulldog, contrasts with Anansi the clever spider which is a popular cultural figure amongst African-Caribbeans, derived from West African folk tales. Table 2 summarises key findings from this study.

	CARIBBEAN	BRITAIN
	CONSTRUCTION WORKER ATTITUDES	
locus of control	relatively high	relatively low
risk perception	relatively high	relatively low
communications	relatively high	relatively low
sense of rushing	low	high
	CONSTRUCTION SITE BEHAVIOURS	
housekeeping	generally good	generally good
ladders	made on site - few accidents	manufactured - many accidents
scaffolds	made from timber, not used for storage of materials edge protection rare	made from metal often used for material storage edge protection generally good
PPE	poor	variable
techniques	simple methods, robust structures, limited use of technology	often complex designs, common use of technology
	CONSTRUCTION ORGANISATIONS	
bonus schemes	rare	common
safety management systems	little proactive safety management, safety seen as site function for foreman and workers	variable - good in civil engineering, poor in smaller contractors, safety often seen as a site function
safety training	rare	national schemes increasing
pressures	financial and material supplies lack of specialist skills	fierce finance and time pressures skills shortages
dispute resolution	litigation rare	frequent litigation
project management	contingency approach	taylorist approach
	CONSTRUCTION INDUSTRY	
adversity	little	common
legislation	little	comprehensive
inspectors	few	many
enforcement	rare	common
approach	negotiation	rule based
	SOCIETAL FACTORS	
regulation	little influence	large influence
climate	tropical	temperate
use of technology	restricted	extensive
life/work relationship	work to live	live to work
focus	spirituality	materialism
time	time synchronous	time sequential
risk	risk averse	risk taking
values	joie de vivre Anansi smartness	PWE Bulldog spirit

Table 2 Construction Industry Safety Culture - Summary of Key Findings

Conclusion

Comparative profiles of the two safety cultures can be built up combining the significant factors identified in this study. The radar map (Figure 2) provides a conceptual depiction of the safety culture of the construction industry in the Caribbean and Britain. The data points are the key issues that emerge from this study. Personal factors such as risk taking and locus of control are positioned in the upper right hand third of the diagram. Construction industry factors such as site relations, training and safety management are located in the bottom third, while societal factors occupy the left hand third of the diagram. The data points are placed on a five-point scale rising from zero at the centre of the map. The relative magnitude of each data point within each safety culture is derived from results of this study. The further the point away from the centre of the map, the greater is the influence of that factor. Positive influences within the safety culture of the British construction industry, include relatively high levels of regulation, resources and formal safety management systems.

Negative influences include adversity, complex subcontracting relationships, risk taking and rushing. Positive influences within the safety culture of the Caribbean construction industry include a strong personal locus of control for safety, high risk perception and relatively slow work pace. Both industries suffer from a lack of job security and training, effective quality management and trust. Accident and ill-health data for the construction industry are inherently unreliable due to the endemic failure to report non-fatal accidents, both in Britain and the Caribbean, and must therefore be treated with caution. From available data the accident rates for the Caribbean construction industry are substantially less than those in the British construction industry (Appendix 2). Between 1987 and 1991 the average fatal accident incidence rate for employees in the British construction industry was 9.7 (HSC, 1992). Averaging the often-sketchy employment and accident data for Caribbean states gives a regional fatal accident incidence rate of 1.7 for the construction industry in 1990. The all accident incidence rates for the Caribbean construction industry were generally half the British figures.

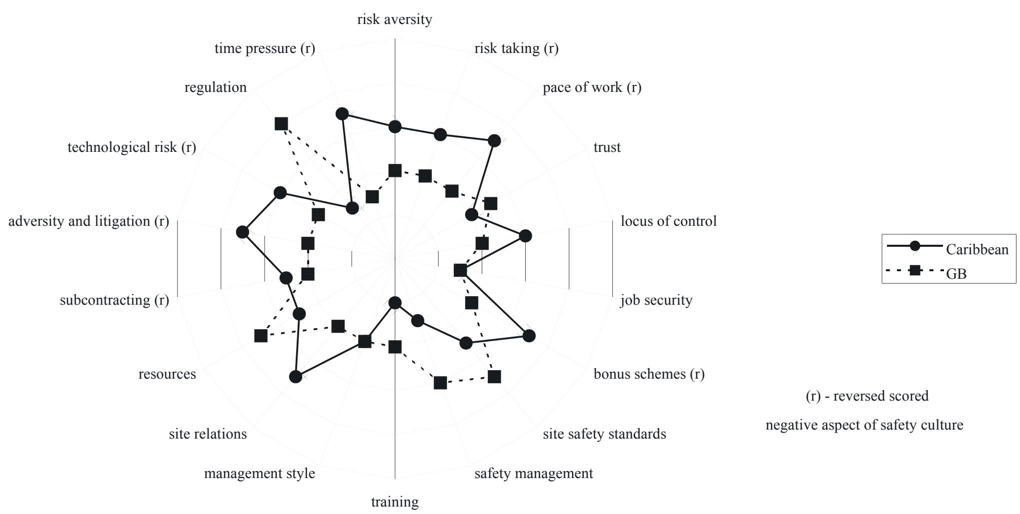

Figure 2 Radar map of the construction safety cultures of the Caribbean and Britain

Despite significant regulatory and site management efforts to provide fall protection, falls account for half of all British construction fatalities. In the Caribbean edge protection is commonly lacking, fall arrest equipment is rare and working platforms are not fully boarded. In the Caribbean the relatively slow pace of work, sense of locus of control over safety and risk are cultural factors that help to explain the relative lack of falling accidents compared with Britain. Despite the common occurrence of unprotected drops, mediating cultural factors reduce the potential for falls, corresponding with Hinze's (1996) *Distractions Theory* and Leather's (1987) *PAS Model*. The absence of formal safety management systems was balanced to a degree by the strong locus of control for their safety exhibited by Caribbean workers who were agile, avoided rushing work and also tended to be risk averse.

The Caribbean construction industry faces less technological risk due to the comparatively limited use of chemicals, complex construction techniques, plant and machinery. The Caribbean construction industry is less adversarial, less pressurised and less regulated than the British construction industry. Time is less of a pressure, production related bonus schemes are generally absent and work pace is relatively slow. British concepts of time and risk ensure that construction clients and contractors frequently focus too much on costs and progress at the expense of quality and safety, resulting in frequent accidents, disputes, litigation, poor quality and rushed work. Societal cultural biases have a significant impact upon safety culture of the construction industry. Conceptions of time, human relations and risk taking emerge as important societal factors that impact on safety culture. The key to improving risk management in the construction industry is the recognition of the negative impact of specific cultural biases and implementing effective measures to counter them.

References

Lewis, T.M. & Atherley, B. A. (1996). Analysis of Construction Delays *The Organisation and Management of Construction: Managing the Construction Project and Managing Risk, Vol 2*, Eds D.A. Langford & A. Retik, London:E & FN Spon, pp 60-71.

Atkin, B. Flanagan, R. Marsh, L., & Agapiou, A. (1995). *Improving value for money in construction guidance for chartered surveyors and their clients.* London: Royal Institution of Chartered Surveyors.

Bandura, A. (1977). *Social Learning Theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1986). *Social foundations of thought and action*. *A social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1991). Social Cognitive Theory of Self Regulation. *Organisation, Behaviour, and Human Decision Process*, *50*, 248-287.

Birchall, S.J., & Finlayson, H. (1996). The Application of European Directive Safety Management Regulations to the British Construction Industry. In L. M. Alvez Dias, & R. J. Coble (eds), *Implementation of Safety and Health on Construction Sites.* CIB W99 1996 Lisbon. Balkema, Rotterdam, pp. 41-52.

Bryman, A. (1988), *Quantity and Quality in Social Research,* London: Unwin Hyman.

Cameron, I. (1997). A social learning approach to the practice of safety management. *The Health and Safety Practitioner,* March, pp.26-32.

Cooper, M.D. (1993). *Reciprocal model for measuring safety culture*, Applied Behavioural Sciences, Hull.

Cooper, M.D., & Phillips, R. A. (1995). Killing Two Birds With one stone: achieving quality via total safety management. *Leadership and Organizational Development Journal, 16*, 3-9.

Cooper, M.D., Phillips, R. A., Robertson, I. T., & Duff, A. R. (1991). Improving safety on construction sites by the utilization of psychologically based techniques: Alternative approaches to the measurement of safety behaviour. Paper given at the Vth European Congress of the Psychology of Work and Organization, Rouen, France.

Dedobbeleer, N., & Beland, F. (1991). Safety Climate Measure for Construction Sites. *Journal of Safety Research, 22*, 97-103.

Duff, A.R., Robertson, I.T., Cooper, M.D., & Phillips R.A. (1993). Improving Safety on Construction Sites by Changing Personnel Behaviour. Health and Safety Executive Contract Research Report No. 51/1993, HSE Books.

Geller, S.E. (1994). Ten principles for achieving a total safety culture. *Professional Safety*, September, 18-24.

Guest, D.E., Peccei, R., & Thomas, R. (1994). Safety culture and safety performance: British Rail in the Aftermath of Clapham Junction Disaster. Paper presented at the Bolton Business School Conference on Changing Perceptions of Risk, Bolton, February 23 - March 1.

Health and Safety Commission (1992). *Annual Report 1994/95* HSE Books.

Health and Safety Commission (1993). *ACSNI Human Factors Study Group Third Report: Organising for Safety,* London: HMSO.

Hinze, J.W. (1981). Human Aspects of Construction Safety. *Journal of Construction Division,* ASCE Vol 107 No CO1 Proc. Paper 14848 Sept pp. 253-262.

Hinze, J.W. (1996). The Distractions Theory of Accident Causation. In L.M. Alvez Dias, & R.J. Coble (eds), *Implementation of Safety and Health on Construction Sites,*CIB W99 1996 Lisbon. Balkema, Rotterdam. pp. 375-373.

Hofstede, G. (1980). *Cultures' Consequences*. International Differences in Work-related Values. Volume 5, Crosscultural Research and Methodology Series: Sage.

Latham, M. (1994). *Constructing the Team,* London: HMSO.

Leather, P.J. (1987). Safety and Accidents in the Construction Industry: A Work Design Perspective. *Work & Stress, 1*, 167-174.

Leather, P.J. (1988). Attitudes Towards Safety Performance on Construction Work: an investigation of public and private sector differences. *Work & Stress, 2*, 155-167.

Lewis, T.M., & Mugishagwe, D.D. (1996) Operational Problems Facing a Sample of Construction Firms in Trinidad and Tobago. *The Organisation and Management of Construction: Managing the Construction Project and Managing Risk, Vol 2*, Eds D.A. Langford & A. Retik, London: E&FN Spon, pp 273-282.

Phillips, R.A., Cooper, M.D., Sutherland, V.J., & Makin, P.J. (1994). A Question of Safety Climate – Measuring Perceptions of the Working Environment. *Proceedings of the BPS 1994 Conference,* Birmingham.

Robertson, I.T., Duff, A.R., Phillips R.A., Weyman, A.K., & Cooper, M.D.(1999). Improving Safety on Construction Sites by Changing Personnel Behaviour Phase II. Contract Research Report No. 229, HSE Books.

Rowlinson, S., & Linguard, H. (1996). Behavioural Safety Management in Hong Kong's Construction Industry; Success and Limitations. In L.M. Alvez Dias, & R.J. Coble (eds). *Implementation of Safety and Health on Construction Sites,* CIB W99 Lisbon. Balkema, Rotterdam pp. 281-289.

Schein, E.H. (1990). Organizational Culture. *American Psychologist*, *45*, 109-119.

Waring, A.E. (1992). Organisational Culture, Management and Safety, *Paper presented at the British Academy of Management 6th Annual Conference,* 14-16 September,Bradford University.

Appendix 1

Measure	Originator	Number of Items		Focus	Comments
Attitude Scales					
UMIST Safety Climate Scale	Cooper *et al*. (1991)	**Original** 36	**Actual** 26	Caribbean and British Manual Workers	Ten non-applicable items removed
Leather's Attitude Scale	Leather (1987)	12	10	Caribbean and British Manua1 Workers	Two non-Applicable items removed
Interview Schedules					
Government	Peckitt	22		Caribbean Government Officials	
Company	Peckitt	19		Caribbean Construction Company Directors	
T U /Employers Schedule	Peckitt	16		Caribbean TU/ Employers Organisation	Includes TU and Emp, ILO, UNECLAC
Site Safety Schedule	Peckitt after Hinze	11		Caribbean and British Manual Workers	Developed in Barbados
Physical Site Safety Audit					
Site Safety Audit	Cooper *et al*. (1991)	24		Sites audited in the Caribbean	Some items not applicable

Summary of Measures Used in this Study

Appendix 2

Accident Data

The construction industry is globally renowned for its informal employment practices and operations. In the 1990s the Labour Force Survey of Britain estimated that 60% of nonfatal reportable accidents in the construction industry go unreported to the HSE (HSC, 1995). The dubious accuracy of particularly nonfatal accident data, limits the extent to which meaningful comparisons can be made. However, available data suggest that there is significant underreporting of industrial accidents and cases of ill-health under the relevant industrial health and safety legislation in both Britain and the Caribbean.

Britain

On the basis of reported accident data, the British construction industry is more dangerous than any other land-based industrial activity except for mining. Between 1986/7 and 1991/2, 851 fatalities occurred in the construction industry. On average five workers were killed every fortnight and a member of the public was killed every month (HSE, 1994). The rate of fatalities in the construction industry was six times greater than that in the manufacturing sector and nearly 16 times the rate in the service sector. In the mid-1990s the annual accident toll from the construction industry included around 85 fatalities, 3000 major injuries and 11,000 over three-day accidents every year (HSC, 1995). With an estimated 60% under-reporting of non-fatal construction accidents, the actual number of major and over three-day injuries is likely to be 6000 and 22,000 per year respectively for all construction workers. British figures exclude road traffic accidents, which are a significant cause of fatal accidents to construction workers and are included in the statistics of many countries – e.g., USA, France, Denmark.

Falls from height account for around half of all fatal construction industry injuries to workers in Britain, the majority of which result from treading on fragile roof lights. Other common causes of fatalities include trapping, collapsing or overturning accidents (14%), being struck by a moving vehicle (14%) and being struck by a moving or falling object (9%). Roofing, ground works and demolition are the activities that produce the most fatal accidents. Inadequate training or instruction, and inadequate supervision each contributed to around 100 deaths between 1986/87 and 1991/92 (HSE, 1994). Compared with other workers, British construction workers' experience increased mortality rates from malignant diseases particularly lung cancer and stomach cancer, as well as from work-related accidents. These result from exposures to hazardous substances and physical agents of harm at work, and poor diet, excessive alcohol consumption, smoking, and stress induced by living away from home (Dong, *et al.* 1995). The number of cases of ill health caused by the industry is difficult to gauge accurately. HSE (1994) estimates that annually:

- up to 48,000 suffer from musco-skeletal problems;
- up to 23,000 suffer respiratory diseases;
- up to 10,000 suffer from dermatitis; and
- almost 6000 workers suffer occupational deafness.

In the 1990s, asbestos-related diseases are estimated to kill between 3000 and 3500 people every year in Britain. This figure is likely to go on rising, probably for the next 25 years, when the death rate could be between 5000 and 10,000 each year (HSE, 1994). The long latency of asbestos-related diseases (those for cancers and mesotheleoma are anything from 15 to 60 years) means that these deaths are occurring from exposures that have already taken place. Construction workers such as carpenters, electricians, plumbers, gas fitters and cabling installers form the largest high-risk group. This is because of the common use of asbestos materials in buildings in Britain for insulation and fire protection from the start of the 20th century.

The Caribbean

In the Caribbean there is no standard method of collecting and recording occupational accident and ill-health data. In most of the countries studied limited industrial accident and ill-health data were available from both Labour Departments and the National Insurance Scheme (NIS). However, Anguilla did not collect any occupational accident data, and in Saint Lucia data were only available from the NIS. There were often large differences between the two sets of data available from labour departments and the NIS, due to differing reporting requirements, the wider scope of coverage of the NIS and the beneficial aspects of reporting to the NIS. The definition of what constitutes a reportable work accident differs between countries within the Caribbean Region. In Guyana, employers are legally required to report all one-day absences from work both to the NIS and by occupational health and safety legislation. In Jamaica the Factories Act 1943 requires submission of reports of all incidents resulting in over 48-hour absences from work. Barbados, Saint Vincent and the Grenadines, and Trinidad and Tobago require reports of greater than three-day absences from work caused by occupational accidents. Little information was available concerning occupational diseases throughout the Region. Table 3 shows available relevant Caribbean occupational accident data.

Country	Date	Fatal Accidents		Non-Fatal Accidents		Notes
		Number	Rate per 100,000	Number	Incidence rate	
Anguilla	1989 1990 1991	- - -	- - -	- - -	- - -	No industrial accident data available.
Barbados	1989 1990 1991	1 0 1	10.75 0 11.76	70 22 27	642 230 318	Figures from Labour Dept. (>3day). Employment figures Labour Market Information Report 1990
Guyana	1989 1990 1991	0 1 0	0 1.6 0	15 11 13	165 121 143	Assumes 9,000 construction workers. Reports for greater than one day absences. NIS figures. Total workforce 270,000
Jamaica	1989 1990 1991	0 0 0	0 0 0	68 40 126	224 152 405	Greater than two day absences. Figures from NIS assumed 30,000 construction workers
St. Lucia	1989 1990 1991	0 0 0	0 0 0	- - 36	- - 1663	From National Insurance Figures, not recorded by industry group. (> 3 day)
St. Vincent	1989 1990 1991	0 0 1	0 0 30	23 19 15	675 557 440	Labour Mkt Bulletin Vol 3 1990, (>3 day) Total employees =37,782 Construction workers = 3,380
Trinidad and Tobago	1989 1990 1991	0 0 0	0 0 0	2 1 0	5.2 2.5 0	CSO Reports Trinidad Labour Dept.Figures. (> three day absences.)
Britain	1988/89 1989/90 1990/91	109 108 110	9.9 9.4 9.3	18763 20339 19377	1842.9 1971.4 1876.5	HSE Annual Reports. Employees only RIDDOR Reports

Table 3 Accident Numbers and Incidence Rates by Country

Accident incidence rates

In 1990/91 the fatal accident incidence rate for employees in the British construction industry was 9.3, (HSE, 1993). Averaging the Caribbean employment and fatal accident data gives a regional incidence rate of 1.7 for the construction industry in 1990, (estimated working population of the construction industry in the Caribbean countries studied is 125,000). The variation in rates caused by one fatality in small population size samples is demonstrated in the examples of the construction industry fatal accident rate for Barbados (12) and Saint

Vincent (30), in 1991. Two fatal accidents were recorded in the Caribbean construction industry in 1991, giving a fatal accident incidence rate of 1.6. This may be compared with the British fatal accident incidence rate of 9.3 for the construction industry in the same year. The all accident incidence rates for the Caribbean construction industry were generally less than 50% of the British figure. From the available data, construction accidents occur more frequently in Britain compared with the Caribbean. Electrical, 'struck by' and machinery accidents appear to be more common causes of fatal accidents than falls, in contrast to Britain.

EXPLORATION OF THE POTENTIAL FOR RELIABILITY-UPDATING TECHNIQUES

Peng, D.M. Shenzhen Municipal Engineering Institute, Shenzhen, P.R. China
Baker, M.J. Kings College, United Kingdom

KEYWORD

Survey network, structure, analogue, distribution, probability, reliability index, reliability updating

Introduction

It is commonly recognised that the performance of engineering structures depends on parameters that must be regarded as stochastic. Reliability analysis becomes an increasingly accepted way to assess the performance of engineering structures, from highway bridges to offshore jackets, and to nuclear power stations (Val *et al.*, 1997a, 1997b).

However, uncertainties in the calculation model itself, as well as in the basic input variables, leads to load-carrying capacity and reliability prediction with considerable variance. This provides decision-makers with little constructive information. In the research described here which is aimed at a more precise description of the nature of the uncertainties in the predicted response of a structure (*i.e.* the *object variable*), reliability updating techniques (Baker & MacGregor, 1996) have been proposed with a view to providing a potential, wider application to engineering structures in practice. Reliability updating techniques are based on Bayes's theorem that provides a useful approach for updating subjective knowledge with experimental results or *in-situ* observations (Ang & Tang, 1975; Benjamin & Cornell, 1970).

Without the problem of knowing whether the deterministic models for the response have hidden model uncertainties which would in practice affect the results, calculations have been performed on an analogue of a structural system where the physics of the problem is completely clear. The analogue that has been chosen is a plane survey network.

The main purpose of this paper is to demonstrate the potential or benefits, theoretically or numerically, of applying reliability updating techniques based on measured information (*i.e.* distances, deflections, strains, crack lengths, or frequencies *etc.*) in a proof load test.

The second purpose of this paper is to find the frequency with which a reliability-updating calculation carried out using field measurements will lead to 'incorrect' or 'unsafe' results and to find the corresponding critical value of the standard deviation for the known information.

As a previous study, reliability updating techniques have been successfully applied to the assessment of a bridge deck (MacGregor, 1997) and RC beams (MacGregor, 1994). As a continuing exploration of the potential of reliability updating techniques, in this paper, a distance survey network was considered with a view to demonstrating what the potential of them is, how they could be applied to practical engineering systems, and what limitations of applying them are practically. Some extra distance measurements, not basic measurements, were used to do the corresponding reliability updating as conditioning events. The corresponding results were compared with the unconditioned reliability analysis with a view to exploring the benefit of applying reliability updating techniques in practice.

Due to the existence of the exact solution in such a survey network (analogue), comparisons were carried out between the exact solution and reliability results in the unconditioned or conditioned cases. Some conclusions have been drawn from the corresponding analyses, however, such comparisons are more difficult in structural systems that include an amount of model uncertainties. A parametric study shows the effect of the parameter considered on reliability updatings.

Model Description

As an analogue of a structural system, a 5-station plane distance survey network is illustrated in Figure 1. The distance between points A and D (*i.e.* the *object variable*) is assumed to be required to a high level accuracy. It is understood that direct measurement of the distance AD is impossible because there is no direct line of sight and the distance AD is derived with a function of basic measurements (*i.e. basic variables*). In terms of an analogue of a structural system, the object distance L_{ad} is corresponding to the collapse load of the structural system, while six basic measurements (*i.e.* L_{ab}, L_{ae} *etc.*) are corresponding to geometrical or material properties. Extra measurements (or conditioning measurements) are corresponding to the structural response in the structure system itself.

For this survey network, a deterministic analytical model was set up and the corresponding calculations were carried out. As far as the model is concerned, six quantities are assumed to know exactly. These are the lengths: L_{ab}=9000.0m, L_{ae}=11000.0m, L_{be}=7000.0m, L_{ce}=6000.0m, L_{de}=7000.0m, and L_{cd}=11000.0m. It is also assumed that Stations B and C are fixed. The corresponding values of the unknown distances to the nearest 10^{-4}m have been calculated from a deterministic analytical model and are: L_{ad}=13001.3525m, L_{ac}=16631.7507m, and L_{bd}=13327.4381m. The coordinates of various stations are then as follows: A(-4780.5, 7623.5), B(0.0, 0.0), C(10000.0, 0.0), D(7831.0, 10784.0), and E(5650.0, 4132.5).

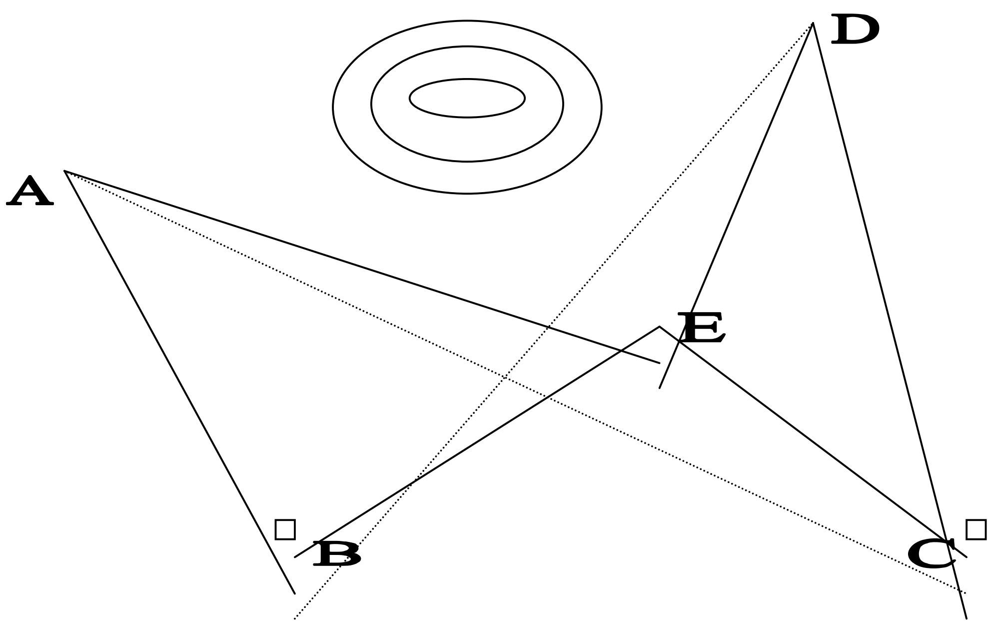

Figure 1 An example of a survey network (L_{ad} is the unknown distance between A and D, or the object distance to be determined. L_{ab}, L_{ae} *etc.* are the known distances between points A and B, A and E, *etc*).

Distribution Updating of Object events

The aim of a so-called distribution analysis in reliability analysis is to find the probability density function or cumulative distribution function for a specified object variable (*i.e.* the distance L_{ad} in Figure 1). For such distribution analyses, the Monte Carlo simulation method was adopted in this study. Without doubt, other simulation methods, such as Latin Hypercube simulation and directional simulation, can also be used here.

It has been assumed that the field measurements of various distances L_{ab}, L_{ae} *etc.* deviate from the true distances because of observational and instrument errors. Thus for each field measurement, we have

$$D_a = D_m + \varepsilon_1 + \varepsilon_2 \quad (1)$$

where D_a = the actual distance
D_m = the measured distance
ε_1 = the instrumental error
ε_2 = the error from observation

By combining these, the mean values of basic variables in this model were assumed to be the exact value (from the deterministic analytical model) *plus* a single random variable. These variables were generated by the following procedure.

(1) Generate a random number using Box and Muller procedure (Box & Muller, 1958). It produces a pair of 'exact' independent standardized normal variates, u_1 and u_2, given by

$$u_1=(-2 \ln r_1)^{1/2} \sin 2\pi r_2 \quad (2)$$

$$u_2=(-2 \ln r_1)^{1/2} \cos 2\pi r_2 \quad (3)$$

where r_1 and r_2 are uniformly distributed independent random variables in the interval [0, 1].

(2) Multiply u_1 and u_2 with standard deviations: 0.015m, or 0.00015m and take the product as the measurement error.

(3) Then for all the 6 basic variables L_{ab}, L_{ae} *etc.*;
Mean value = exact value + u*0.015
Standard deviation σ = 0.015m or 0.00015m

In this analysis, it has been assumed that $\varepsilon_1 + \varepsilon_2$ may be represented by the following expression:

$$\varepsilon_1 + \varepsilon_2 = u \times \sigma \quad (4)$$

where u is generated by Eqns (2) or (3), that is a standard normal variate, and σ is an assumed standard deviation representing the total uncertainty in the measurement.

In order to check the effect of the random errors on the reliability updating process, distribution analyses were repeated in all five cases with various random numbers. The corresponding calculations have been carried out using the commercial software package "PROBAN" (Det norske Veritas, 1992). The detailed results of the distribution analyses are described below.

Case studies

CASE 1
By considering the measurement errors as random values generated from the Box and Muller method, six basic variables are assumed below.

L_{ab}=normal(Mean, StD: 8999.9771,1.5E-2)
L_{ae}=normal(Mean, StD: 11000.0006,1.5E-2)
L_{be}=normal(Mean, StD: 7000.0257,1.5E-2)
L_{cd}=normal(Mean, StD: 10999.9984,1.5E-2)
L_{ce}=normal(Mean, StD: 5999.9986,1.5E-2)
L_{de}=normal(Mean, StD: 7000.0069,1.5E-2)

The conditioning events (*i.e.* equality constraint conditioning events) in Bayes's updating can be described as follows.

Conditioning event 1:
L_{ac} = 16631.7507 + 0.0208 = 16631.7715 (m)
where 16631.7507 is the exact value for L_{ac} from the deterministic analytical model and 0.0208 is the measurement error generated using the Box and Muller method.

Conditioning event 2:

L_{bd} = 13327.4381 – 0.0065 = 13327.4316 (m)
where 13327.4381 is the exact value for L_{bd} from the deterministic analytical model and –0.0065 is the measurement error generated using the Box and Muller method.

Figure 2 shows comparisons of four PDFs between unconditioned and conditioned cases. The flattest (solid line) is a PDF curve for the unconditioned case. All three conditioned cases (dashed lines) show a higher peak of PDF curves than the unconditioned case (solid line). In other words, these conditioned PDF curves show less variance than the unconditioned case. Furthermore, the object distance updated on two measured distances has less variance compared with those updated on one measured distance. It can be concluded that the more information there is, the better the effect on reliability updating is. It is also observed that the mean value of the object distance updated on two measured distances is located mid way between the two mean values for the cases conditioned on only one measured variable. The PDF curve of the object distance shifts in the positive direction on updating with the measured variable L_{ac}, while it shifts into the negative direction on updating with the measured variable L_{bd}. On updating with two measured variables L_{ac} and L_{bd}, the PDF curve of the object distance takes up a position between the two mean values for the cases conditioned on only one measured variable.

Thus for the example shown in Figure 2 it can be concluded that the PDF denoted updated_2 (*i.e.* the density function for the distance L_{ad} updated on the single measured distance L_{bd}) has a mean value (13001.3431m) which is closest to the true distance L_{ad} which is 13001.3525m. However, the PDF denoted updated_3 based on updating L_{ad} with the additional measurements L_{ac} and L_{bd} has a smallest variance.

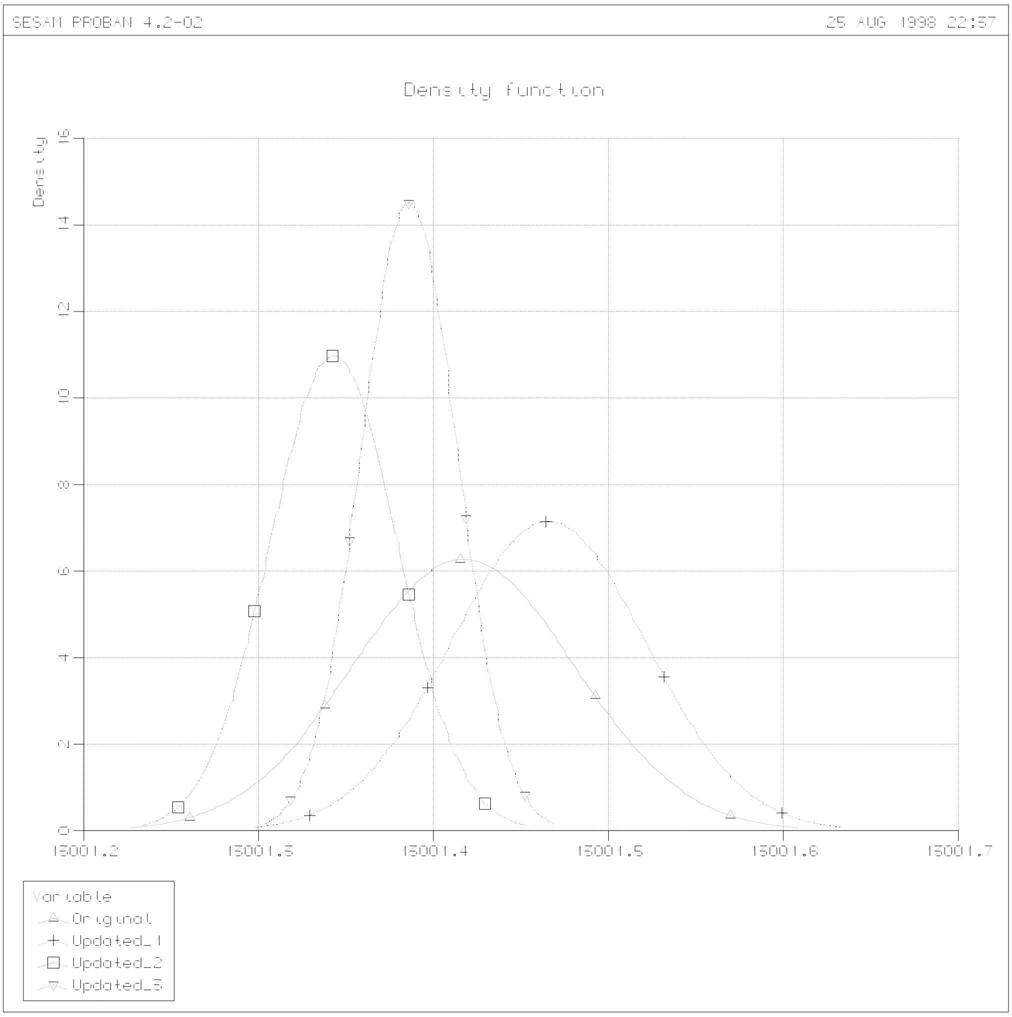

Figure 2 CASE 1: comparisons of probability density functions (pdf), for the object distance L_{ad} (m), between original (unconditioned), updated_1 (updated on one measured distance: L_{ac}), updated_2 (updated on one measured distance: L_{bd}), and updated_3 (updated on two measured distances: L_{ac} and L_{bd}).

Similar with CASE 1, the following four cases are presented with results only for simplicity.

CASE 2

From Figure 3 it can be concluded that for Case 2 the PDF denoted updated_3 (i.e. the density function for the distance L_{ad} updated by two measured distances L_{ac} and L_{bd}) has a mean value (13001.3382m) which is closest to the true distance L_{ad}. It also has the least variance. The 90% confidence interval for the case updated_3 is [13001.28, 13001.39] (confidence interval = 0.11m), compared with [13001.22, 13001.53] (confidence interval = 0.31m) in the unconditioned case. This presents the uncertainty reduction in the object distance as a result of reliability updating.

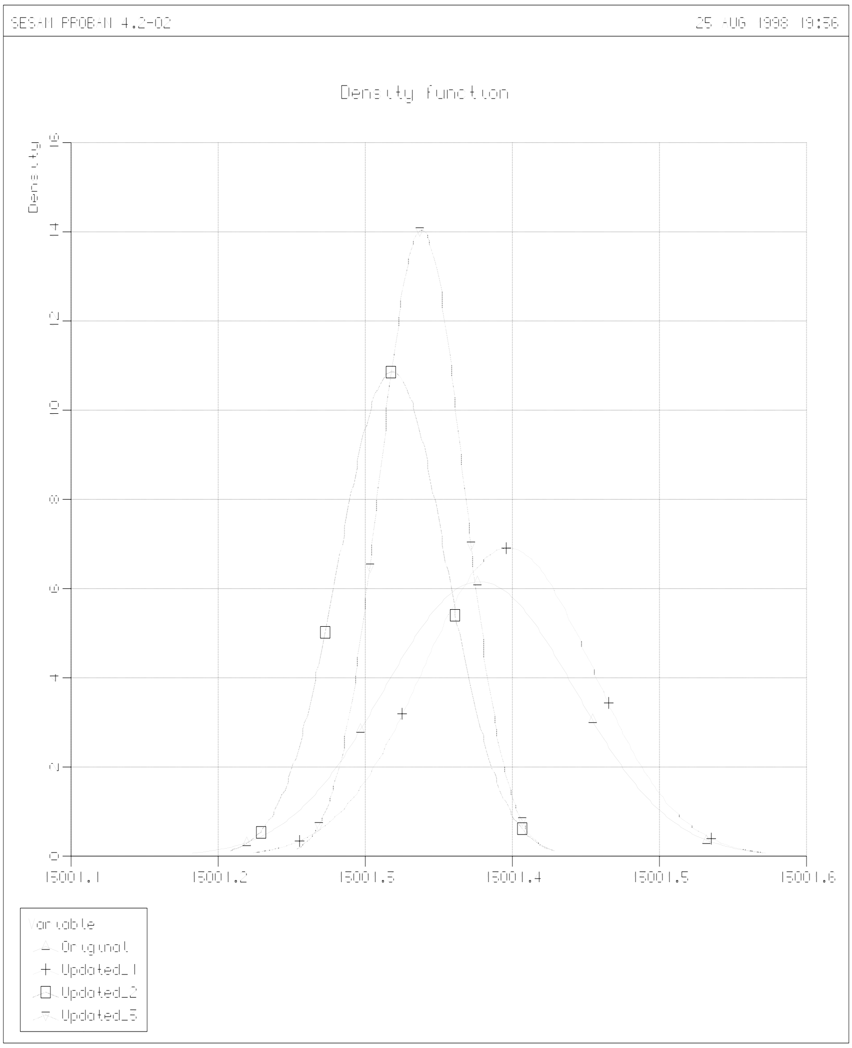

Figure 3 CASE 2: comparisons of probability density functions, for the object distance L_{ad} (m), between original (unconditioned), updated_1 (updated on one measured distance: L_{ac}), updated_2 (updated on one measured distance: L_{bd}), and updated_3 (updated on two measured distances: L_{ac} and L_{bd}).

CASE 3

Different from CASE 1 and CASE 2, it is observed that the mean value of the object distance L_{ad} updated on two measured distances is now not located between the two mean values for the cases conditioned on only one measured variable. This value (13001.3646m) is greater than both mean values (13001.2894m and 13001.3634m) for the cases conditioned on only one measured variable. This has occurred because, by chance, all the measured values of distance happen to be less than their true values.

From Figure 4 it can be seen that for Case 3 the mean value of the PDF for the object variable denoted updated_2 is the closest to the exact value for L_{ad}. The 90% confidence interval for the case updated_2 is [13001.29, 13001.42] (confidence interval = 0.13m), compared with [13001.14, 13001.42] (confidence interval = 0.28m) in the unconditioned case. This presents the uncertainty reduction in the object distance L_{ad} due to reliability updating.

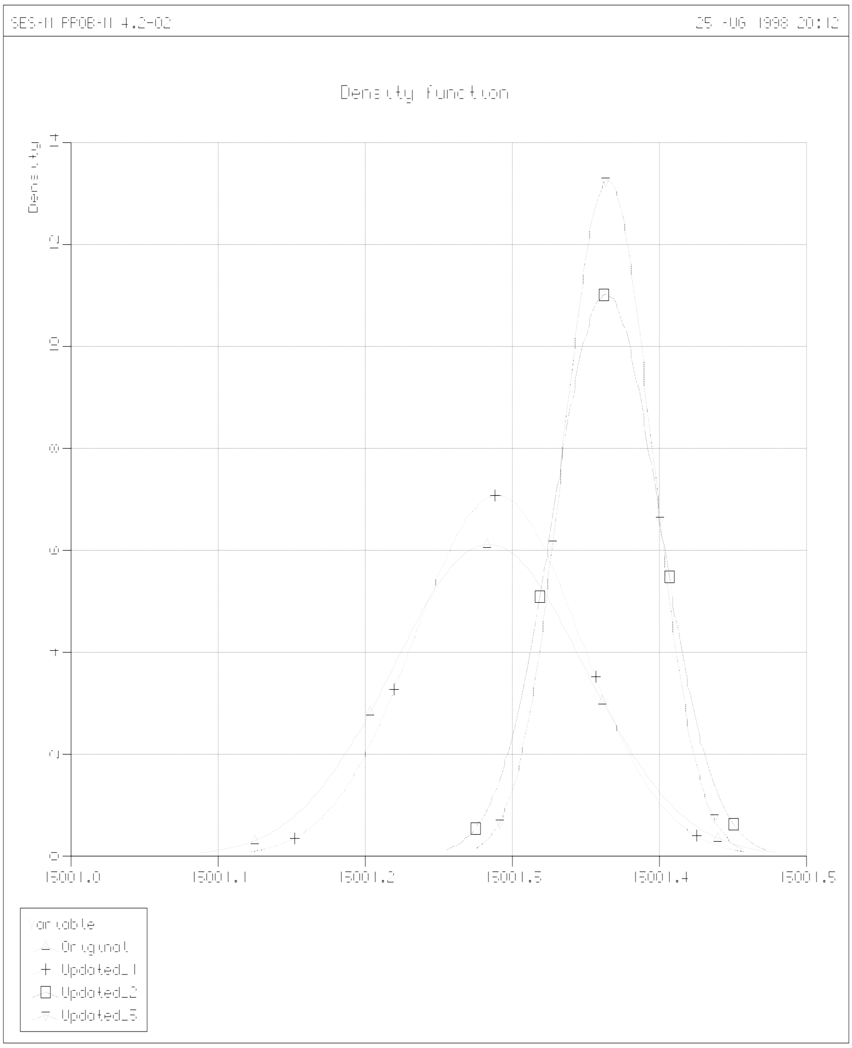

Figure 4 CASE 3: comparisons of probability density functions, for the object distance L_{ad} (m), between original (unconditioned), updated_1 (updated on one measured distance: L_{ac}), updated_2 (updated on one measured distance: L_{bd}), and updated_3 (updated on two measured distances: L_{ac} and L_{bd}).

CASE 4

In this case, there is a progressive shift of the mean, shown in Figure 5, towards higher values with successive updating. In fact, the mean of the unconditioned PDF is the closest to the true value of the object distance L_{ad}. Like CASE 3, it is observed that the mean value of the object distance L_{ad}, updated by two measured distances, is not located amid two mean values in the cases conditioned on only one measured variable. This value (13001.4076m), however, is greater than both mean values (13001.3839m and 13001.3921m) in the cases conditioned on only one measured variable. This can be explained by the fact that due to shifting of mean values into the same positive direction on updating with one measured variable, the mean value would shift further into the same positive direction on updating with two measured variables.

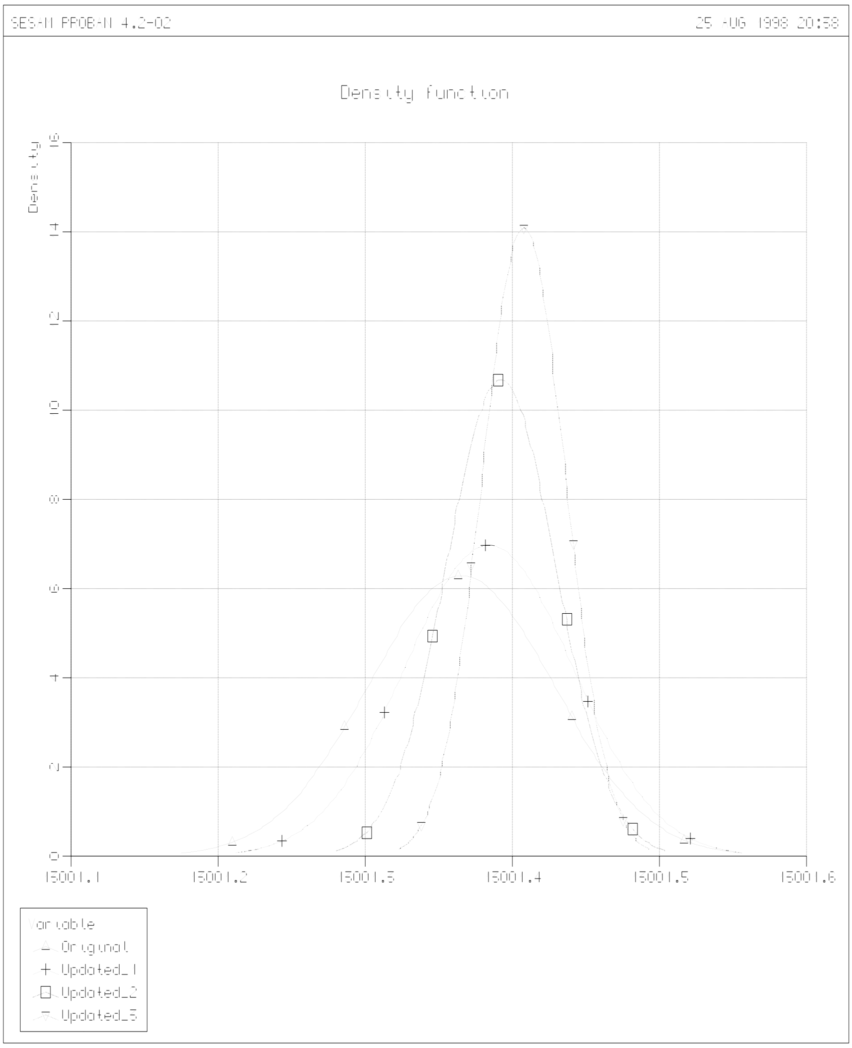

Figure 5 CASE 4: comparisons of probability density functions, for the object distance L_{ad} (m), between original (unconditioned), updated_1 (updated on one measured distance: L_{ac}), updated_2 (updated on one measured distance: L_{bd}), and updated_3 (updated on two measured distances: L_{ac} and L_{bd}).

CASE 5

Figure 6 shows the results for Case 5. In this case the mean of the unconditioned distance is close to the true result and the two separate updating calculations produce PDF's with mean values respectively above and below the unconditioned mean, but with reduced variance. With updating on two measurements, the final PDF has a significantly reduced variance and a mean very close to the true value of L_{ad}.

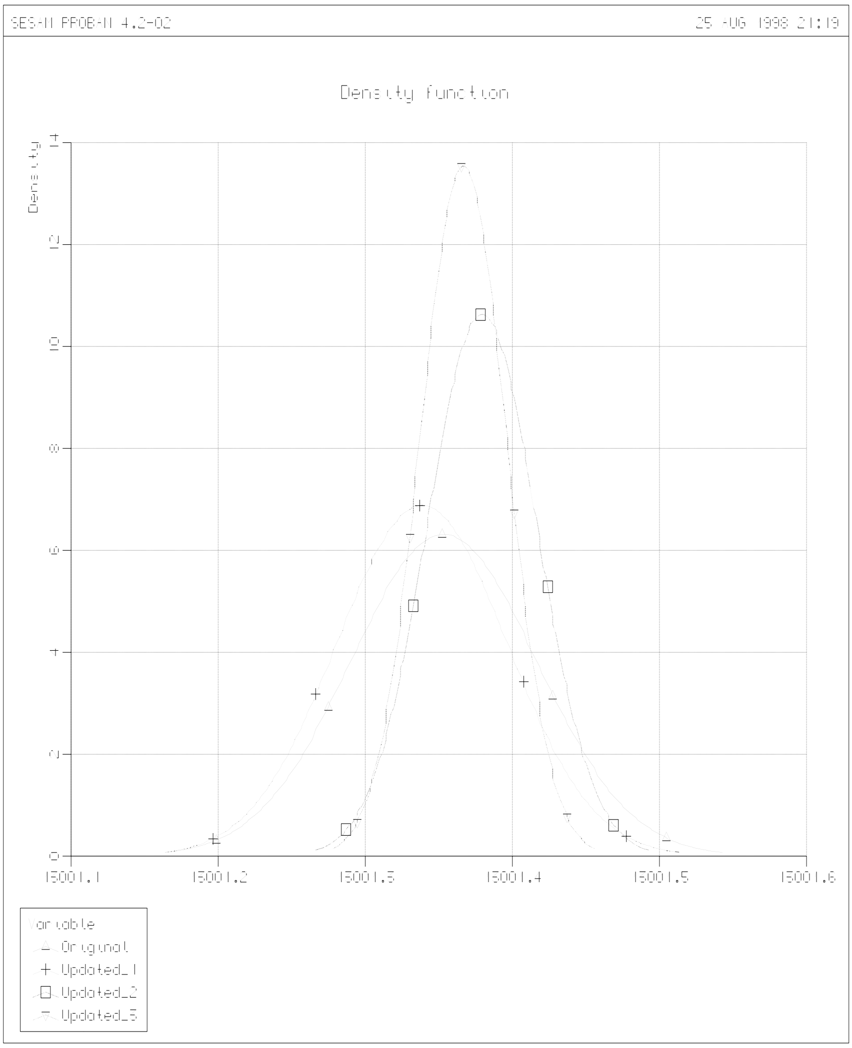

Figure 6 Comparisons of probability density functions, for the object distance L_{ad} (m), between original (unconditioned), updated_1 (updated on one measured distance: L_{ac}), updated_2 (updated on one measured distance: L_{bd}), and updated_3 (updated on two measured distances: L_{ac} and L_{bd}).

Case summary

All five cases show some common conclusions. For example, all three conditioned cases show a higher peak of PDF curves than the unconditioned case. In other words, these conditioned PDF curves show less variance than the unconditioned case. Furthermore, the object distance updated on two measured distances has a lower variance compared with those updated on one measured distance. The more information there is, the greater the reduction in the uncertainty.

However, as far as the mean values are concerned, there is a less clear pattern and the results depend on the precise value of the random errors in both the initial measured distances L_{ab} *etc.* and the additional distances L_{ac} and L_{bd} which are used for the updating calculations. Nevertheless, in spite of the shifts that occur in the updated PDFs, it appears that the reduction in variance through the updating process leads to the possibility of the exact value of the (assumed) unknown object distance being predicted with much greater accuracy. It is anticipated that the same conclusion would apply to any other systems, including structural systems.

Parametric study: effect of accuracy of the measured information

Taking CASE 2 and CASE 5 as examples, it can be concluded that the standard deviations of the object distance become smaller if smaller errors for conditioning distance are applied. In other words, accuracy of given information decreases the uncertainty of the object distance to a certain extent. In Case 2 presented in Table 1, the exact knowledge of L_{bd} leads to an object distance L_{ad} with a 5.8% lower standard deviation, compared with the approximate knowledge of L_{bd} having an error 0.015m. Similarly, exact knowledge of L_{ac} and L_{bd} lead to an object distance L_{ad} with a 18.3% lower standard deviation, compared with the approximate knowledge of L_{ac} and L_{bd} having an error 0.015m.

	Given information with errors: σ=Z×0.015 (m)	Given information with errors: σ=Z×0.00015 (m)	Given information with errors: σ=0.0 (exact knowledge)
L_{ad} given L_{ac}	5.7736E-2	5.5315E-2	5.5398E-2
L_{ad} given L_{bd}	3.6838E-2	3.5791E-2	3.4712E-2
L_{ad} given L_{ac} and L_{bd}	2.8428E-2	2.4972E-2	2.3232E-2

Note: Z is a random number in [0,1] generated by BOX's method.

Table 1 Comparisons of standard deviations in various models (CASE 2)

	Given information with errors: σ=Z×0.015 (m)	Given information with errors: σ=Z×0.00015 (m)	Given information with errors: σ=0.0 (exact knowledge)
L_{ad} given L_{ac}	5.7969E-2	5.6579E-2	5.6322E-2
L_{ad} given L_{bd}	3.7532E-2	3.3655E-2	3.2998E-2
L_{ad} given L_{ac} and L_{bd}	2.9468E-2	2.3532E-2	2.1324E-2

Note: Z is a random number in [0,1] generated by BOX's method.

Table 2 Comparisons of standard deviations in various models (CASE 5)

In Table 2 (CASE 5), exact knowledge of L_{ac} leads to an object distance L_{ad} with a 2.8% lower standard deviation, compared with approximate knowledge of L_{ac} having an error 0.015m. Meanwhile, exact knowledge of L_{ac} and L_{bd} lead to an object distance L_{ad} with a 27.6% lower standard deviation, compared with the approximate knowledge of L_{ac} and L_{bd} having an error 0.015m. These two cases effectively show the benefit of the exact knowledge of L_{ac} and L_{bd}.

Parametric study: effect of basic variables plus the measured information

For assessment, this study aimed to find the optimal information combination scheme that leads to the least standard deviation after completing reliability updating based on some extra information. It is assumed that there are two extra distances available and only one basic variable is known deterministically. The corresponding optimal combination was

(1) Precise knowledge of the measurement L_{ab};
(2) Knowledge of exact distances L_{ac} and L_{bd}.

Figures 7 shows comparisons of probability density functions for the object distance L_{ad} between Original, Updated_1, Updated_2, and Updated_3. The flattest (solid line) is a PDF curve for the unconditioned case (no extra information and no fixed basic variables). Case Updated_1 (updated on the fixed L_{ab} *plus* two measured distances: L_{ac} and L_{bd}) had the highest peak of PDF curves in all cases. In other words, the combination (the fixed L_{ab} *plus* two measured distances: L_{ac} and L_{bd}) gave the smallest standard deviation for the object distance L_{ad}. The resultant standard deviation from the optimal information combination scheme is 0.012m, about 80.8% less than that from the unconditioned reliability updating analysis. Furthermore, the resultant 90% confidence interval is [13001.32, 13001.38] (confidence interval = 0.06m), compared with [13001.21, 13001.47] (confidence interval = 0.26m) in the unconditioned case. Reliability updating decreases much of the uncertainty of the object distance L_{ad}.

If the conditioned distribution, shown in Figure 7, is considered to represent to be either a loading type parameter or a material capacity type parameter, the resultant characteristic value will be more cost-effective and unconservative than that from the corresponding design codes. Such a conclusion is based on knowledge of the parameter distribution with less variance.

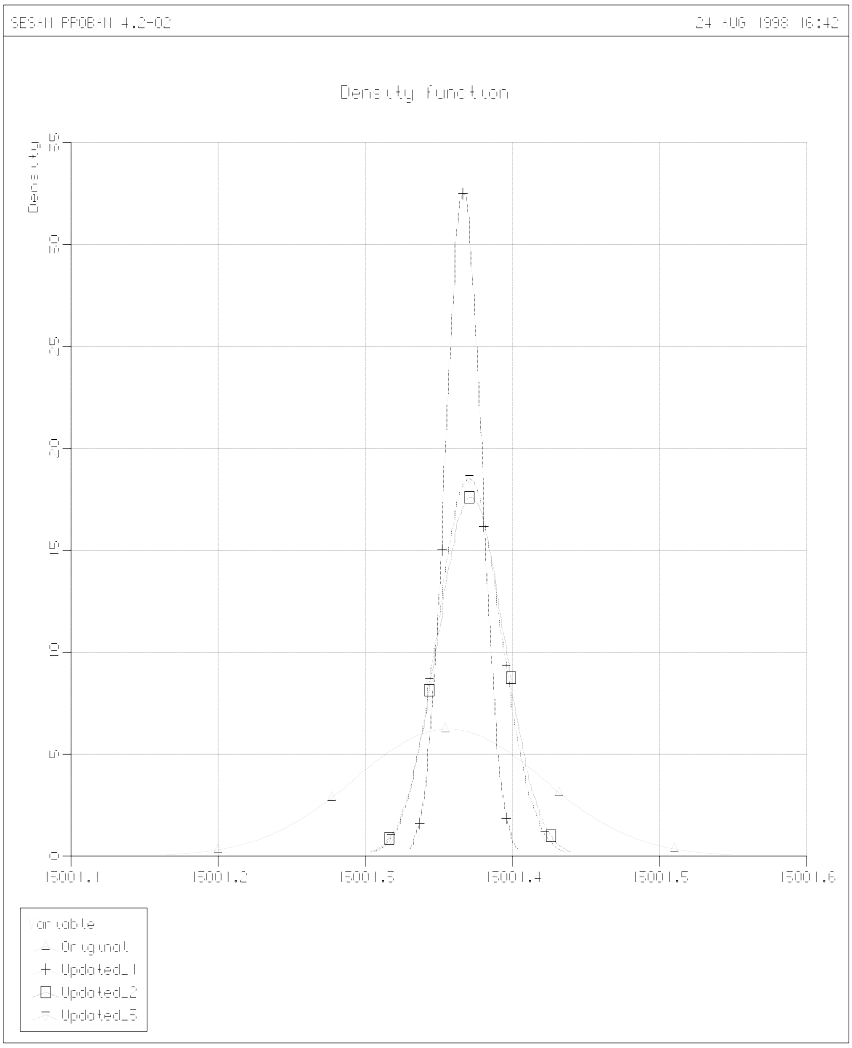

Figure 7 Comparisons of probability density functions, for the object distance L_{ad} (m), between Original (unconditioned), Updated_1 (updated on the fixed L_{ab} *plus* two measured distances: L_{ac} and L_{bd}), Updated_2 (updated on the fixed L_{ae} *plus* two measured distances: L_{ac} and L_{bd}), and Updated_3 (updated on the fixed L_{ce} *plus* two measured distances: L_{ac} and L_{bd}).

<u>Probability updating of survey network based on the measured information</u>

FORM and SORM (First and Second Order Reliability Methods) are adopted in this study. Simulation methods can also be used for such probability analyses, but take longer time to run than FORM and SORM.

For those distance survey networks, two kinds of 'failure' probability analysis of object events have been carried out. The first 'failure' event was defined as an event in which the object distance was less than some specified critical value. The second 'failure' event was defined as a union event in which the object distance was either less than some critical value or greater than another critical value.

The first 'failure' model: $P(L_{ad}<L_{cr})$

For convenience, the value of L_{cr} (or critical value of L_{ad}) was chosen to be 13001.2225m such that it will lead to an approximate reliability index of 3.0.

Due to insufficient statistical data being available (to model a real survey network), all basic variables are assumed to be statistically independent. Furthermore, no statistical dependency between basic variables and the conditioning variables (*i.e.* L_{ac} and L_{bd}) were assumed. However, such correlations could be easily incorporated. The corresponding reliability analytical results are as follows.

For this selected critical value of L_{cr} = 13001.2225m, the reliability index was computed to be 2.0828 with the 'failure' probability of 1.86E-2.

Comparisons between Unconditioned Analyses and Conditioned Reliability Index

Table 3 presents comparisons between the unconditioned and the conditioned probability analyses in various conditioning events for the selected event. Generally, the conditioned reliability indices (RI) (*i.e.* the conditioned RI on the measured distances L_{ac} and L_{bd}) are greater than that in the unconditioned case. The updating effect on the measured distance L_{bd} is greater than that on the measured distance L_{ac} in terms of the reliability index improvement. In other words, the accuracy of the measured distance L_{bd} has a greater effect in reducing the assessment uncertainty in the predicted distance survey model, compared with the accuracy of the measured distance L_{ac}. In terms of importance, distance L_{bd} is a more important measurement than distance L_{ac} in the reliability updating.

	Reliability index	Probability
(L_{ad} - L_{cr} <0) unconditioned	2.0828	1.86E-2
(L_{ad} - L_{cr} <0) given L_{ac}	1.9909	2.32E-2
(L_{ad} - L_{cr} <0) given L_{bd}	4.5000	3.40E-6
(L_{ad} - L_{cr} <0) given L_{ac} and L_{bd}	6.1434	4.04E-10

Table 3 Comparisons of reliability index and probability in various conditioning events for 'failure' probability: $P[(L_{ad} - L_{cr}) < 0]$

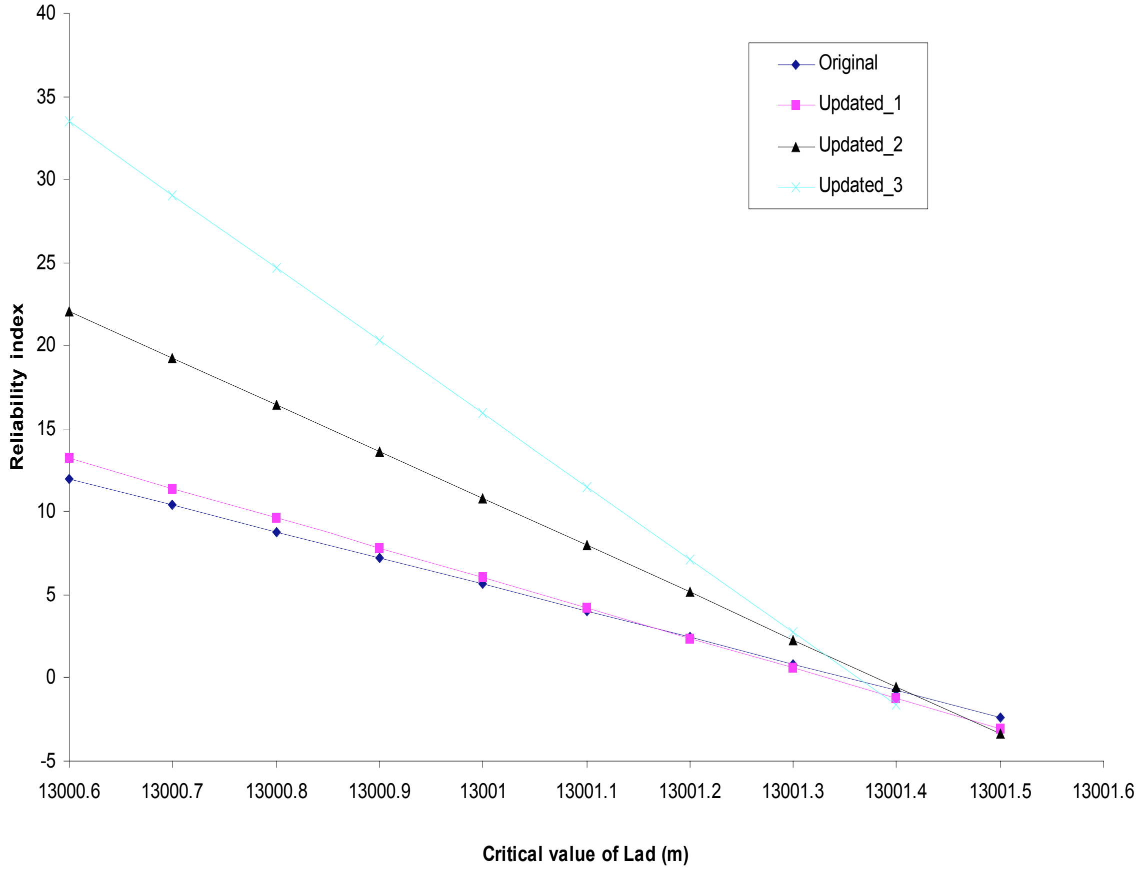

Figure 8 Reliability index comparisons of event (L_{ad} - L_{cr} < 0) between Original (unconditioned), Updated_1 (conditioned on the measured L_{ac}), Updated_2 (conditioned on the measured L_{bd}), and Updated_3 (conditioned on both measured distances: L_{ac} and L_{bd}).

Figure 8 shows reliability index comparisons of event (L_{ad} - L_{cr} < 0) between various conditioning environments: Original (unconditioned), Updated_1 (conditioned on the measured L_{ac}), Updated_2 (conditioned on the measured L_{bd}), and Updated_3 (conditioned on both measured distances: L_{ac} and L_{bd}). Up to a critical value of L_{cr} of 13001.1m, all conditioned reliability indices are greater than the unconditioned ones, which demonstrates the benefits of applying reliability updating techniques for this particular configuration. At L_{cr} = 13001.1m, for example, the RI for the unconditioned case (Base case) is 4.04, while the reliability indices for the conditioned case are 4.20 (Updated_1), 7.96 (Updated_2), and 11.52 (Updated_3) respectively. The RI improvements are 3.96% (Updated_1), 97.03% (Updated_2), and 185.15% (Updated_3) respectively, compared with the base case (unconditioned).

The second 'failure' model: $P[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$

In the distance survey network, a 'failure' event was defined to be a union event in which the object distance was either less than one critical value of it or greater than the other critical value. The acceptable probability level is assumed to be 5.0×10^{-3} (corresponding to $\beta\approx2.58$).

Table 4 shows comparisons of the reliability index and probability in various conditioning events for 'failure' probability models: $P[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$: L_{cr1}=13001.2025m and L_{cr2}=13001.5025m. All conditioned reliability indices (*i.e.* β=2.4416, 3.4051, and 5.6694, respectively) are greater than the unconditioned one (*i.e.* β=2.1261). Extra data, *i.e.* the measured distances L_{ac} and L_{bd}, are helpful in reducing the uncertainty in the object distance L_{ad}. The allowable probability level is taken to be the 5.0×10^{-3} ($\beta\approx2.58$) and the unconditioned union event $[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ is the 'failure' event.

Meanwhile the same event, conditioned on the measured distance L_{bd} or on the given L_{ac} and L_{bd}, is a 'safe' event, due to the corresponding index being greater than the allowable probability level 5.0×10^{-3}.

Event	Reliability index β	Probability
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ unconditioned	2.1261	1.67E-2
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ given L_{ac}	2.4416	7.31E-3
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ given L_{bd}	3.4051	3.31E-4
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ given L_{ac} and L_{bd}	5.6694	7.17E-9

Table 4 Comparisons of the reliability index and probability in various conditioning events for 'failure' probability models

Table 5 shows comparisons of reliability index and probability in various conditioning events for 'failure' probability models: $P_f[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$: L_{cr1}=13001.1525m and L_{cr2}=13001.5525m. All conditioned reliability indices (*i.e.* 3.3914, 4.8176, and 7.8698) are greater than unconditioned one (*i.e.* 2.9836). Extra data, or the measured distances L_{ac} and L_{bd}, are therefore helpful in reducing the uncertainty of the object distance L_{ad}.

	Reliability index	Probability
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$	2.9836	1.42E-3
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ given L_{ac}	3.3914	3.48E-4
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ given L_{bd}	4.8176	7.30E-7
$[(L_{ad}<L_{cr1}) \cup (L_{ad}>L_{cr2})]$ given L_{ac} and L_{bd}	7.8698	1.86E-15

Table 5 Comparisons of the reliability index and probability in various conditioning events for 'failure' probability models

From Tables 4 and 5, reliability updating effect using the measured distance L_{bd} is observed to be greater than that on the measured L_{ac} in terms of the reliability index improvement.

Effect of Model Uncertainty on Reliability Updating Techniques

In this section, the effects of model uncertainties on reliability updating techniques were studied in analytical models for object distance L_{ad}, conditioning distances such as L_{ac} and L_{bd}. It is worth mentioning that such model uncertainties are imaginary because actual analytical models are exact, or without uncertainties. However, it is this characteristic that separates the effect of model uncertainties from the effect of other uncertainties (*i.e.* statistical parameters and correlation coefficients of basic input variables) of exact models on reliability updating techniques.

All sources of model uncertainty are included together in this study by using a combined model uncertainty factor with a mean of 1.0 and a changeable coefficient of variation. The corresponding COVs were assumed to be 0.00001%, 0.0001%, 0.001%, 0.01%, 0.1%, 1.0%, and 10% for a parametric study on the COV of the model uncertainty variables.

As far as the measurement of extra information used to do reliability updating is concerned, there also exists randomness and uncertainty. Randomness in extra information, in general, is associated with the inherent variability in the characteristics of the distance survey network. Uncertainty of extra information depends on the model applied. For convenience, the measurement uncertainty is described by a combined factor with a mean of 1.0 and a changeable coefficient of variation.

Without loss of generality, the basic variables were assumed:

L_{ab}=normal(Mean, StD: 9000.0061,1.5E-2)
L_{ae}=normal(Mean, StD: 11000.0099,1.5E-2)
L_{be}=normal(Mean, StD: 6999.9954,1.5E-2)
L_{cd}=normal(Mean, StD: 10999.9973,1.5E-2)
L_{ce}=normal(Mean, StD: 5999.9908,1.5E-2)
L_{de}=normal(Mean, StD: 7000.0071,1.5E-2)

Detailed analyses are described below.

Effect of the COVs of the uncertainty coefficient Xm_{ad} for Distance L_{ad} on the distribution analysis of Distance L_{ad}

As no statistical data were available, the model uncertainty coefficient Xm_{ad} was assumed to be normally distributed with a mean of 1.0 and a changeable coefficients of variation from 0.00001% to 10.0%. The corresponding parametric study was carried out on the uncertainty coefficient Xm_{ad}.

	Estimated mean (m)	Estimated standard deviation (m)
Xm_{ad}•L_{ad} with the COV of Xm_{ad} = 10.0%	12981.9079	1289.7440
Xm_{ad}•L_{ad} with the COV of Xm_{ad} = 1.0%	13000.6685	132.1166
Xm_{ad}•L_{ad} with the COV of Xm_{ad} = 0.1%	13001.2024	12.9324
Xm_{ad}•L_{ad} with the COV of Xm_{ad} = 0.01%	13001.3413	1.3044
Xm_{ad}•L_{ad} with the COV of Xm_{ad} = 0.0001%	13001.3526	0.1431
Xm_{ad}•L_{ad} with the COV of Xm_{ad} = 0.00001%	13001.3529	0.0643
L_{ad} with the COV of Xm_{ad} = 0.0 (no model uncertainty)	13001.3531	0.0624

Table 6 Distribution analysis of Distance L_{ad}: Xm_{ad} = uncertainty coefficient of distance L_{ad}

Table 6 shows distribution analysis results of distance L_{ad} with various uncertainty coefficients of distance L_{ad}. The greater the COV of Xm_{ad}, the higher the estimated standard deviation and the lower the estimated mean values (or the more the mean shifted from the mean without the model uncertainty). It is worth mentioning that the estimated standard deviation at the COV of Xm_{ad} = 0.00001% is close to the standard deviation without the model uncertainty.

Effect of the COVs of the uncertainty coefficient Xm_{ad} for Distance L_{ad} on the probability analyses

In this section, a parametric study on the COV of the uncertainty coefficient Xm_{ad} for distance L_{ad} was carried out, assuming the COVs of both L_{ad} and L_{ac} are fixed to be 1.0^{-6}.

Table 7 shows unconditioned probability analyses in terms of various COVs of Xm_{ad}. The greater the COV of Xm_{ad}, the greater the failure probability and the smaller the estimated reliability index. It is worth mentioning that the reliability index at the COV of $Xm_{ad} \leq 0.00001\%$ (*i.e.* a small model uncertainty) is close to the reliability index without the model uncertainty. At the COV of $Xm_{ad} \geq 0.01\%$ (*i.e.* a significant model uncertainty), the failure probability is close to 50.0%.

	FORM reliability index	FORM probability
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 10.0%	0.0001	5.00E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 1.0%	0.001	5.00E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.10%	0.01	4.96E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.01%	0.1003	4.60E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.001%	0.9047	1.83E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.0001%	2.0394	2.07E-2
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.0% (*i.e.* without model uncertainty)	2.0828	1.86E-2

Note: the SORM results are very similar to the FORM results.

Table 7 Unconditioned probability analyses in term of various COVs of Xm_{ad}

	FORM reliability index	FORM probability
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 1.0%	0.0009	5.00E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.10%	0.0093	4.96E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.01%	0.0924	4.63E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.001%	0.8422	2.00E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.0001%	1.9876	2.34E-2
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.00001%	2.0346	2.09E-2
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.000001%	2.0351	2.09E-2

Table 8 Conditioned probability analysis: CASE 1 (given the measured distance L_{ac}) and Xm_{ac} = normal(Mean, COV: 1.0, 0.0001%)

Table 8 shows results from the conditioned probability analysis in CASE 1 (given the measured distance L_{ac}). It can conclude that the corresponding reliability indices conditioned on the measured distance L_{ac} are less than the unconditioned reliability indices.

	FORM Reliability index	FORM probability
($Xm_{ad} \bullet L_{ad}$ - L_{cr} <0) with the COV of Xm_{ad} = 1.0%	0.0012	5.00E-1
($Xm_{ad} \bullet L_{ad}$ - L_{cr} <0) with the COV of Xm_{ad} = 0.10%	0.0120	4.95E-1
($Xm_{ad} \bullet L_{ad}$ - L_{cr} <0) with the COV of Xm_{ad} = 0.01%	0.1197	4.52E-1
($Xm_{ad} \bullet L_{ad}$ - L_{cr} <0) with the COV of Xm_{ad} = 0.001%	1.1441	1.26E-1
($Xm_{ad} \bullet L_{ad}$ - L_{cr} <0) with the COV of Xm_{ad} = 0.0001%	3.6973	1.09E-4
($Xm_{ad} \bullet L_{ad}$ - L_{cr} <0) with the COV of Xm_{ad} = 0.00001%	3.8853	5.11E-5
($Xm_{ad} \bullet L_{ad}$ - L_{cr} <0) with the COV of Xm_{ad} = 0.000001%	3.8873	5.07E-5

Table 9 Conditioned probability analysis: CASE 2 (given the measured distance L_{bd}) and Xm_{bd} = normal(Mean, COV: 1.0, 0.0001%)

Table 9 shows results from the conditioned probability analysis in CASE 2 (given the measured distance L_{bd}). The corresponding unconditioned reliability index is 2.0394. Comparison between Tables 8 and 9 shows that the reliability updating effect (or, the decrease in the variance of the object event) is greater when using the measured distance L_{bd} than when using the measured distance L_{ac}.

Table 10 shows results from the conditioned probability analysis in CASE 3 (given the measured distances L_{ac} and L_{bd}). Note that the corresponding unconditioned reliability index is 2.0394. The conditioned reliability index at the COV of Xm_{ad} ≤ 0.0001% (*i.e.* a small model uncertainty) is greater than that, or 2.0394, in the unconditioned reliability analysis. At the COV of Xm_{ad} ≥ 0.01% (*i.e.* a large model uncertainty), the FORM or SORM failure probability is close to 50.0%.

	FORM Reliability index	FORM probability
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 1.0%	0.0011	5.00E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.10%	0.0112	4.96E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.01%	0.1120	4.55E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.001%	1.0824	1.40E-1
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.0001%	3.9070	4.67E-5
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.00001%	4.1655	1.55E-5
($Xm_{ad} \bullet L_{ad} - L_{cr} < 0$) with the COV of Xm_{ad} = 0.000001%	4.1684	1.53E-5

Table 10 Conditioned probability analysis: CASE 3 (given the measured distances: L_{ac} and L_{bd}), Xm_{ac} = normal(Mean, COV: 1.0, 0.0001%), Xm_{bd}=normal(Mean, COV: 1.0, 0.0001%)

Concluding remarks on the model uncertainty

The main conclusions can be summarized as follows:

(1) In the presence of model uncertainties, the object distance variance is definitely greater than that without model uncertainties.

(2) If the model uncertainty is far greater than the uncertainty in the basic variables (say, 1.0 *versus* 1.0×10^{-3}), the resulting reliability index will be close to 0.0 (failure probability of the specified event ≈ 50.0%).

(3) For a distribution analysis, the greater the COV of the model uncertainty coefficient, the higher the estimated standard deviation.

Conclusions

A study has been undertaken to examine the properties of an engineering system whose ‘response’ is a function of a number of variables and a model uncertainty parameter.

The survey network used here is simply an analogue for some structural system (*e.g.* a bridge) but with clearly defined properties that can be easily understood and studied. The predicted ‘response’ of the system is a calculated distance which deviates in some way from the true distance, which in this study is assumed to be known. The variation in the calculated distance from the true distance represents the variation in the predicted response from the true response (*e.g.* collapse load, deflection greater than some specified limit, fatigue life, etc) of the real structure.

The uncertainty in the prediction of the true response is a function of the uncertainties in the input variables and the model uncertainty, or uncertainties present. The model uncertainties represent the effect of modelling a *real* (and indeed infinitely complex) engineering system with what in most cases is a highly simplified mathematical model of reality.

The updating procedure in the survey network analogue corresponds to the inclusion of some additional 'redundant' observations of distances. The additional information provided by these measurements is, to a certain extent, always incompatible with the original information (equivalent to a lack of fit in a statically indeterminate structure) but has to be accommodated, probabilistically, into the data set that already exists. This is the updating process.

The purpose of this part of the research has therefore been to find a way in which the benefits of reliability updating may be explored on a sound theoretical basis. The knowledge gained can be transferred directly to structural systems, as the representation of the corresponding 'failure boundaries' in multi-variate standard normal space is identical to that of a structural system (or indeed any other engineering, or other, system), only differing in the detail and the magnitudes of the sensitivity or importance factors of the variables.

A number of specific conclusions have been reached in relation to the survey network analysis:

(1) In nearly all cases, the introduction of more information through the updating process leads to a reduction in the variance of the estimate of the object parameter (in this case a known distance).
(2) Updating with two pieces of independent information typically leads to a greater reduction in the variance of the estimate of the object parameter than the incorporation of either item separately. However, if the two pieces of additional information conflict in some way, then a decrease in variance may not result.
(3) The mean value of the estimate of the object parameter may deviate further from the exact value of the parameter after updating than before, but it depends by how much the pre-updating estimate deviates from the true value in the first place.
(4) The effect of the reduction in variance is likely to be much more important than any shift in the mean value of the estimate of the object parameter when using the updating process to provide increased confidence that the object parameter does not lie outside some particular confidence interval.
(5) This result is of particular importance in updating the probability that, for example, the load-carrying capacity of a bridge is greater than some required value.
(6) The influence of model uncertainty on the reliability updating calculations has been studied, and some important conclusions have been reached. Perhaps not surprisingly, it has been shown that when the variance of the estimate of the object parameter falls below a value corresponding the residual model uncertainty in the 'response' calculation model, little additional benefit can be gained by reliability up-dating. This has practical implications for the effectiveness of proving load tests and indicates the need for finding ways of reducing the model uncertainty associated with engineering normal calculations. However, when large model uncertainties exist and cannot be removed, safety can only be assured by designing and assessing structures by incorporating a model uncertainty-related partial safety factor corresponding to a small fractile of the model uncertainty distribution – *e.g.* $F_{X_m}^{-1}(P_f)$ in the extreme case, where P_f is an acceptable target failure probability.
(7) The study has shown the way forward for a means of calculating the confidence that can be placed in a single up-dating calculation following, for example, a load proving test on a bridge.

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References

Ang, A. H-S. & Tang W. (1975). Probability concepts in engineering planning and design. Vol. 1, John Wiley & Sons, New York.

Baker, M. J. & MacGregor, B. W. (1996). Reliability-based proving load tests for bridges. Int. Sym. Safety Bridges, London.

Benjamin, J. R. & Cornell, C. A. (1970). Probability, statistics, and decision for civil engineers. McGraw-Hill Inc., New York.

Box, G. E. P. & Muller, M. E. (1958). A note on the generation of normal deviates. Ann. Math. Stat., 29, pp. 610 – 611.

der Kiureghian, A. (1989). Measures of structural safety under imperfect states of knowledge. J. Struct. Div., ASCE, 115(5), pp. 1119-1140.

Det norske Veritas (1992). Sesam PROBAN general purpose probabilistic analysis program user's manual, Veritas Sesam System A.S.

Enright, M. P. & Frangopol, D. M. (1998). Service-life prediction of deteriorating concrete bridges. Journal of Structural Engineering, ASCE, 124(3), pp. 309 - 317.

MacGregor, B. A. (1994). The reliability assessment of bridges. Undergraduate honours project, Univ. Aberdeen.

MacGregor, B. A. (1997). Reliability updating: application to a composite bridge deck. MSc Thesis. Aberdeen University.

Martz, H.F. & Waller, R. A. (1982). Bayesian reliability analysis. John Wiley & Sons, London.

Thoft-Christensen, P. & Baker, M. J. (1982). Structural reliability theory and its applications. Springer Verlag, London.

Val, D. V., Bljuger, F. & Yankelevsky, D. Z. (1997a). Reliability assessment of damaged RC framed structures. J. Struct. Engrg, ASCE, 123(7), pp. 889-895.

Val, D. V. & Melchers, R. E. (1997b). Reliability of deteriorating RC slab bridges. J. Struct. Engng, Vol. 123, No. 12, Am. Soc. Civ. Engng, pp. 1638-1644.

INTEGRATING SAFETY INTO PRODUCTION PLANNING AND CONTROL: AN EMPIRICAL STUDY IN THE REFURBISHMENT OF AN INDUSTRIAL BUILDING

Saurin, Tarcisio A. LOPP/UFRGS (Products and Processes Optimization Laboratory, Federal University of Rio Grande do Sul)
Formoso, Carlos T. NORIE/UFRGS (Building Innovation Research Group, Federal University of Rio Grande do Sul)
Guimarães, Lia B.M. LOPP/UFRGS
Soares, Alexandre C. NORIE/UFRGS, BSF Engenharia

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Safety, production planning and control, operations management, macro-ergonomics

Introduction

In spite of the high costs of work accidents (Hinze, 1991), many construction companies in Brazil adopt as their only safety management strategy being in compliance with safety mandatory regulations. In Brazil, the main regulation related to construction industry is the NR-18 standard (Work Conditions and Environment in the Construction Industry). However, compliance with these standards might not be sufficient to guarantee excellence in safety performance, since they cover only minimal acceptable preventive actions. This statement is also applicable to regulations on safety and health management systems, such as OHSAS 18001 (Occupational Health and Safety Management Systems). Like quality systems standards, OHSAS 18001 also does not establish performance targets, but is concerned with the compliance to some managerial routines.

Safety planning appears as a core requirement at OHSAS 18001 as well as at NR-18. From one hand, OHSAS 18001 safety planning requirements consist of a risk management cycle, involving the continuous risk identification, evaluation and control. On the other hand, NR-18 (like similar regulations in many other countries) requires the elaboration of a safety and health plan, named PCMAT (Plan of Conditions and Work Conditions in the Construction Industry), which has a minimal mandatory scope. Since NR-18 was established in 1995, most companies produce the PCMAT only to avoid fines from governmental inspectors and do not effectively use it as a mechanism for managing site safety. Its main shortcomings are presented below:

a) PCMAT implementation is usually regarded as an extra activity to managers, since it is not integrated to routine production management activities. NR-18 does not require its integration to other plans, except for site layout planning;

b) Safety experts (usually external from the company) produce it and normally there is no involvement of production managers, representatives of subcontractors or workers;

c) PCMAT does not usually take into account the uncertainty of construction projects. A fairly detailed plan is produced at the beginning of the construction stage and it is not usually updated during the production stage. The lack of update is caused by another common problem: the absence of formal control;

d) PCMAT emphasizes physical protections, normally neglecting the necessary managerial actions (for instance, implementing proactive performance indicators) for achieving a safe work environment; and

e) PCMAT does not induce risk elimination through preventive measures at the design stage.

Such shortcomings in both conception and implementation of mandatory plans indicate that it is necessary to improve safety planning and control (SPC) methods, beyond what is required by the regulations. Some studies that have investigated causes of accidents and good practices to avoid them support this statement. Suraji and Duff (2000), for example, based on the analysis of approximately five hundred accidents in the UK, found that planning and control failures contributed 45.4% of the accidents. Consistent with these findings, a study carried out at the Construction Industry Institute (Liska *et al*, 1993) found that, among several preventive actions that had been used by the industry, detailed safety planning was the most effective one towards achieving the zero accident target. However, that study did not provide details on how safety planning worked in the companies that were investigated.

The integration of safety into planning has been studied by a number of authors such as Ciribini and Rigamonti (1999) and Kartam (1997). However, those research studies have been limited to the introduction of safety measures into construction plans, using CPM or line of balance planning techniques. This approach tends to have not much impact, since it has been accepted that planning should not be limited to the application of techniques for generating plans. By contrast, planning should be treated as a broader managerial process composed by several stages, including data collection, implementation of corrective actions, and information diffusion (Laufer and Tucker, 1987). These stages, as well as some of the main requirements for effective production planning and control, such as hierarchical decision making, cooperation, continuity and systemic view (Laufer *et al*, 1994), are also requirements for safety management. This indicates that there are several similarities between those two processes.

Thus, there seems to be an opportunity for improving SPC methods, based on concepts and principles that have been successfully used in production planning and control (Ballard, 2000; Hopp and Spearman, 1996; Laufer *et al*, 1994; Laufer and Tucker, 1987). This paper aims to devise a model for SPC, integrated to the production planning and control process. The model was tested in an empirical study, which is reported in the following sections.

Context of the Empirical Study

Description of the site

The empirical study took place in the refurbishment of a steel mill building, in the Metropolitan Region of Porto Alegre, South of Brazil. The construction project was carried out by a small sized construction company, involving six main processes: (a) demolition and construction of the roof, (b) substitution of the windows, (c) demolition of external walls, (d) construction of brick walls, (e) wall plastering and painting, and (f) structural repairs in columns and beams. The peak number of workers in the site was around fifty.

The construction stage took around six months. The implementation of the model took place during the first four months of the project. As in most industrial refurbishment projects, the steel mill production was not interrupted to allow the construction project to be undertaken. In this situation, the steel mill health and safety risks also affected construction workers. The most important risks in the existing mill were: (a) noise level (110 dBA), specially near blast furnaces while these were working, (b) widespread dust, (c) heavy vehicle traffic, and (d) blast furnaces chemical reactions, which sometimes expelled some melt iron around them. Besides, the main steel mill building was relatively old, and had not been designed for performing maintenance and repairs easily. Such constraints made this a high risk project, especially in terms of safety issues. In order to comply with contractual requirements, the construction company assigned a safety specialist to work full time on the site.

Existing production planning and control process

The construction company had a fairly well structured production planning and control system, based on the Last Planner Method (Ballard, 2000). There were four hierarchical planning and control levels: one-week or one-day short-term commitment planning, three-week look-ahead planning, and long-term planning, that was concerned with the whole construction stage.

At the short-term level, work packages were assigned to different gangs, and an initial negotiation concerned the release of working areas took place in weekly meetings. Due to the variability of the work environment, caused by the interference between the steel mill production and the construction process, weekly plans needed to be reevaluated in daily meetings. In such meetings, the final definition of working areas for each crew was made, and, based on that, the client provided work permits. The PPC -

Percentage of Plans Completed - indicator (Ballard, 2000) was collected on both weekly and daily basis.

Regarding the look-ahead planning level, its main function was support the removal of constraints related to work packages. A three-week plan was produced weekly, containing a list of constraints (e.g. space, materials, labour and equipment), and the deadline for its removal. Finally, the master plan, including the whole construction project was updated on a monthly basis. Based on the long-term plan, an initial resource schedule was produced - this was updated through the look-ahead constraints analysis. The site layout was roughly defined before starting construction.

Empirical Study Development

An action-research strategy was adopted in this research project. The aim of the study was to devise and test the SPC model through its implementation in a real project. The construction company was particularly interested in successfully implementing SPC, since many of their clients have strict safety requirements. The implementation of the model in the construction project was co-ordinated by the contractor's quality manager. The stages of the empirical study are presented in following sections.

Integration to long-term planning

Long-term safety planning was carried out based on the construction stages established in the long-term production plans as a basis. For each construction stage (i.e. demolition and construction of the roof, replacement of the windows, etc.) a plan was produced using the technique of preliminary hazard analysis (PHA). PHA is a widely used tool in safety planning (Kolluru *et al*, 1996) dealing with three out of the four major stages of risk management: risk identification, risk evaluation and risk response. Risk monitoring is the fourth one. These four stages together correspond to the risk management cycle (Baker *et al*, 1999) that should be repeated throughout the project.

Although one safety plan has been made for each stage of the construction, this is not necessarily a general rule. If an activity takes place in different construction stages, it might be better to produce a specific plan for it. For instance, if welding performed several stages, it is easier to produce a specific safety plan for this activity instead of including its risks into several PHA. Besides the plans were directly related to productive activities, also two additional types of safety plans were produced: a plan for the risks in temporary facilities (lodges and bathrooms), and a plan for the risks in the circulation areas of the site - the majority of the risks in the latest category were related to the steel mill operation.

Safety plans were produced by a working team, which was formed by the site manager, the safety specialist, a representative of the research team, subcontractors, and representatives of the steel mill management. The participation of different stakeholders was important, since they could provide different insights about risks, allowing safety plans to be more realistic and effective. The main steps for producing the safety plans are presented below:

a) establish the necessary steps to carry out the activity: both conversion (for instance, place bricks on the wall) and flow (for instance, moving or storage of materials) should be considered, as suggested by Koskela (2000);

b) identify the risks: this must include risks of any nature, i.e. - health risks, ergonomic risks, environmental risks, etc. - in each step of the process. This is a critical task, since if a risk is not identified it cannot be controlled. The effort to identify risks can be more successful if this activity uses supporting tools such as check-lists and brainstorming, as well as technical literature or plans from past projects (Baker *et al*, 1999). In order to establish a common language for all plans, it is also helpful to adopt a risk classification (e.g. caught in, stuck by, etc.) at this stage. In addition, different stakeholders should be involved, as mentioned above, since they are all valuable sources of information;

c) define how each risk will be controlled: considering that safety control will be based on what has been written down in the plans, it is important not to establish a control if there are no resources to apply them or if they are not considered to be necessary. Although the aim should be to eliminate all risks, such objective will be rarely possible and residual risks will always remain. The solution is to put such residual risks within an acceptable level. Managers are the ones who must decide what is acceptable or not (obviously, following regulations as minimal requirements). In this study, an informal risk evaluation procedure for establishing the magnitude of the safety measures was adopted. A formal risk evaluation procedure was considered not to be cost-effective at this stage, due to the subjectivity involved in this activity (Tah, 1997). A formal risk evaluation was only used to re-evaluate controls after near misses or accidents, as explained later in this paper.

Considering that construction is a dynamic environment, procedures were established to update safety plans when necessary. Such updates took place through the integration of safety planning and look-ahead and short-term production planning. At these planning levels, it is easier to anticipate risks and to evaluate the impact of the production methods on safety than at the long-term planning level.

Integration to look-ahead planning

Safety constraints were systematically included in the look-ahead constraints analysis, which took place in a three week basis. At this level of planning, only the production manager, the safety specialist and a member of the researcher team were involved. Four types of safety constraints were identified: training, collective protections, design of safety facilities and space in the steel mill building. Personal Protective Equipment (PPE) was not considered as a constraint since this was readily available from the site warehouse.

Considering five weeks of constraints analysis, safety constraints represented, on average, 41 % of all constraints. Safety related space constraints corresponded to 20 %. In this way, safety constraints were made more visible in advance, avoiding stoppages of construction processes.

Integration to short-term planning

At this level, safety measures were discussed in both weekly and daily planning meetings. Such meetings were effective for discussing safety issues, since most key people involved in production management were involved. Production methods were discussed and detailed, providing an additional opportunity to evaluate their impact on safety. Also, the meetings were useful to report near misses or any other safety or production problem. In addition, safety and production performance indicators were presented and discussed.

If a new risk was identified or risk control measures were changed, this information was used to update the safety plans and retrain workers. Such changes were documented in a specific form (Table 1), and copies were distributed to the steel mill management and subcontractors, as attachments to the plans.

Data	Nº PHA	Risk	Control
01/03/29	PHA 06	Break energy cables during windows demolition *(the cables are inside the building)*	Remove windows from inside to outside

Table 1 Form to document changes in safety planning, for future updates

Short-term planning also provided an opportunity to apply one of the core techniques of the Last Planner method, shielding production. Such technique recommends that a work package must only be assigned if five quality requirements have been fulfilled: definition, soundness, sequence, size and learning (Ballard, 2000). In this study, safety was considered to be an additional requirement.

Safety control

The main performance indicator used to evaluate safety effectiveness is fairly similar to PPC (Percentage of Plans Completed). It is called **PSW (Percentage of Safe Work Packages),** indicating the percentage of work packages that were carried out 100 % safe. A work package is considered 100 % safe when all preventive measures planned have been implemented and when no accident, near miss or other unforeseen safety event has happened. The formulae used to calculate PSW is presented below:

$$PSW = \frac{\sum \text{number of work packages 100 \% safe}}{\sum \text{total number of work packages}}$$

PSW emphasizes preventive measures, since it measures the degree of safety planning effectiveness, which may influence the probability of accidents to happen. The original reasons for not followings the plans are identified and classified according to a checklist of problems. In spite of its importance, calculating PSW is relatively time consuming, since some problems can be only identified by intensive observation of the site activities, if possible on a daily basis. Regarding PSW target, it is believed that it should be higher than the one pursued in PPC, since the lack of safety can lead to an accident (or even to a delay), while a delay in the schedule does not have such a serious consequence.

Besides PSW, other performance indicators were also collected. Some of them were related to the impact of the lack of safety, such as the number of accidents and delays provoked by work stops caused by the lack of safety. However, in this research project emphasis was given to controls that had a preventive character. In this respect, two proactive indicators were proposed: (a) the degree of compliance to NR-18, and (b) a training indicator, calculated through the ratio between man-hours of training and total man-hours. The documentation and investigation of all near misses was another important preventive measure. Such events were reported by safety specialists and by PSW observers. Ideally, workers should also report such events - this could be achieved by training them to report near misses or unsafe conditions. Table 2 presents an example of a near miss investigation report.

Nº	Description	Immediate causes	Corrective actions	Severity*	Probability **	Zone
3	Mortar recipient fell down from scaffolds, due to a rolling bridge stuck, during the night	The recipient should be removed after the work has been finished	After work, all materials must be taken off scaffolds	Low	Remote	Green

* Severity if the accident takes place
** Probability of the accident to take place after the corrective actions have been implemented.

Table 2 Example of near miss investigation report

A review of safety controls took place after each near miss or accident. Such review was made through a subjective risk evaluation, adopting the risk zones presented in table 3. Due to the difficult in obtaining reliable data to calculate probability and severity accurately, authors such as Tah (1997) support the use of subjective criteria to estimate these variables. Although this is not a key element of the model, it helps to perform a systematic analysis of near misses and accidents, and establish priorities in terms of corrective actions.

PROBABILITY	SEVERITY				
	very high	high	Moderated	low	minor
extremely remote			9		
Remote	6,7			3	5
Unlikely	1		10	4	2, 8
Likely					
Frequent					

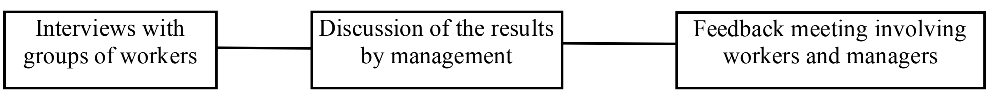
Notes:
Risk not acceptable, controls must be improved
Residual risk is in an acceptable level
Residual risk is not meaningful
- The numbers in the cells correspond to the number of the accident or near miss.

Table 3 Re-evaluation of controls after accidents or near misses

In order to evaluate the safety performance of the construction, a monthly meeting was carried out involving a director, the quality manager, the production manager and all the safety staff of the company. Such meetings were based on reports which presented performance indicator results.

Workers participation

Workers should take an active role in the SPC process, since they are its main customer. In order to get workers involved, the SPC model proposes a cycle of risk identification and control based on workers perceptions, as illustrated in figure 1.



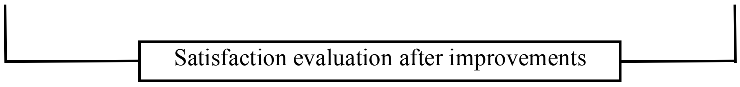


Figure 1 Risk identification and control cycle based on workers perceptions

The **first stage** involves interviews with small groups of workers. The interviews are divided in two stages: (a) an open section, in which workers are encouraged to talk about their work - not only about the tasks performed by them, but mainly about both good and bad aspects of their work, and (b) an induced section in which workers are asked to talk about specific issues. In the latter section a check-list is used, including the following topics: material handling, awkward postures, PPE, workload, relationship with colleagues and managers, food, tools, the most difficult tasks, knowledge on the environmental risks, emergence procedures and temporary facilities. When a problem is reported, workers are asked to suggest ways to solve it.

The interviews have a role to identify new risks as well as to evaluate the effectiveness of existing controls. Regarding risk identification it must be pointed out that, through the interviews, workers are prone to point out risks that are related to organizational issues, such as job enrichment, rhythm or workload. According to the macro-ergonomic approach (Hendrick, 2001), such variables have a strong influence on safety, health and productivity performance.

The **second stage** consists of discussing the results of the interviews in a meeting involving project managers (including a company director). In this meeting the first draft of an action plan aiming to solve some of the problems reported by the workers is established. The **third stage** consists of a meeting involving both workers and management. The action plan is presented by the management and discussed with the workers. A justification is presented by the management if any of the demands by the workers have not been dealt with. The meeting is also another opportunity to report both new problems and suggestions and to solve communication gaps between managers and operatives. Finally, the **fourth stage** aims to evaluate workers satisfaction after the improvements have (or have not) taken place. This evaluation is carried out in a group interview, in which new risks may be identified and controls are re-evaluated. No strict interval between interviews has been proposed in this study. However, new interviews should be carried out when new teams come into the site or after some substantial improvements have taken place.

Empirical Study Results

Safety performance indicators

Figure 2 presents the number of near misses and losses observed on site. In addition to accidents, there were three situations in which tasks did not take place due to safety failures. One of these situations illustrates the major importance of safety constraints. Crane maintenance personnel could not come into the steel mill when that machine broke down because they had not attended the safety training program provided by the client. Since this training was provided only on Mondays, the maintenance personnel had to wait for a few days before coming into the steel mill.

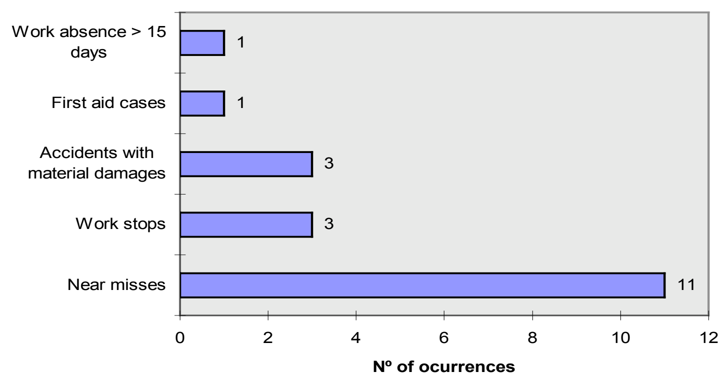


Figure 2 Losses and near misses due to lack of safety

The PSW indicator was collected in thirty two working days, between 2nd of March and 1st of June. This sample corresponded to 40,5 % of the total number of working days in that period. Such data was collected by two researchers. The decision was made not to assign this task to the safety specialist in the research project, since his observation could be biased. Figure 3 compares the evolution of PSW and PPC in the empirical study.

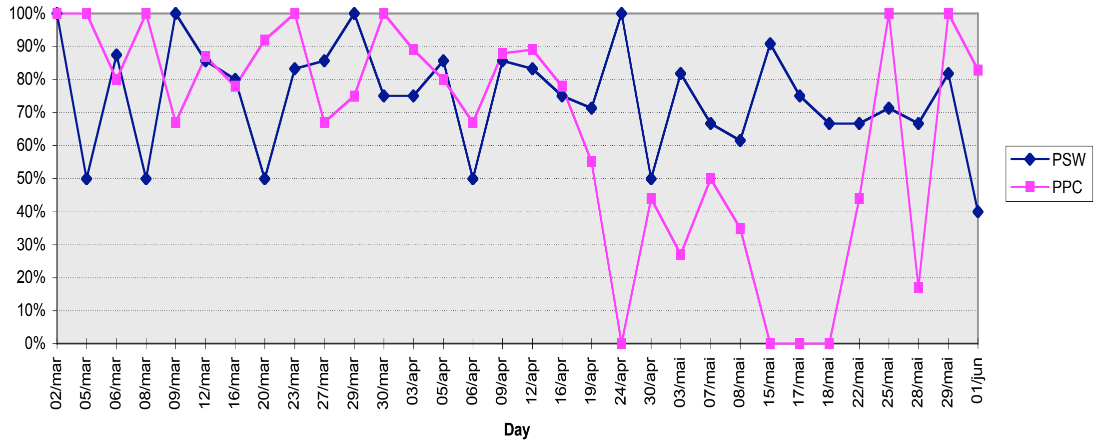


Figure 3 PSW and PPC results

PSW was on average 74,8 % (S.D. = 16,5 %), while PPC was on average 65,4 % (S.D. = 33,8 %). Sometimes PPC was higher than PSW, while in other days PSW was higher than PPC. In one study carried out by Hinze and Parker (1978) safety and productivity were not in conflict, but appeared to be dependent on each other. These authors stated that superior production performance cannot be achieved in the absence of good safety performance. According to those findings, PSW and PPC should have a positive correlation. However, no statistical correlation was found between these two indicators (*p-value = 0,7*).

Similarly to the Last Planner Method, the reasons for not followings the plans were analysed. Figure 4 indicates that failures in collective protections planning were the main problem. Many problems have been included in this broad category, such as the lack of isolation under scaffoldings and the lack of supports on ladders. However, the main problem within this category (32 % of the problems) was failure in the arrangement of cables to tie body harnesses. Often, such cables were not properly installed in both length and directions needed to allow workers to move easily move on the roof.

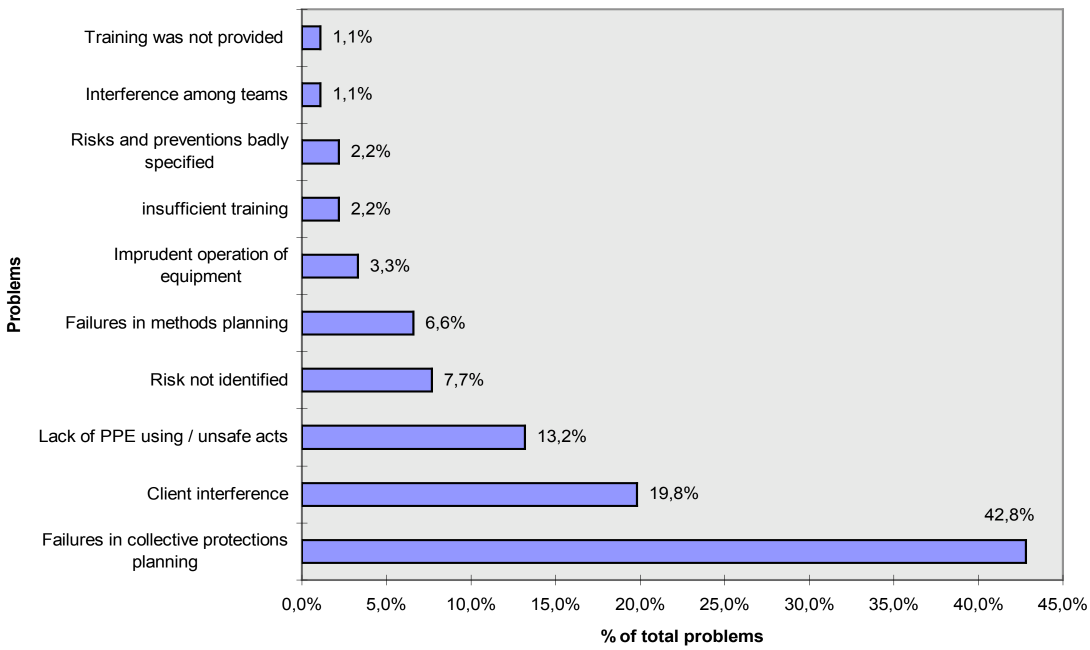


Figure 4 Reasons for not following safety planning

The category client interference involved situations in which the steel mill production did not allow the complete installation of the physical protections or when construction activities took place near a dangerous area inside the building. Although work permits were provided daily, it did not mean that steel mill activities were completely stopped in the construction area. Regarding unsafe acts, it must be pointed out that four workers were removed from the site by client representatives, because they were found working without body harnesses. However, this procedure was not fully effective since they did not carry out a detailed investigation to check why those workers were not using the harnesses.

Four evaluation meetings took place during the study. In the first two meetings, some participants adopted a reactive posture. Such posture can be exemplified by a statement of the safety specialist in one of the monthly meetings: ″accidents sound like incompetence of the safety specialist″. They often tried to blame client interference or unsafe acts as the source of safety failures. In fact, a similar attitude is often found on PPC analyses, when, for instance, rain or other uncontrollable factor are blamed for production failures. Photographs of the problems, pressure exerted by directors and repeated explanations that the objective of safety control is not to find ″who made the mistake″, contributed to change this posture. However, the reactive postures avoid that some corrective actions were better implemented, so some problems remained almost the same during all the study.

Summary of workers perceptions

The participatory cycle took place twice during the empirical study. The second round of interviews happened forty days after the first one. At this time, a new team had came into the site (painters), as well as others bricklayers had been hired. In addition, some of the suggestions given at the first round had already been implemented. The interviews involved groups of eight workers, on average, and all reports were recorded. The results of the first round are presented in table 4.

Problems		MC*	SC1*	SC2*
1.	Widespread dust		x	
2.	Excessive noise		x	
3.	Heat on the roof, especially near blast furnaces			x
4.	Lodges are small and badly divided	x	x	x
5.	Lodges are untidy and dirty	x	x	
6.	Body harnesses do not fit properly		x	
7.	Body harnesses with two lanyards are necessary to work on scaffoldings		x	
8.	Rubber gloves have poor quality	x		
9.	Assembly scaffoldings without previous experience		x	
10.	Lack of knowledge on risk areas in the steel mill (where am I not allowed to walk?)		x	x
11.	Access to the steel mill bathroom is risky		x	x
12.	The initial training provided by the steel mill to their subcontractors does not highlight the risks in the steel mill		x	
13.	Safety specialist spends too much time operating the crane. He should walk more around the site		x	
14.	There are not enough ladders to leave the roof in case of emergence or rain	x		x
15.	Equipment for horizontal transportation are not adequate	x		
16.	Horizontal transportation distances are too large (layout problems)	x		
17.	Some tools are not well maintained	x		
18.	Bad quality of food	x		

Notes:
* MC: main contractor (bricklaying, change of windows and general support);
SC1: subcontractor 1 (structural repairs); SC2: subcontractor 2 (change of roof).

Table 4 Problems according to workers (first round).

Several of the complaints indicated that some risk controls were not being efficient. For instance, complaints 6 and 7 pointed out that other models of safety belts should be provided. Others complaints revealed some risks that had not been identified in safety planning. For instance, in problem 9 the subcontractors of structural repairs complained that they were assembling their own scaffoldings, although they had no previous experience in this task. In reality, the root cause for this problem was that the responsibility for scaffold assembling was not clearly defined in the contracts. Following the cycle proposed, an action plan was produced by the management. Table 5 illustrates one of the decisions included in the action plan.

Problems	Action	Responsible	Deadline
Lodges are untidy and dirty	Assign a labourer to carry out a daily cleanness	Safety specialist	03/22

Table 5: Example of action plan to attend workers demands.

Such action plan was presented and discussed in the feedback meeting involving workers and managers. The meeting took place in the site. The first participatory cycle ended with the second round of interviews, in which workers were asked to comment on the measures that had been carried out. Based on their evaluation, a new table was produced, indicating whether the complaint was totally solved, partially solved or not solved. A new improvement cycle is then started. Table 6 illustrates this evaluation.

	Solved?	New suggestions or comments
Lodges are untidy and dirty	Partially	The worker assigned to clean lodges is often required to carry out other tasks

Table 6: Example of workers opinions on the solving of their complaints.

Twenty one new complaints were also reported in the second interview. This increase might be explained for two main reasons: painting team came into the site and workers were more confident to express their opinions. Also, it is normal that new demands are continuously appearing, due to the dynamic nature of construction sites.

Conclusions

This paper presented a safety planning and control model (SPC) which was tested in an empirical study in the refurbishment of an industrial building. The technique of preliminary hazard analysis (PHA) was used for producing basic safety plans, which were continuously updated through the integration of safety into look-ahead and short-term level of planning. It was found that several concepts and methods of production planning and control (such as constraints analysis, shielding production or analysis of causes for not followings the plans) can be easily extended to safety management. Although this integration makes it easier to manage both safety and production, its effectiveness depends on the existence of a well structured planning system.

Two elements of the model must be emphasized. The first is the percentage of safe work packages (PSW), a new indicator to evaluate safety performance. By collecting PSW, it is possible to carry out an objective and detailed inspection on the site, using safety plans as references to the control. The second is the participatory cycle, a method to identify and control risks based on workers perceptions.

References

BALLARD, G. *The Last Planner System of Production Control*. PhD thesis. School of Civil Engineering. The University of Birmingham, 2000.

BAKER, S. *et al* Risk response techniques employed currently for major projects. *Construction Management and Economics*, v. 17, p. 205-213. 1999.

CIRIBINI, A.; RIGAMONTI, G. Time/space chart drawings techniques for the safety management. In: INTERNATIONAL CONFERENCE OF CIB WORKING COMMISSION W99, 2°, 1999, Hawai. *Proceedings...* p. 25-32, Rotterdam: A.A. Balkema, 1999.

HENDRICK, H. *Macroergonomics:* an introduction to work system design. Santa Monica: Human Factors and Ergonomics Society, 2001.

HINZE, J. *Indirect costs of construction accidents.* Austin: The Construction Industry Institute, 1991.

HINZE, J.; PARKER, H. Safety: productivity and job pressures. *Journal of the Construction Division,* v.104, n. 1, p. 27-34. 1978.

HOPP, W.; SPEARMAN, M. *Factory physics:* foundations of manufacturing management. Boston: McGraw-Hill, 1996. 668 p.

KARTAM, N. Integrating safety and health performance into construction CPM. *Journal of Construction Engineering and Management*, v. 123, n. 2, p. 121-126. Jun 1997.

KOLLURU, R. *et al*. *Risk assessment and management handbook.* Mc Graw Hill, 1996.

KOSKELA, L. *An exploration towards a production theory and its application to construction*. VTT, Technical Research Centre of Finland, 2000. 258 p.

LAUFER, A. *et al*. The multiplicity concept in construction project planning. *Construction Management and Economics,* London, v.12, n. 1, p. 53-65, 1994.

LAUFER, A.; TUCKER, R. L. Is construction planning really doing its job ? A critical examination of focus, role and process. *Construction Management and Economics*, London, n. 5, p. 243-266, 1987.

LISKA, R.W. *et al*. *Zero accident techniques.* Austin: The Construction Industry Institute, 1993.

SURAJI, A.; DUFF, R. Construction management actions: a stimulation of construction accident causation. In: ASSOCIATION OF RESEARCHERS IN CONSTRUCTION MANAGEMENT, 16ª, 2000b, Glasgow. *Proceeding..* www.eci-online.org.

TAH, J. Towards A Qualitative Risk Assessment Framework for Construction Projects. In: IPMA SYMPOSIUM ON PROJECT MANAGEMENT, 1997, Helsinki. *Proceedings...* p. 265-274, London:

E&FN SPON, 1997.

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CONSTRUCTION MANAGEMENT HEALTH AND SAFETY (H&S) COURSE CONTENT: TOWARDS THE OPTIMUM

Smallwood, John Department of Construction Management, University of Port Elizabeth, South Africa

Although H&S education is both essential and a pre-requisite for management commitment, South African construction management programmes address H&S to varying degrees. Those that do so to a lesser degree invariably focus on legislation and do not address procurement and other dynamic issues of H&S. However, no particular H&S curriculum should be viewed as optimum, as new management strategies, systems, processes and research findings amplify the need for amendment and improvement of a curriculum.

Given the aforementioned, two surveys were conducted. The first survey was conducted to determine the extent to which construction management programmes addressed H&S. The second survey was conducted among a group of 'H&S best practice' general contractors (GCs) to determine the important issues relative to a construction H&S curriculum. Findings of the surveys include: H&S/Productivity/Quality, role of management, legislation, worker participation, role of unions, and programmes predominate among construction management H&S curricula subject areas, and legislation, management of subcontractors (SCs),

H&S/Productivity/Quality, and role of management predominate among subject areas preferred by GCs.

KEYWORDS

Construction management, health and safety, education

LITERATURE

Introduction

Construction management programmes are invariably structured to prepare graduates to fulfil a range of functions in terms of the built environment. These include construction management, project management for clients, property development and administration, management consulting and materials manufacturing.

Construction is a multi-stakeholder process undertaken by generally four teams: design; construction; client, and financial. In general, design, which precedes and which influences construction, is separated therefrom. Research conducted world wide indicates that clients, project managers, designers, construction managers, workers and unions all influence, and have a role to play in H&S.

According to Al-Mufti (1999) civil engineers have a pivotal role in ensuring the H&S of construction workers, which is challenging at the best of times, but more so given that young graduates may be faced with major responsibilities for considerable human and material resources, without necessarily having the full experience and competency at the early stages of their careers. Consequently, it is necessary that they be provided with adequate H&S knowledge during their degree studies. This contention applies equally to construction management.

Anderson (1999) attributes the non-improvement in the UK construction industry accident rate to seven factors, inter alia, lack of education and training. Anderson maintains that management education and training, particularly that provided by tertiary institutions, "fails to give the necessary emphasis to the subject, and those new to the industry have to fall back on 'learning on the job' as opposed to gaining experience on the job."

Given the aforementioned the objectives of this study are to determine:

- The importance of H&S to the discipline of construction management;
- The preferred subject areas for a construction management H&S programme, and
- The extent to which construction management programmes address H&S and the subject areas included in such programmes.

Issues relative to H&S

Laakanen (1999) relates the main developments and key issues arising from studies conducted in construction H&S relative to programme content: new regulations; the level of musculoskeletal injuries; new approaches to H&S; occupational health; accidents; work experience; rehabilitation; promotion of employment; need for development in the work environment, and new H&S measures.

The promulgation of the EU Construction Directive 92/57/EEC on the implementation of minimum H&S requirements at temporary or mobile construction sites, required development of knowledge and skills with respect to the participation of clients and designers in H&S, and the integration of design and construction in terms of H&S.

Ergonomic interventions have major potential to mitigate the high number of musculoskeletal injuries. Physical training also contributes to the mitigation of such injuries.

A holistic approach requires the integrated development of work organisation, physical environment and rehabilitation. Work organisation and physical environment requires an appreciation and understanding of the role of planning and pre-planning of H&S to realise optimum ergonomics. Rehabilitation forms an integral part of H&S and needs to be integrated with other interventions to ensure feedback. Relative to H&S, the role of programmes, awareness in the form of information, motivation and goal setting, training, campaigns, audits and enhanced vocational education in H&S performance, amplify the need for the inclusion of such subject areas in a tertiary programme.

The risk of occupational diseases amplifies the need for related education. The need for expertise related to induction and other forms of training is reinforced by the incidence of accidents involving new workers. The disproportionate number of accidents involving falls indicates a need for expertise relative to accident prevention. Similarly, inadequate housekeeping indicates a need for expertise relative to planning, pre-planning, systems, and audits.

Course content

Research conducted by Smith and Arnold (1999) among GCs in the USA to investigate the optimum H&S course content for construction students at Pennsylvania State University determined the following to be the significant skills required of employees with between one and five years experience: pre-project hazard analysis; preparation of accident reports; conducting tool box talks; participating in project H&S meetings; performing hazard analysis; recognising common hazards; conducting H&S audits; maintaining material safety data sheet (MSDS) files, and the managing of permits. The following H&S topics were also considered to be important: experience modification rating (EMR); incident ratings, and the cost of accidents (CoA), in particular the indirect CoA.

Form of presentation

45% of College and University respondents to a study conducted in the USA, stated that their curriculum includes a subject wholly devoted to construction H&S. Of the 55% of respondents that responded in the negative, some stated that H&S is either addressed in a generalised manner in other subjects, or that a certain group of subjects address H&S relative to the subject material (Coble *et al.*, 1999). Suckarieh and Diamantes (1995) report that only about 50% of construction management programmes in the USA have courses that are dedicated to H&S. However, Coble *et al.* (1999) recommend that all construction management programmes seriously consider specifically addressing H&S in their curricula.

Research

Sample frame, methodology and analysis

The first sample frame consisted of 24 general contractors (GCs), which had achieved placings in the Building Industries Federation South Africa (BIFSA) National Health and Safety (H&S) Competition and, or BIFSA 4 or 5-Star H&S gradings on one or more of their projects. A 4-question questionnaire consisting of 35 sub-questions was mailed to the GCs, 14 of which responded, which represents a response rate of 58.3%.

The second sample frame consisted of 12 (66.7%) Technikon and 6 (33.3%) University Departments of Building / Construction Management and Quantity Surveying. A 6-question questionnaire consisting of 35 sub-questions was mailed to the Departments, 9 of which responded – 5 Technikons (55.6%) and 4 Universities, which represents an overall response rate of 50%.

Given that respondents were required to respond in terms of concurrence, and importance on a scale of 1 to 5, it was necessary to compute an importance index (II) with a minimum value of 0, and a maximum value of 4.0, to enable a comparison of, and to rank various aspects. The II is calculated using the formula:

$$\frac{4n_1 + 3n_2 + 2n_3 + 1n_4 + 0n_5}{(n_1 + n_2 + n_3 + n_4 + n_5)}$$

where n_1 = Strongly agree, or Very important (1)
n_2 = Agree, or Important (2)
n_3 = Neutral (3)
n_4 = Disagree, or Not really important (4)
n_5 = Strongly disagree, or Unimportant

GC findings

In terms of the degree of importance of the inclusion of construction H&S in the tertiary education programmes of various construction related disciplines, construction managers are ranked first, followed by project managers and civil engineers (Table 1).

Discipline	Response (%) Very important…. Unimportant					II	Rank
	1	2	3	4	5		
Construction managers	92.8	7.2	0.0	0.0	0.0	3.93	1
Project managers	71.4	21.4	7.2	0.0	0.0	3.64	2
Civil engineers	57.1	42.9	0.0	0.0	0.0	3.57	3
Electrical engineers	50.0	50.0	0.0	0.0	0.0	3.50	4=
Structural engineers	50.0	50.0	0.0	0.0	0.0	3.50	4=
Mechanical engineers	50.0	42.8	7.2	0.0	0.0	3.43	6
Architects	35.7	50.0	14.3	0.0	0.0	3.21	7
Quantity surveyors	14.3	35.7	50.0	0.0	0.0	2.64	8

Table 1 Perceived importance of the inclusion of construction H&S in the tertiary education programmes of various construction related disciplines according to GCs

Table 2 indicates that the GCs are essentially divided in terms of whether H&S should be included in a construction management programme as a separate subject, or as a component of a subject, such as construction management. However, the respective levels of affirmative and negative response are in favour of 'component of a subject'.

Form of presentation	Response (%) Yes	No	Don't know	No response
Separate subject	50.0	28.6	0.0	21.4
Component of a subject eg. construction management	57.1	14.3	0.0	28.6
Module in various subjects	14.3	7.1	0.0	78.6

Table 2 Form of presentation of H&S in a construction management programme according to GCs

Respondents were requested to indicate the extent to which they agreed/disagreed with respect to the inclusion of various subject areas in a honours level (final year) construction management H&S curriculum (Table 3).

It is notable that the values of all the IIs are above the midpoint value of 2.0, which indicates that GCs perceive all subject areas to be relevant.

It is significant that the 'OH&S Act and regulations' achieved a ranking of first, as this legislation provides the framework within which H&S occurs, or does not occur. The second ranked management of subcontractors (SCs), is possibly attributable to the frequent citing of SCs as a problem relative to H&S by GCs. The third ranked 'H&S/Productivity/Quality' indicates the importance of addressing synergy, which is the optimum basis for the promotion of H&S.

The fourth ranked 'role of management', and joint fifth ranked 'worker participation', constitute the 'two pillars' of any H&S programme/process. The other joint fifth ranked subject area, 'culture', is at the upstream end of the 'upstream/downstream' sequence: culture-> management system-> exposure -> incidents i.e. an optimum H&S culture is a pre-requisite for realising a healthy and safe project and, or an improvement in H&S performance.

'Programmes', 'education and training' and 'pre-planning' achieved a joint ranking of seventh. Given that invariably H&S courses and curricula primarily address 'programmes', the ranking of seventh is notable. International research indicates there to be an inverse relationship between education and training, and the occurrence of incidents. 'Best practice' H&S requires that both designers and contractors need to engender and focus on the pre-planning of H&S.

The Compensation for Occupational Injuries and Diseases (COID) Act, which achieved a joint ranking of tenth with environment and role of project managers, provides the legislative framework for workers' compensation. The joint tenth ranking of 'environment' is possibly attributable to the current level of focus thereon. Although the 'role of project managers' only achieved a joint ranking of tenth with an II of 3.29, the ranking is nevertheless higher than that achieved by 'role of clients' and 'role of designers', namely joint sixteenth.

It is notable that only four of the ten subject areas, which achieved a ranking between thirteenth and twenty second, had an II with a value lower than 3.00. Although the importance of these ten subject areas to construction management can be debated, 'project plans', 'economics of H&S', 'health and hygiene', and 'ergonomics', are of particular importance. 'Project plans' entail a risk assessment and the development of strategies to realise healthy and safe projects. 'Health and hygiene' is concerned with the welfare of workers and 'ergonomics' is concerned with the relationship between workers and their workplace. Both these aspects indirectly affect productivity, quality and schedule.

Tertiary institution findings

44.5% of respondents regarded construction H&S as 'very important' to their discipline, 22.2% as 'more than important', 22.2% as 'important', and 11.1 % as 'fairly important'.

100% of respondents maintained that H&S is included in their construction management programme, the year levels being: year 1 (22.2%); year 2 (22.2%); year 3 (88.9%); year 4 (55.6%), and year 5 (11.1%).

Table 4 indicates that the majority (66.7%) of TIs include construction H&S as a component of the subject construction management. Although 50% of GCs advocate the presentation of construction H&S as a separate subject there is greater convergence between the TIs' and GCs' response relative to 'component of the subject construction management'.

Subject area	Response (%)*					II	Rank
	SA	A	N	D	SD		
OH&S Act and Regulations	78.6	21.4	0.0	0.0	0.0	3.79	1
Management of subcontractors	71.4	21.4	7.2	0.0	0.0	3.64	2
H&S / Productivity / Quality	57.1	35.7	0.0	0.0	0.0	3.62	3
Role of management	61.5	38.5	0.0	0.0	0.0	3.57	4
Culture (values, vision, purpose, mission, goals, policy)	57.1	35.7	7.2	0.0	0.0	3.50	5=
Worker participation	50.0	50.0	0.0	0.0	0.0	3.50	5=
Programmes **	50.0	42.8	0.0	7.2	0.0	3.36	7=
Education and training	50.0	35.7	14.3	0.0	0.0	3.36	7=
Pre-planning	50.0	35.7	14.3	0.0	0.0	3.36	7=
COID Act (Workers' compensation)	35.7	57.1	7.2	0.0	0.0	3.29	10=
Environment	50.0	28.6	21.4	0.0	0.0	3.29	10=
Role of project managers	42.8	42.8	14.4	0.0	0.0	3.29	10=
Project plans	35.7	50.0	14.3	0.0	0.0	3.21	13
Economics of H&S	23.1	69.2	7.7	0.0	0.0	3.15	14
Health and hygiene	28.6	50.0	21.4	0.0	0.0	3.07	15
Measurement and statistics	14.3	78.5	0.0	7.2	0.0	3.00	16=
Role of clients	28.6	42.8	28.6	0.0	0.0	3.00	16=
Role of designers	35.7	28.6	35.7	0.0	0.0	3.00	16=
Influence of procurement systems	14.3	57.1	28.6	0.0	0.0	2.86	19
Role of the media and awareness	21.4	42.8	28.6	7.2	0.0	2.79	20
Ergonomics	7.2	64.2	21.4	7.2	0.0	2.71	21
Role of unions	7.2	50.0	35.7	0.0	7.2	2.50	22

* (SA = Strongly agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly disagree)

**Includes inspections, investigations and audits

Table 3 Extent to which GCs support the inclusion of various subject areas in a honours level (final year) construction management health and safety H&S) curriculum

Form of presentation	Response (%)
Separate subject	11.1
Component of the subject construction management	66.7
Module in various subjects	55.6

Table 4 Form of presentation of H&S in a construction management programe according to tertiary institutions

The minimum total duration of contact sessions is 90 minutes (1.5 hours), the maximum 4480 minutes (74.7 hours), and the median 450 minutes (7.5 hours). The mean is 937 minutes (15.6 hours).
H&S / Productivity / Quality, role of management, OH&S Act and Regulations, worker participation, role of unions, and programmes predominated among subject areas addressed by tertiary construction management programmes (Table 5). The majority of programmes also address the COID Act, management of SCs, pre-planning, project plans, and role of project managers. Given their significance to the welfare of workers, productivity, and quality, the low level of response relative to ergonomics, and to a lesser extent, health and hygiene, is significant. Given the total cost of accidents, the financial benefits of H&S, and the importance of goals and feedback relative to H&S performance, the same can be said relative to the economics of H&S, and measurement and statistics respectively. Given the influence of designers on, and the role of clients in H&S, the level of response relative thereto is notable.

Subject Area	Response (%)		
	Yes	No	Unsure
Culture (values, vision, purpose, mission, goals, policy)	57.1	28.6	14.3
Economics of H&S	42.9	42.9	14.2
H&S / Productivity / Quality	100.0	0.0	0.0
OH&S Act and Regulations	88.9	11.1	0.0
COID Act (Workers' compensation)	75.0	12.5	12.5
Role of management	100.0	0.0	0.0
Worker participation	87.5	12.5	0.0
Role of unions	87.5	12.5	0.0
Programmes	87.5	12.5	0.0
Education and training	62.5	37.5	0.0
Management of subcontractors	75.0	25.0	0.0
Measurement and statistics	25.0	50.0	25.0
Health and hygiene	50.0	25.0	25.0
Environment	62.5	25.0	12.5
Ergonomics	14.3	57.1	28.6
Influence of procurement systems	57.1	42.9	0.0
Pre-planning	75.0	25.0	0.0
Project plans	75.0	25.0	0.0
Role of clients	50.0	37.5	12.5
Role of project managers	75.0	25.0	0.0
Role of designers	28.6	71.4	0.0
Role of the media and awareness	28.6	57.1	14.3

Table 5 Extent to which various H&S subject areas are addressed by tertiary construction management programmes

Table 6 indicates the extent to which the GCs' preference for the inclusion of subject areas in a honours level (final year) programme is addressed by tertiary institutions (TIs). Given that the lowest GC II value is 2.50, ideally all subject areas should be included in the majority of TI curricula. However, in terms of the degree of congruence between GC preference in the form of II values, and the extent to which TI curricula address H&S subject areas in the form of percentage response, the following subject areas are notable: management of SCs; culture; economics of H&S; health and hygiene; measurement and statistics; role of clients; role of designers; role of the media and awareness, and ergonomics.

Subject area	Extent to which addressed by TI (%)	Rank	GC preference	
			II	Rank
OH&S Act and Regulations	88.9		3.79	1
Management of subcontractors	75.0		3.64	2
H&S / Productivity / Quality	100.0		3.62	3
Role of management	100.0		3.57	4
Culture (values, vision, purpose, mission, goals, policy)	57.1		3.50	5=
Worker participation	87.5		3.50	5=
Programmes	87.5		3.36	7=
Education and training	62.5		3.36	7=
Pre-planning	75.0		3.36	7=
COID Act (Workers' compensation)	75.0		3.29	10=
Environment	62.5		3.29	10=
Role of project managers	75.0		3.29	10=
Project plans	75.0		3.21	13
Economics of H&S	42.9		3.15	14
Health and hygiene	50.0		3.07	15
Measurement and statistics	25.0		3.00	16=
Role of clients	50.0		3.00	16=
Role of designers	28.6		3.00	16=
Influence of procurement systems	57.1		2.86	19
Role of the media and awareness	28.6		2.79	20
Ergonomics	14.3		2.71	21
Role of unions	87.5		2.50	22

Table 6 Importance of various subject areas to GCs and the extent to which they are addressed by TIs

Conclusions

The inclusion of construction H&S in a construction management programme is essential due to a practicing construction manager's responsibilities for human and other resources, legislation, and the catalytic role of H&S relative to productivity, quality and schedule, and ultimately, cost.

The ranking achieved by management of SCs and H&S/Productivity/Quality relative to GCs, reinforces the critical role of H&S in overall project performance. The ranking of management of SCs reinforces the increased role of SCs due to increased: specialization; labour only subcontracting; pyramid subcontracting, and use of alternative procurement systems. The ranking achieved by culture relative to GCs reinforces the critical role of culture in H&S performance. The low level of emphasis on ergonomics and health and hygiene reflects the traditional level of focus by industry. However, the related II values resulting from the GC responses indicate that these areas need to be addressed. The low level of emphasis on the role of designers and the role of clients, is possibly attributable to a lack of appreciation thereof.

Recommendations

Ideally, construction H&S should be included in a construction management programme as a separate subject, if not, then at least as an identifiable component of a subject such as construction management. This will ensure that construction H&S is afforded the requisite status.

Given the influence of all stakeholders on construction H&S, and that construction management graduates invariably fulfill a range of roles in industry, the requisite subject areas should be included in a final year honours level programme.

References

Al-Mufti, M.A., 1999, Continuous Enhancement of Health and Safety Awareness in Undergraduate Civil Engineering Courses, in *proceedings of the Second International Conference of CIB Working Commission W99*, Honolulu, Hawaii, dited by Singh, A., Hinze, J.H. and Coble, R.J., (Rotterdam: Balkema), pp. 277 –– 282.

Anderson, J., 1999, Construction Safety: Seven Factors Which Hold Us Back. *The Safety & Health Practitioner*, August, pp. 16 - 18.

Coble, R.J., Hinze, J.H., McDermott, M.J. and Elliott, B.R., 1999, College's Emphasis on Safety in *Proceedings of the Second International Conference of CIB Working Commission W99*, Honolulu, Hawaii, edited by Singh, A., Hinze, J.H. and Coble, R.J., (Rotterdam: Balkema), pp. 257 – 264.

Laukkanen, T., 1999, Construction Work and Education: Occupational Health and Safety Reviewed. *Construction Management and Economics*, 17 (1), pp. 53 – 62.

Smith, G.R. and Arnold, T.M., 1999, Safety Education Expectations for Construction Engineering and Management Students in *Proceedings of the Second International Conference of CIB Working Commission W99*, Honolulu, Hawaii, edited by Singh, A., Hinze, J.H. and Coble, R.J., (Rotterdam: Balkema), pp.265 – 272.

Suckarieh, G. and Diamantes, J., 1995, Educating Construction Management Students in Safety in *Safety and Health in Construction*, CIB Publication 209 (Gainesville, Florida: CIB W99), pp. 154 – 164.

HEALTH AND SAFETY (H&S) AND RELIGION: IS THERE A LINK?

Smallwood, John Department of Construction Management, University of Port Elizabeth, South Africa

Values are an integral part of H&S culture. Values reflect, among other, ethics, moral standards and principles. Religious beliefs influence values through morality. The value, 'People are the most important resource' will engender the Islamic 'Tawhidic' principles of justice and equity, dignity of labour and removal of hardship. Such a clause will also avert 'picking and choosing', and engender and reinforce a vision of 'accident free' workplaces.

The belief that one is one's 'brother's keeper' is not only a religious perspective, but a basic premise of worker participation in H&S and concern for a peer's wellbeing. The 'golden rule' 'do unto others as you would have them do unto you, which is encapsulated in all religions, reinforces the 'brother's keeper' perspective.

Respect and concern for the environment is related to both H&S, and most religions, in particular Buddhism. The purpose of H&S is ultimately, sustainability of any organisation and the environment. Buddhism, in particular, stresses the need to sustain the environment, reflecting a further link. Similarly, most religions advocate the minimisation of waste – H&S is also directed towards loss prevention.

This paper reports on a literature and descriptive survey conducted among a sample frame of 'H&S best practice' general contractors (GCs). The descriptive survey, which entailed response in terms of the degree of concurrence relative to 21 statements, determined that there is a link between H&S and religion.

KEYWORDS

Health and safety, religion, culture

Literature Survey

Introduction

Research conducted in South Africa investigated, inter alia, the extent to which general contractors (GCs) agreed/disagreed with the statement: 'Belief in and practice of a religion eg. Buddhism, Christianity, Islam, Judaism, positively affects a person's approach to, each of occupational H&S, labour productivity, and quality (Smallwood, 2000). Given the possible range of responses and the need to determine the level of concurrence an importance index (II) with a minimum value of 0, and a maximum value of 4.0, was computed to enable facilitate assessment and ranking. Given that the resultant II of 2.18 was above the midpoint value of 2.0, belief in and practice of a religion can be deemed to positively affect a person's approach to occupational H&S. It is notable that the II values for labour productivity and quality were 2.24 and 2.31 respectively.

The findings emanating from the aforementioned study and a survey of the literature, which at best can be described as perfunctory, provided the catalyst for an expanded study to determine the link between H&S and religion.

Religion, thought, feeling and behaviour

Loewenthal (2000) contends religion relates to behaviour via morality:

Religion → Morality → Behaviour

Morality involves ethical standards of behaviour, the evaluation of intentions and behaviour as right or wrong, good or bad. Moral standards can be rooted in religious tradition, and moral laws can be seen as having a divine origin.

Loewenthal (2000) also cites Eysenck's theory relative to personality and religion. Eysenck suggested that there are fundamental dimensions of personality:

- Extraversion – involving both sociability and impulsivity;
- Neuroticism – involving anxiety, depression, low self-esteem and tension, and
- Psychoticism – involving lack of impulse control, and
- Social desirability – assessed by the so-called 'lie scale'.

Recent work relative to personality does not include psychotocism.

Eysenck invoked the concept of conditionality, and found evidence that religious beliefs were 'tender-minded' rather than 'tough-minded'. His reasoning lead to the suggestion that individuals low on extraversion – introverts – were more conditionable, and more likely to hold religious and moral attitudes. His theses also suggested that those low on psychoticsm and those high on neuroticism would be more likely to hold religious beliefs. Although subsequent studies have generally not supported Eysenck's theses, a study by Lewis and Joseph did determine that low psychoticism is more strongly associated with religiosity. However, Loewenthal (2000) suggests Eysenck's theories relative to religion, personality and morality could still remain on the agenda for investigation.

The Golden Rule

Eckhardt (2001) says the 'golden rule', which establishes a moral level of care for others that we are responsible to provide, is a common theme in most, if not all, of the world's major religions:

- Buddhist: hurt not others in ways that you would find hurtful;
- Christian: all things whatsoever he would that men should do to you, do ye even so to them;
- Confucian: do not unto others what you would not have them do unto you;
- Hindu: this is the sum of the duty; do naught unto others which if done to thee would cause thee pain;
- Islamic: no one of you is a believer until he desires for his brother that which he desires for himself;
- Jain: in happiness and suffering, in joy and grief, we should regard all creatures as we regard our own self;
- Sikh: as thou deemest thyself, so deem others;
- Taoist: regard your neighbours gain as your own gain, and your neighbour's loss as your own loss, and
- Zoroastrian: that nature alone is good which refrains from doing unto another whatsoever is not good for itself.

Work is a deed of spiritual value

According to Sadeq and Ahmad (1999), work is a deed of spiritual value, which requires that Allah approve actions and behaviours. The Islamic 'Tawhidic' principles of justice and equity, dignity of labour, and removal of hardship, all amplify the need for H&S.

Values

Values are defined as: code of behaviour, ethics, standards (moral) and principles (Allen, 1990). Values are important as they influence the vision, goals, mission, assumptions, and to a degree, the perceived purpose of H&S (Krause, 1993). H&S should be a value, as opposed to a priority, as priorities change depending upon prevailing circumstances and priorities (Griffiths, 1995). An example thereof is schedule, which often becomes the priority on projects, to the detriment of H&S.

The Islamic 'Tawhidic' principles of justice and equity, dignity of labour, and removal of hardship, clearly influence the inclusion of H&S as a value.

Inoue (1997) in his book 'Putting Buddhism to Work', cites Schumacher's conclusion that the biggest problem facing humankind is the disappearance of a set of values and attitudes that will prevent economic activity from becoming all consuming. Inoue maintains that not only is it necessary to incorporate economics into a more holistic framework, but that it is necessary to live with more integrity.

Ethical business practice includes compliance with legislation. Given that values embrace ethics, the existence of Occupational Health and Safety legislation amplifies the need for the inclusion of H&S as a value.

Hinze (1997) is emphatic and says that although even a cold, calculating economist can be convinced that there is a financial payback in being healthy and safe, a holistic H&S culture recognises the humanitarian aspects of H&S.

Waste

Accidents can result in fatalities, injuries, disease, damage to materials, plant and equipment, which results in waste. Waste in solid and other forms impacts on the sustainability of the earth.

Sadeq and Ahmad (1999) maintain that Islam seeks to unify the schism between ethics and economics, one of the six issues being the avoidance of undue waste.

Economic issues

The concept of the 'economic man', which entails the taking of decisions based on the calculation of the benefits relative to the costs of an intervention, may result in a decision, which is in conflict with values and the 'Tawhidic' principles (Sadeq and Ahmad, 1999).

Inoue (1997) cites the Buddhist principle of 'enlightenment', the release from 'picking and choosing' ie. the preference for one thing over another, often at the expense of other people.

From a Christian perspective, Neff (1991) maintains that emphasis on the financial 'bottom line' to measure success can result in unreasonable practices, which can result in hardship and suffering, and consequently, lack of justice. Interms of Christianity, justice is important, as it reflects God's character and His concern for his people.

Accountability

The Islamic 'Tawhidic' principles include public accountability. Public accountability implies and requires organizations to protect and ensure the H&S of workers derived from their respective communities. It also implies and requires public safety and the preservation of the environment.

Sustainability

Larkin (1999) describes a 'right livelihood business' as a business where the 'bottom line' is one of principles. Such a business embraces balance and does not waste resources, acknowledging that energy and creativity flow naturally out of well-rounded lifestyles. Larkin maintains the characteristic that best differentiates between a 'right livelihood business' and other businesses is that they are driven by spirituality-based principles. These principles can be communicated in the form of five precepts, inter alia, commitment to cultivating compassion and learning ways to protect the lives of people, animals, plants, and minerals, and commitment to cultivating loving kindness and learning ways to work for the well-being of people, animals, plants, and minerals.

Research

Sample frame and Methodology

The sample frame consisted of 26 GCs, who had achieved placings in the Building Industries Federation South Africa (BIFSA) national Health and Safety (H&S) competition and, or BIFSA 4 or 5-Star H&S gradings on one or more of their projects, for the years 1995 to 2000.

A single-question questionnaire consisting of 21 sub-questions was mailed to the GCs. 17 GCs responded, which represents a response rate of 65.4.

Given that respondents were required to respond in terms of the extent to which they agree / disagree, it was necessary to compute an importance index (II) with a minimum value of 0, and a maximum value of 4, to determine concurrence, and to rank the various statements. The II is calculated using the formula:

$$\frac{4n_1 + 3n_2 + 2n_3 + 1n_4 + 0n_5}{(n_1 + n_2 + n_3 + n_4 + n_5)}$$

where n_1 = Strongly agree
n_2 = Agree
n_3 = Neutral
n_4 = Disagree
n_5 = Strongly disagree and unsure

Findings

Table 1 indicates the extent to which respondents concurred relative to 21 statements. It is notable that the II values for all the statements are above the midpoint value of 2.0, which indicates that concurrence can be deemed to exist. It is significant that 15 of the 21 II values are 3.0, which indicates that respondents 'strongly agree' / 'agree' with the statements.

The top four ranked statements, 'A price cannot be put on a person's life', 'People are an organisation's most important resource', 'People have a body, mind and a soul', and 'Values are important for H&S' predominate in terms of the level of concurrence.

The first ranking of 'A price cannot be put on a person's life' has important implications for risk management, which requires the computation of the financial impact of risk: probability x financial impact. The aforementioned, along with 'People are an organisation's most important resource' and 'People have a body, mind, and soul' amplify the humanitarian aspect of H&S. The relevance of values to H&S are reinforced by the joint third ranking of 'Values are important for H&S', the seventh and eighth ranking of ' 'Values influence a person's concern for another person's well being' and 'H&S should be a value and not a priority' respectively.

The joint fifth ranked 'Optimum H&S reduces waste' and 'Accidents result in hardship to the injured' reinforces the role of H&S in the control and minimisation of injuries, damage and waste. Respect for and the role of H&S in the preservation of the environment are amplified by ninth ranking of the 'People and the environment (nature) are inter-connected'. The tenth ranking of 'Non-compliance with legislation is unethical' indicates that there are ethical issues relative to H&S, in terms of compliance per se, and that socially acceptable norms and practices relative to H&S are enshrined in legislation.

Although 'Optimum H&S engenders sustainability of the organisation' and 'Optimum H&S engenders sustainability of the earth' achieved rankings of eleventh and fourteenth respectively, their II values being above 3.0 amplifies the 'holistic' purpose of H&S. The twelfth ranked 'Workers should be assigned work which suits their abilities' is referred to in literature from both a religious and H&S perspective. 'We as people are our brother's keeper' achieved an II value of 3.12, which reinforces the religious perspective of care for our fellow beings.

The fifteenth ranked 'Exclusive/Primary focus on cost compromises H&S', which achieved an II value of 3.0, reflects both religious and H&S related contentions in literature.

Although 'A healthy and safe work place results in justice and equity (fairness)' achieved a joint ranking of sixteenth, its II value of 2.94 reinforces the relevance of the Islamic principle recorded in literature. Similarly the II values of 2.82, 2.76 and 2.65 relative to 'A healthy and safe work place results in dignity of labour', 'A healthy and safe work place results in avoidance/removal of hardship', and 'Work is a deed of spiritual value' reinforce the relevance of such Islamic principles. The II value of 2.94 of the joint sixteenth ranked 'Belief in and practice of a religion influences a person's values', reflects generic religious literature, and reinforces the indirect influence of religion on H&S through the medium of values.

The II value of 2.88 of eighteenth ranked 'Management is responsible for workers' well being' reflects both legislation and holistic H&S literature.

Statement	Response (%)					II	Rank
	SA	A	N	D	SD		
A price cannot be put on a person's life	94.1	5.9	0.0	0.0	0.0	3.94	1
People are an organisation's most important resource	88.2	11.8	0.0	0.0	0.0	3.88	2
People have a body, mind and a soul	82.4	17.6	0.0	0.0	0.0	3.82	3=
Values are important for H&S	82.4	17.6	0.0	0.0	0.0	3.82	3=
Optimum H&S reduces waste	58.8	41.2	0.0	0.0	0.0	3.59	5=
Accidents result in hardship to the injured	58.8	41.2	0.0	0.0	0.0	3.59	5=
Values influence a person's concern for another person's well being	52.9	47.1	0.0	0.0	0.0	3.53	7
H&S should be a value and not a priority	52.9	35.2	5.9	0.0	0.0	3.50	8
People and the environment (nature) are inter-connected	41.2	58.8	0.0	0.0	0.0	3.41	9
Non-compliance with legislation is unethical	35.3	64.7	0.0	0.0	0.0	3.35	10
Optimum H&S engenders sustainability of the organisation	35.3	58.8	0.0	5.9	0.0	3.24	11
Workers should be assigned work which suits their abilities	23.4	58.8	11.8	0.0	0.0	3.13	12
We as people are 'our brother's keeper'	29.4	53.0	17.6	0.0	0.0	3.12	13
Optimum H&S engenders sustainability of the earth	29.4	52.9	11.8	5.9	0.0	3.06	14
Exclusive/Primary focus on cost compromises H&S	23.5	53.0	23.5	0.0	0.0	3.00	15
Belief in and practice of a religion influences a person's values	23.5	47.1	29.4	0.0	0.0	2.94	16=
A healthy and safe work place results in justice and equity (fairness)	17.6	64.7	11.8	5.9	0.0	2.94	16=
Management is responsible for workers' well being	17.6	64.7	5.9	11.8	0.0	2.88	18
A healthy and safe work place results in dignity of labour	11.8	64.7	17.6	5.9	0.0	2.82	19
A healthy and safe work place results in avoidance/removal of hardship	0.0	82.3	11.8	5.9	0.0	2.76	20
Work is a deed of spiritual value	11.8	41.1	47.1	0.0	0.0	2.65	21

Table 1 Degree of concurrence relative to various statements

Conclusions

Literature indicates that there is both an explicit and implied link between H&S and religion. The explicit link manifests itself through the belief by some religions that work is a deed of spiritual value, which requires justice and equity, dignity of labour, and removal of hardship. Other religions stress the importance of sustainability of the environment. The inter-relationship between religion and morality and values, and the resultant influence on behaviour is a further manifestation of the explicit link.

The implied link manifests itself in the underlying principle of all religions, namely the 'golden rule', 'do not unto others what you would not have them do unto you' – would you like to have your life compromised as a result of inadequate H&S on the part of someone else?

In conclusion, all religions explicitly and imply the need for human life and the environment to be respected and preserved.

Recommendations

The implications of these research findings are profound. However, does an organisation only employ religious people? If so, then how does the organisation determine the degree of belief in and practice of the religion? The aforementioned are hardly feasible. Quo vadis? The most likely route is the promotion of H&S on the basis of the explicit and implied need for H&S by all religions.

References

Allen, R.E., 1990, *The Concise Oxford Dictionary of Current English,* 8th Edition (New York: Oxford University Press, Inc.)

Eckhardt, R.E., 2001, The Moral Duty to Provide for Workplace Safety, *Professional Safety*, August, pp. 36 – 38.

Griffiths, B., 1995, Ten principles for achieving a total safety culture Part 3, *National Safety*, September / October, p.18.

Hinze, J.H., 1997, *Construction Safety*, (New York: Prentice Hall, Inc.).

Inoue, S., 1997, *Putting Buddhism to Work*, (Tokyo: Kodansha International Ltd.).

Krause, T.R., 1993, Safety and Quality: Two Sides of the Same Coin, *Occupational Hazards*, April, pp. 47-50.

Larkin, G., 1999, *Building a Business the Buddhist Way*, (Berkeley, California: Celestial Arts).

Neff, M., 1991, *Devotions for Women in the Workplace*, (Chicago: Moody Press)

Sadeq, A.M. and Ahamd, A.K. (eds.), 1996. In *Quality Management Isalmic Perspectives*, (Kuala Lumpur: Leeds Publications).

THE NEED FOR THE INCLUSION OF CONSTRUCTION HEALTH AND SAFETY (H&S) IN ARCHITECTURAL EDUCATION

Smallwood, John Department of Construction Management, University of Port Elizabeth, South Africa

A disproportionate number of accidents occur in construction relative to other industries, the direct and indirect cost of which, contributes to the cost of construction. Construction is a multi-stakeholder process and consequently all stakeholders, architectural designers included, influence the construction process.

Design influences and impacts on construction H&S directly and indirectly. Directly through the: design concept; selection of structural frame; detailed design; selection of cladding, and specification of materials. Indirectly through: the selection of procurement system; related interventions such as prequalification; decision regarding project duration, and selection of contractor.

Given the aforementioned, architectural designers should be empowered to contribute to construction H&S. However, the need for such empowerment is amplified by legislation in certain countries, such as the United Kingdom, namely the Construction (Design and Management) Regulations. Similar legislation exists in the European Union countries. Despite the influence of architectural design on construction H&S and the evolution of legislation in certain countries, traditionally South African architectural designers have perceived construction H&S to be the responsibility of the contractor.

This paper reports on a descriptive survey conducted among architectural departments at Technikons and Universities in South Africa, which determined that: architectural programmes address construction H&S to a limited extent; construction H&S is perceived to be fairly important to the discipline of architecture, and design related activities have a moderate impact on construction H&S.

The findings of the literature and descriptive survey amplify the need for the following relative to architectural programmes: the inclusion of construction H&S as a module; consideration of H&S when designing, detailing, and specifying, and the inclusion of H&S among the criteria used for evaluating design projects and working drawings.

KEYWORDS

Architectural education, design, construction health and safety

Literature Survey

Introduction

Various authors have documented and raised the level of awareness with respect to the influence of design on H&S, inter alia, Hinze (1997) and Jeffrey and Douglas (1994). However, the International Labour Office (ILO) (1992) specifically states that designers should: receive training in H&S; integrate the H&S of construction workers into the design and planning process; not include anything in a design which would necessitate the use of dangerous structural or other procedures or hazardous materials which could be avoided by design modifications or by substitute materials, and take into account the H&S of workers during subsequent maintenance.

However, the influence of design is not limited to design per se. The design function often includes advising clients with respect to the type of procurement system (PS) and form of contract to be used, the selecting of a contractor, including pre-qualifying, and the project duration. Designers also participate in partnering and can facilitate the pre-planning of H&S through completeness of design.

Further, given that clients invariably appoint designers or project managers as the principal agent (PA), the specific ILO (1992) recommendations relative to clients should be noted. These are that clients should: coordinate or nominate a competent person to coordinate all activities relating to health and safety; inform all contractors of special risks to H&S of which they are or should be aware; require contractors submitting tenders to make provision for H&S, and consider H&S requirements when estimating dates for stage and overall completion of the project.

Motivation

The cost of accidents (CoA) is frequently cited as a major motivation for addressing H&S (Hinze, 1997; Levitt and Samelson, 1993). Research indicates the total CoA to constitute 6.5% of the value of completed construction (The Business Roundtable, 1991) and approximately 8.5% of tender price (Anderson, 1997). A further motivation is the synergy between H&S and other project parameters of: cost; environment; productivity; quality, and schedule (Smallwood, 1996).

Legislation

Section 10 of the South African Occupational Health and Safety Act (OH&S Act) (Republic of South Africa, 1993) allocates responsibility to designers to ensure that any 'article' is safe and without risks to health.

The draft South African Construction Regulations (Department of Labour, 2001) schedule important requirements with respect to clients and designers. Clients shall, inter alia: allow sufficient time for the completion of projects; pre-qualify contractors; conduct periodic audits of the contractors' H&S performance, and ensure that where design changes are made sufficient H&S information is provided to the contractors. Designers shall, inter alia: make available all relevant information about the design such as the soil investigation report, design loadings of the structure, and methods and sequence of construction, and inform the principle contractors of any known or anticipated dangers or hazards or special measures required for the safe execution of the works.

Influence of design

The overall design, manifested in shape of the structure, configuration on plan, type of structural frame and enclosing fabric, influence H&S (Hinze and Gambatese, 1994). Jeffrey and Douglas (1994) cite research conducted in Europe, which determined that of site fatalities, 35% were caused by falls, which could have been reduced through design decisions.

Detail and method of fixing may require bending or twisting the back in an awkward way; working in awkward or cramped positions, reaching away from the body; reaching overhead; repetitive movements, and use of body force (Schneider and Susi, 1994). According to Schneider and Susi (1994) materials may be heavy and present manual materials handling problems.

Jeffrey and Douglas (1994) also advocate optimal interaction with clients at the design brief stage, as deviations from it at a later stage result in variation orders (VOs) which can be the catalyst that trigger a series of events from designer through to workers that culminate in an accident on site.

'Design for safe construction' is one of sixteen constructability design principles listed by Adams and Ferguson (McGeorge and Palmer, 1997). However, most of the other fifteen principles are indirectly related to, and consequently influence H&S.

Research conducted in South Africa among architectural practices investigated, inter alia, the frequency at which H&S is considered / referred to relative to various aspects. Given the range of responses, an importance index (II) with a minimum value of 0, and a maximum value of 4.0, was computed to enable a comparison and ranking of the aspects (Smallwood, 2000). Table 1 indicates that 11 of the II values of the 16 aspects are above the midpoint value of 2.0, which indicates that consideration/reference to the aspects can be deemed to be prevalent.

The top three ranked aspects, position of components, method of fixing, and specification, predominate in terms of II values.

Aspect	Response (%)					II	Rank
	A	O	S	R	N		
Position of components	17.3	31.7	20.2	14.4	7.7	2.52	1
Method of fixing	22.1	32.7	18.3	15.4	5.8	2.51	2
Specification	26.9	24.0	19.2	16.3	5.8	2.49	3
Content of material	21.2	24.0	21.2	19.2	7.7	2.29	4
Edge of materials	26.0	21.2	14.4	19.2	10.6	2.26	5
Details	21.2	23.1	21.2	14.4	11.5	2.24	6
Finishes	20.2	22.1	19.2	20.2	8.7	2.18	7
Type of structural frame	19.2	24.0	18.3	21.2	8.7	2.17	8
Plan layout	21.2	18.3	20.0	18.3	11.5	2.10	9
Texture of materials	18.3	19.2	25.0	17.3	12.5	2.08	10
Design (general)	16.3	17.3	26.9	22.1	10.6	2.05	11
Schedule	14.4	20.2	20.2	19.2	13.5	1.91	12=
Surface area of materials	16.3	20.0	18.3	17.3	16.3	1.91	12=
Elevations	17.3	14.4	21.2	22.1	14.4	1.88	14
Site location	18.3	13.5	19.2	25.0	17.3	1.84	15
Mass of Materials	11.5	15.4	25.0	25.0	12.5	1.78	16

(A=Always; O=Often; S=Sometimes; R=Rarely; N=Never)

Table 1 Frequency at which architectural practices consider/refer to H&S relative to various aspects (Smallwood, 2000)

Procurement

Rwelamila and Smallwood (1999) say evidence gathered suggests incorrect choice and use of PSs has contributed to neglecting of H&S by project stakeholders. Dreger (1996) concurs and says the form of construction delivery affects contractual relationships and the development of mutual goals.

Research conducted in South Africa determined the traditional construction procurement system (TCPS) to dominate among PSs used (Rwelamila and Smallwood, 1999). The TCPS follows a sequence of four phases: preparation; design; preparing and obtaining tenders, and construction. Ideally, design is complete when preparing bills of quantities. However, invariably an optimum design brief is not realised, a bill of quantities or schedule of rates is evolved from the partially complete design and details, resulting in ‘provisional’ quantities and a plethora of prime cost and provisional sums. Further, a contractor is appointed primarily on the basis of ‘lowest cost’ and commences work on site shortly after having been awarded the contract, having very little knowledge of the structure to be erected. Other findings include that clients are not familiar with other PSs and that the designers do not raise the choice of procurement method as an issue.

Meere (1990) advocates the integration of design and construction as a contribution to improving H&S. Dreger (1996) concurs and recommends the design-build contract form as the integration of design and construction has the greatest potential for success as it creates common project goals.

Current references to H&S in standard South African contract documentation are generally indirect, hardly coercive, and depending upon the level of commitment, contractors address H&S to varying degrees (Smallwood and Rwelamila, 1996).

RESEARCH

Sample frame, methodology and analysis

The sample frame consisted of 8 (57.1%) Technikon and 6 (42.9%) University Departments / Schools of Architecture.

A 6-question questionnaire consisting of 18 sub-questions was mailed to the Departments / Schools, 9 of which responded – 5 Technikons (55.6%) and 4 Universities (44.4%), which represents an overall response rate of 64.3%.

Given that respondents were required to respond in terms of impact on a scale of 1 to 5, it was necessary to compute an importance index (II) with a minimum value of 0, and a maximum value of 4, to enable a comparison of, and to rank various aspects. The II is calculated using the formula:

$$\frac{4n_1 + 3n_2 + 2n_3 + 1n_4 + 0n_5}{(n_1 + n_2 + n_3 + n_4 + n_5)}$$

where n_1 = Major impact (1)
n_2 = Substantial impact (2)
n_3 = Impact (3)
n_4 = Minor impact (4)
n_5 = No impact (5)

Findings

33.3% of respondents maintained that construction H&S is included in the architectural programme / curriculum offered by their Department / School. Of those that responded in the negative, 16.7% responded that their Department / School intended to include it within the next two years, 16.7% did not intend to ever include it, and 66.7% did not know. Of those that included it, 66.7% included it as, inter alia, a component of a subject, and 33.3% as, inter alia, a module of a subject.

33.3% of respondents regarded construction H&S as 'important' to their discipline, 33.3% as 'fairly important' and 22.2% as 'not important'.

100% of respondents were not aware of the Construction (Design and Management) Regulations in the United Kingdom, which regulations link clients and designers to construction H&S.

Table 2 indicates that the predominating design and procurement related aspects in terms of the extent to which they impact on H&S, are all design related: method of fixing; details; specification; design (general), and content of materials. It is also significant that the other seven aspects have II values below the midpoint value of 2.0, which indicates that they can be deemed to be perceived as having a minor impact.

Aspect	Impact (%) Major ……………………No					Don't know	II	Rank
	1	2	3	4	5			
Design related:								
Method of fixing	44.4	33.3	11.1	0.0	0.0	11.2	3.00	1
Details	22.2	55.6	11.1	0.0	0.0	11.1	2.78	2
Specification	33.4	22.2	22.2	11.1	11.1	0.0	2.56	3
Design (general)	22.2	22.2	22.2	22.2	11.2	0.0	2.22	4=
Content of materials	11.1	33.3	33.3	11.1	0.0	11.2	2.22	4=
Concept design	0.0	25.0	12.5	37.5	25.0	0.0	1.38	6
Size (bulk) of materials	0.0	22.2	22.2	11.1	11.1	33.3	1.22	7
Mass of materials	0.0	25.0	12.5	12.5	12.5	37.5	1.13	8
Texture of materials	0.0	0.0	33.3	33.3	11.2	22.2	1.00	9
Procurement related:								
Form of contract	0.0	11.1	22.2	11.1	11.1	44.4	0.89	10
Procurement system	0.0	0.0	25.0	37.5	0.0	37.5	0.88	11
Contract duration	0.0	0.0	22.2	22.2	16.2	44.4	0.67	12

Table 2 Perceived extent to which various design and procurement related aspects impact on construction H&S according to Architectural Departments / Schools

55.6% of respondents had one or more comments in general regarding construction H&S, and construction H&S education. Selected comments include: "Something that needs more publicity and development." and "This aspect is discussed in the Construction Economics and Management Department."

Conclusions

Architectural designers influence construction H&S directly and indirectly, through both design related activities and procurement related interventions.

Current and pending South African legislation and international legislation and best practice amplifies the need for architectural designers to address construction H&S. This in turn indicates an ethical imperative for architectural tertiary education to address construction H&S. This imperative is reinforced by previous South African research reported on in the literature, which indicates that architectural designers do consider/refer to construction H&S relative to various design related aspects.

A low level of awareness exists among Architectural Departments /Schools in terms of the extent to which various design and procurement related aspects impact on construction H&S. The perceived degree of importance of, and the minimal extent to which construction H&S is addressed in architectural tertiary education programmes is probably attributable to this low level of awareness.

Recommendations

Tertiary education architectural programmes should include construction H&S education as a module of a subject and it should be included among criteria used for evaluating design projects, working drawings and details.

Continuing professional development (CPD) for architects should include construction H&S. The professional institute for architects should develop practice notes relative to construction H&S.

References

Anderson, J., 1997, The problems with construction. *The Safety & Health Practitioner.* May, pp. 29&30.

Department of Labour, 2001, *Draft Construction Regulations*. Revision 3, Version 5, (Pretoria: Department of Labour).

Dreger, G.T., 1996, Sustainable Development in Construction: Management Strategies for Success *in Proceedings of the 1996 CIB W89 Beijing International Conference – Construction Modernization & Education*, Beijing, CD – file://D1/papers/160-169/163/p.163.htm.

Hinze, J.W. and Gambatese, J.A., 1994, Design Decisions that Impact Construction Worker Safety *in Proceedings of the 5th Annual Rinker International Conference focusing on Construction Safety and Loss Control.*

Gainesville, Florida, edited by Issa, R., Coble, R.J. and Elliott, B.R., (Rotterdam: Balkema), pp. 187-199.

Hinze, J.W., 1997, *Construction Safety,* (New Jersey: Prentice-Hall, Inc.).

International Labour Office (ILO). 1992, *Safety and health in construction,* (Geneva: ILO).

Jeffrey, J. and Douglas, I., 1994, Safety Performance of the UK Construction Industry *in Proceedings of the 5th Annual Rinker International Conference focusing on Construction Safety and Loss Control,* edited by Singh, A., Hinze, J.H. and Coble, R.J., Gainesville, Florida, (Gainesville: University of Florida), pp. 233-253.

Levitt, R.E. and Samelson, N.M., 1993, *Construction Safety Management.* 2nd Edition, (New York: John Wiley & Sons Inc.).

McGeorge, D. and Palmer, A., 1997, *Construction Management New Directions*. Oxford, Blackwell Science.

Meere, R., 1990, Building can seriously damage your health. *Chartered Builder*, December, pp. 8-9.

Republic of South Africa., 1993, *Government Gazette No. 14918. Occupational Health & Safety Act: No. 85 of 1993,* (Pretoria).

Rwelamila, P.D. and Smallwood, J.J., 1999, Appropriate Project Procurement Systems for Hybrid TQM *in Proceedings of the Second International Conference of CIB Working Commission W99 Implementation of Safety and Health on Construction Sites.* Honolulu, Hawaii., edited by Singh, A., Hinze, J.H. and Coble, R.J., (Rotterdam: Balkema), pp. 87-94.

Schneider, S and Susi, P., 1994, Ergonomics and Construction: A Review of Potential Hazards in New Construction *in Proceedings of the 5th Annual Rinker International Conference focusing on Construction Safety and Loss Control.* Gainesville, Florida, edited by Issa, R., Coble, R.J. and Elliott, B.R., (Gainesville: University of Florida), pp. 103-129.

Smallwood, J.J., 1996, The Role of Project Managers in Occupational Health & Safety *in Proceedings of the First International Conference of CIB Working Commission W99 Implementation of Safety & Health on Construction Sites.* Lisbon, Portugal, edited by Dias, L.A. and Coble, R.J., (Rotterdam: Balkema), pp. 227-236.

Smallwood, J.J., 2000, *A Study of the Relationship between Occupational Health and Safety, Labour Productivity and Quality in South African Construction*, [Unpublished PhD (Construction Management) thesis, University of Port Elizabeth].

Smallwood. J.J. and Rwelamila, P.D., 1996, *Department of Public Works Enabling Environment Initiative Final Report on Initiatives to Promote Health & Safety. Productivity & Quality in South African Construction,* (Unpublished report).

The Business Roundtable, 1991, *Improving Construction Safety Performance. Report A-3*, (New York: The Business Roundtable).

FINANCIAL AND SOCIAL COSTS OF CONSTRUCTION ACCIDENTS

Tang, S.L. Civil and Structural Engineering Department, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong

Introduction

In Hong Kong, the construction industry, especially for building projects, has a very poor safety record (Lee, 1991). The number of construction accidents is consistently at a very high level (Hong Kong Government, 1995). It accounted for more than one third of all industrial accidents and most fatalities in industrial accidents occurred in the construction industry. There is a general consensus that construction contractors should increase their safety investment in their construction projects. The higher the safety investment is, the better the safety performance will be. However, the extent of the investment is always a major concern. Recent research has revealed that in Hong Kong, most contractors set aside an amount of less than 0.5%, and some even less than 0.25% of the contract sum for investing in safety for their contracts (Lai, 1995). But is that enough?

Safety investments cannot be limitless. A methodology has been developed in a study (Tang, Lee and Wong, 1997) to quantify the minimum amount of safety investment for a building project. In that research, only financial costs of construction accidents have been considered. The social costs have not been included. The next section of this paper will discuss only the financial costs and the results of the said research. After that, a section will follow which describes the social costs of construction accidents.

Financial Costs of Construction Accidents

What Are Financial Costs?

Financial costs of construction accidents represent the losses incurred by the private investors, such as contractors, due to the occurrence of construction site accidents. In financial analysis, market prices are always used to represent benefits and costs (Tang, 1996). There are a number of studies concerning accident costs (e.g. Heinrich *et al*, 1980; Lee, 1991; Levitt and Samelson, 1993). The following financial losses were used in the research carried out by Tang, Lee and Wong 1997):

(a) Loss due to the injured person
- The compensation paid to the injured worker by the contractor is 2/3 of the wage of the injured person for each day of absence from work.
- Disability compensation, which depends on the percentage of disability (determined by a registered doctor) that the injured worker suffers.

(b) Loss due to the inefficiency of the worker who just recovered from injury upon resuming work
- When the injured worker returns to work, he cannot initially work with 100% efficiency
- A formula to calculate the loss:
  Loss = Wage of injured worker × (Day loss × 1/10 + % of disability)

(c) Loss due to medical expenses
- Medical expenses of the injured worker, including the cost of transport to hospital

(d) Loss due to fines and legal expenses
- If the contractor faces prosecution, he may have to pay the solicitor's fees and fines imposed by the court.

(e) Loss of productivity of other employees
- The safety officer, site agent, site engineer and the foremen may be involved in assisting the injured and carry out works relating to the accident such as accident investigation and accident report writing.
- Other workers may have to stop work immediately after the occurrence of the accident
- Loss assumptions (based on the experience of site safety staff interviewed):
  (1) Site agent: 0.05 day
  (2) Site engineer: 0.05 day
  (3) Foreman: 0.25 day
  (4) Other workers: 0.25 day for each worker and on average 4 other workers are involved in each

accident

(f) Loss due to damaged equipment or plant
(g) Loss due to damaged material or finished work
(h) Loss due to idle machinery or equipment
    - After the accident occurred, the workers may stop work temporarily and hence there will be idle machinery or equipment
    - Loss formula is based on the assumption that 20% of the contract sum is attributable to plant and equipment and that 2% of the plant and equipment will be idle on the day of accident:

$$\text{Loss} = \frac{\text{Contract sum} \times 20\% \times 2\%}{\text{Number of working days of the contract}}$$

Figure 1 was the questionnaire the researchers used to acquire the financial costs of accident from contractors. Readers should note that insurance premium, particularly the additional premium paid to the insurance company by a contractor when his safety record is poor, represents financial cost. This is, however, extremely difficult to quantify and therefore is not considered in the research. This is obviously a drawback. The insurance payment, together with fines imposed by the court, however, are financial costs only and not social costs. This will be further discussed in section 3.1.

Accident costs and safety performance

The total costs of accidents on a construction site depend greatly on project safety performance. If the safety performance is good, the accident costs will be low and vice versa. In order to compare site accident costs of projects of different contract sums and carried out at different time (so that no inflation adjustment is necessary), the Accident Loss Ratio (ALR), a dimensionless quantity, is defined as follows:

$$\text{ALR} = \frac{\text{TC}}{\text{Contract Sum}} \times 100\%$$

where TC is the total costs of site accidents in a project.

The assumed general shape of an ALR versus safety performance curve is shown in Figure 2.

Cost items arising from each accident

1. Injured person (Job nature: ______________________________)
   - Day loss ____________ days
   - Amount of compensation HK$___________
   - % of disability ______________ %
   - Disability compensation HK$___________
2. Loss from injured person (after resuming work)
   - Day loss (×1/10 + % of disability × 100) ____________ days
   - Equivalent loss HK$___________
3. Medical services and expenses
   - Hospitalization / medical expenses HK$___________
   - Others HK$___________
4. Fines and legal expenses
   - Fine by court and solicitor fees HK$___________
   - Others (e.g. transportation costs, etc.) HK$___________
5. Lost time of other employees
   (time taken by other employees in assisting the injured person)

Post	Monthly wages	Time incurred	Amount
- Site Agent	HK$_________	____________days	HK$___________
- Site Engineer	HK$_________	____________days	HK$___________
- Site Foreman	HK$_________	____________days	HK$___________
* Other Labourers			HK$___________

6. Equipment or plant loss
   - Damaged / replacement cost HK$___________
   - Repairing cost HK$___________
   - Others HK$___________
7. Damaged material or finished work
   - Cost of damaged material HK$___________
   - Cost of damaged finished work HK$___________
   - Others HK$___________

Figure 1 Financial Losses of Each Site Accident

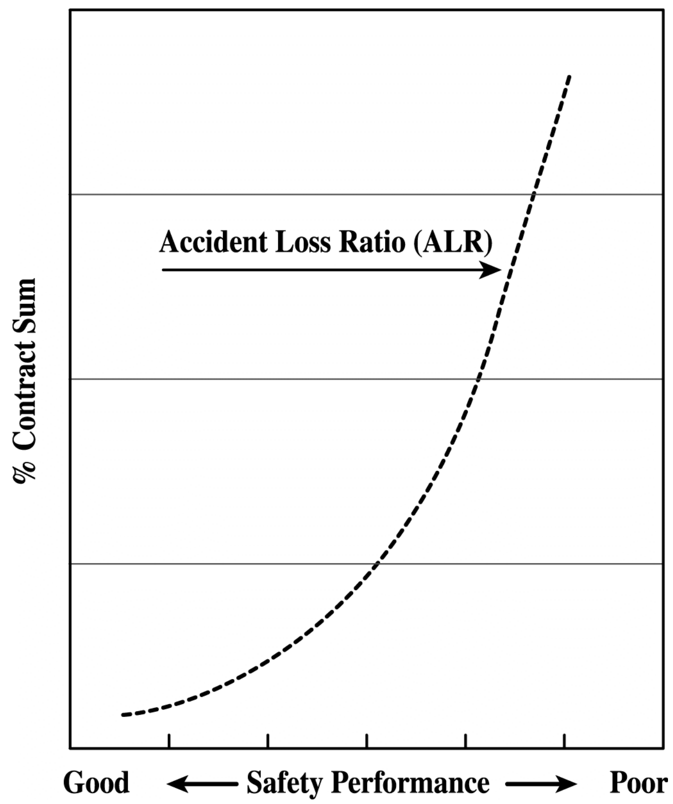

Figure 2 Accident loss ratio (ALR) versus safety performance

Safety investment

Safety investment is aimed at protecting the health and physical integrity of workers and the material assets of the contractor. Safety investment consists of the following 3 components:

(a) Safety administration personnel
   - Site staff and head office staff: according to Hong Kong law, a contractor has to employ safety officers and safety supervisors on site to monitor safety-related matters
   - Some large contractors will also employ safety managers / senior safety officers to direct and coordinate site safety staff
   - The salary of these personnel and their supporting staff (e.g. clerks, typists) are part of the safety investment
(b) Safety equipment
   - Purchasing of safety boots, goggles, helmets, safety fences, first-aid facilities, etc which are related to the provision of safety on site
(c) Safety training and promotion
   - Safety training courses are organized by contractors for their employees
   - Safety promotion includes the printing of pamphlets and posters, the production of safety advertising banners and boards, organization of safety campaign and monetary rewarding of individual workers who achieve a good safety standard of work, etc.

Figure 3 was the questionnaire used by the researchers to acquire information on safety investment.

Safety investment on each project

1. Investment on safety administration personnel

1.1 On-site module

Post	Number	Monthly wages
- Safety supervisor	( )	HK$__________
- Safety officer	( )	HK$__________
- Secretary/typist/clerk	( )	HK$__________
- Others	( )	HK$__________

1.2 Head office module

(please fill in monthly wages on pro rata according to no. of projects supervised in the same period)

Post	Number	Monthly wages
- Safety manager	( )	HK$__________
- Chief safety officer	( )	HK$__________
- Senior safety officer	( )	HK$__________
- Secretary/typist/clerk	( )	HK$__________
- Others	( )	HK$__________

2. Safety equipment investment on the project

2.1 Safety equipment investment HK$__________

3. Safety training cost

3.1 Safety training cost HK$__________

4. Safety promotion cost

4.1 Safety promotion cost HK$__________

Figure 3 Safety Investment on Each Site/Project

Safety investment and performance

The safety performance of a construction site varies with the amount of safety investment in the project. The higher the safety investment, the better the safety performance will be, and vice versa. As for ALR, safety investments on projects of different sizes and of different times can be compared if a dimensionless quantity, the Safety Investment Ratio (SIR) is used. SIR is defined as follows:

$$SIR = \frac{TSI}{\text{Contract Sum}} \times 100\%$$

where TSI is the total safety investment in a project.

Figure 4 shows the assumed shape of an SIR versus safety performance curve.

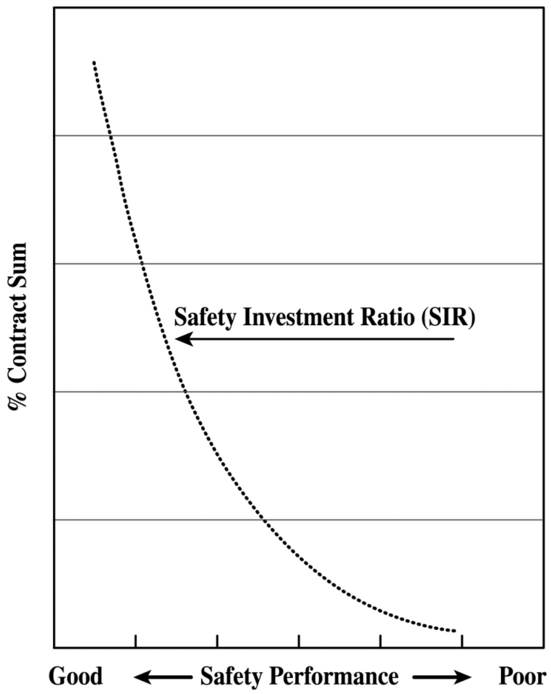

Figure 4 Safety investment ratio (SIR) versus safety performance

ALR and SIR curves combined

If the two curves in Figures 2 and 4 are combined, a third curve of total costs ratio (i.e. ALR + SIR) versus safety performance can be obtained. This curve will have a minimum point, as shown in Figure 5, which corresponds to the optimal safety investment of a construction project.

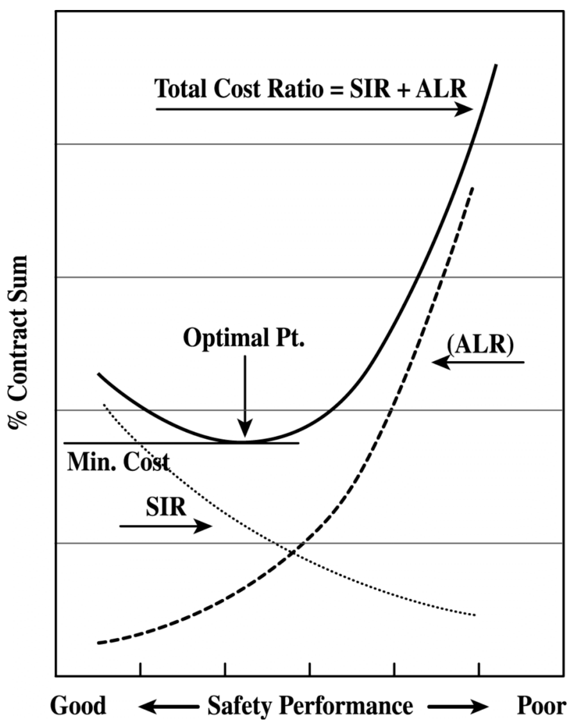

Figure 5 Total costs ratio (ALR + SIR) versus safety performance

Accident occurrence index

Accident Occurrence Index (AOI) is used to measure safety performance. It is defined as follows:

$$\text{AOI} = \frac{\text{Total equivalent day loss}}{\text{Total man-days required of the project}}$$

where Total equivalent day loss = $\sum_{i=1}^{n}$ Equivalent day loss of an accident,

where n is the total number of accidents in a project, and
Equivalent day loss of an accident = Day loss + (20 × % disability)

For example, if a worker is injured in an accident, has been absent for 30 days, and is certified by a doctor to be of 2% permanent disability as a result of the accident, then the equivalent day loss will 70 days (30 + 20 × 2). The maximum percentage of disability is 100. Twenty times 100 is 2,000, and this means that the equivalent day loss for a case of 100% disability is 2,000 days. A worker in Hong Kong earns an average of HK$600 a day, and the compensation for a fatality is HK$ 1,200,000. This is consistent with the current compensation practice if a factor 20 is assumed. The factor 20 will be changed for calculating equivalent day loss if the compensation policy is changed or if the average daily wage of labourers in Hong Kong is changed. Note that the equivalent day loss of a very serious injury may be higher than that of a fatal accident.

To calculate the accident occurrence index, the total equivalent day loss should be divided by the total man-days required of the project. For example, a contractor recorded that there were 12 accidents when a building project was completed. There were a total of 100 days loss for these 12 accidents and a total of 10% disability of the injured workers. There were 10,000 man-days of labor force recorded for completing the project. Then the accident occurrence index would be (100 + 20 × 10) / 10,000 = 0.03.

Figure 6 shows the questionnaire used to acquire information about AOI.

Contractor name : ______________________________
____

Contract title : ______________________________
____

Contract sum : HK$______________________________

Contract period : ______________ to ______________

Number of working days : ______________________ days

Total man-days employed (include subcontractors) : ______________________________

Number of accidents : ______________________________

Result of injury: ______________ Result of death: ______________

Figure 6 Data for calculating Accident Occurrence Index of Each Site/Project

Result of research and optimal safety investment

Altogether 576 accidents from 18 building projects were investigated (Tang *et al*, 1997). Therefore, 576 forms (Figure 1) were filled. 18 forms (Figure 3) and 18 forms (Figure 6) were also filled. The data obtained were used to plot a curve as shown in Figure 5. A minimum point can be obtained from the curve. It was found that in Hong Kong, the optimal safety investment on a building project was about 0.8% of the contract sum. The total cost to the contractors (accident loss + safety investment) was found to be 1.2% of the contract sum. In fact, the 0.8% should be regarded as a minimum amount of safety investment. An investment greater than 0.8% will result in intangible benefits, such as greater peace of mind of workers, better reputation of the company, greater job satisfaction and so on, which, although not considered in this mathematical model, will definitely be valuable assets to the contractor.

Social Costs of Construction Accidents

What Are Social Costs ?

Social costs represent losses incurred by society due to occurrence of construction site accidents. Social costs are defined as any items that will result in the utilization of national resources. Social costs are not based on the contractor's point of view like what were discussed in the previous sections, but are based on the society's point of view. However, most of the financial costs (but not all) are also social costs, and costs incurred by society are of a wider perspective than those incurred by private investors (contractors) and for some individual items costs incurred by society are higher than costs incurred by contractors. For example, hospital fees paid by a contractor (financial loss) to the injured worker is HK$68 per day, but the actual cost incurred (social loss) is about HK$1,800 per day in 2000. That is to say, the society (the Hong Kong Government) subsidizes the injured worker HK$1,732 per day for his stay in a hospital. This point will be further discussed below. The following are examples of social costs (Ngai and Tang, 1999):

(a) The productive years of the injured worker. To evaluate the loss of the productive years of a worker, the method stated in the "Employees' Compensation Ordinance" published by the Hong Kong Government should be adopted. The ordinance establishes the compensation of an injured worker for the case of permanent total incapacity and the case of permanent partial incapacity, with reference to earnings, age and the extent of loss of earning capacity of the injured worker.
(b) Families and relative losses. This refers to the opportunity costs of housewives' work and relatives' work to take care of the injured workers.
(c) Fire Department and rescuer services. Costs are incurred by society to provide rescue services such as the ambulance transportation and first-aid services. Besides, fire-engines services and the wages of the related staff are also social costs. It is found that the average costs per accident, including the human resources and the operation costs of equipment of the Fire Department in 1996 and 1997 were HK$9,014.00 and HK$9,885.00 respectively.
(d) Losses due to the medical expenses and hospitalization. In Hong Kong, the hospitalization fees of local residents in public hospitals were HK$60.00 and HK$68.00 per day per person in 1996 and 1997 respectively. However, the actual expenses that the hospitals incurred were HK$1,570.00 and HK$1,770.00 per day per person in 1996 and 1997 respectively. The losses incurred by the society are the actual expenses.
(e) The Hong Kong Police Force. When a construction site accident is reported to the police, the latter will tackle the case and carry out immediate actions. The police also maintains discipline on site and assists factory inspectors from the Labour Department in investigating the accident. This is also a cost to the society.
(f) The Social Welfare Department. This includes the administration/personnel costs of the Social Welfare Department to provide assistance to the injured worker.
(g) The Labour Department. This includes the costs for regular site inspection for prevention of accidents and the costs for investigation and reporting if accidents occur.
(h) The Court. When a serious or a fatal accident happens, the Court will carryout an investigation to find out the reasons for the injury or the death of the worker, especially when there is any argument between the employer and the family of the employee. This is another cost to society.

The items (a) through (h) described above, when added to the financial costs described in section 2.1, represent total social costs of construction accidents. Note that financial losses such as fines and insurance premium should be excluded from the social costs consideration because they represent internal transfers (Tang, 1996) rather than the costs of the society.

Safety investment by society

Under the social costs of construction accidents, safety investment consists of resources invested both by the contractors and the government. Safety investments by contractors have been discussed in Section 2.3. Safety investments made by the Hong Kong Government include:

(a) Safety administration personnel from government departments
  - Safety inspectors, safety advisors, senior safety advisors of the Labour Department
  - Other supporting staff in the Labour Department and the Occupational Safety and Health Council (OSHC) who are responsible for safety in the construction industry
(b) Safety training and promotion organized by government departments
  - Printing of pamphlets and posters, the making of safety advertising boards and banners, the organizing of safety campaigns, etc.
  - The costs of safety training courses offered by government education institutions [e.g. The Hong Kong Polytechnic University (HKPU) and the Construction Industry Training Authority (CITA)]

Impact of Safety Investment to Construction Site Safety

In view of the present unsatisfactory situation of construction accidents in Hong Kong, it is of no doubt that the government, promoters and contractors should increase their safety investment in construction projects to improve site safety. More measures should be implemented to improve site safety. The increase in safety investment will result in higher social benefits.

Social benefits are defined as any items that will result in a saving of national resources. Social benefits refer to the resources saved owing to the reduction in the number of fatal and/or injured workers. For instance, the number of fatal and injury cases per thousand workers in the construction industry in 1995 were 0.96 and 232.7 respectively and in 1996 were 0.681 and 219.86 respectively. Therefore, the social benefits gained by the society are the resources saved owing to the reduction of 0.279 fatal workers per thousand workers and the 12.84 injury workers per thousand workers. As the saved resources can be used somewhere else in the society, these can represent benefits to the society.

Using the statistical data, the social costs incurred by and the safety resources invested by contractors and the government in 1999 and 2000 can be evaluated. The difference of social costs of 1999 and 2000 represents the social benefits (the social costs in 1999 is expected to be higher than that in 2000 due to a higher safety investment in 2000 than in 1999). As a result, the impact of safety investment on social benefits for construction projects can be established. A large scale survey is being conducted to acquire financial and social costs data of construction accidents in Hong Kong. Data on safety investments made by contractors and public bodies are also being collected. The results are not yet available at the time the author is writing this paper. It is hoped that some results can be released in the conference to be held in April/May of 2002.

Reference

Heinrich, H.W., Peterson, D. and Ross, N. (1980). Industrial Accident Prevention: A Safety Management Approach, 5th edition. McGraw-Hill, New York.

Hong Kong Government (1995). Consultation Paper on the Review of Industrial Safety in Hong Kong. Education and Manpower Branch, Hong Kong Government.

Lee, H.K. (1991). Safety Management: Hong Kong Experience. Lorrainelo Concept Design, Hong Kong.

Levitt, R.E. and N.M. Samelson (1993). Construction Safety Management, 2nd edition. John Wiley & Sons, New York.

Ngai, K.L. and Tang S.L. (1999). Social Costs of Construction Accidents in Hong Kong. Proceedings of the 2nd International Conference of CIB Working Commission W99 on Implementation of Safety and Health on Const4ruction Sites, Honolulu, Hawaii, USA, March 1999, pp. 525-529.

Tang, S.L. (1996). Economic Feasibility of Projects, revised edition. McGraw-Hill.

Tang, S.L., H.K. Lee and K. Wong (1997). Safety Cost Optimization of Building Projects in Hong Kong. Construction Management and economics, Vol.15, No.2, pp.177-186.

A STUDY OF CONSTRUCTION SITE ACCIDENT STATISTICS

Wang, Yousong Dept of Civil Engineering, South China University of Technology, Guangzhou, P.R. China

Zhang, Yan Dept of Civil Engineering, South China University of Technology, Guangzhou, P.R. China

Poon, Sun Wah Dept of Real Estate and Construction, The Univ. of Hong Kong, Hong Kong

Huang, Haiying Dept of Civil Engineering, South China University of Technology, Guangzhou, P.R. China

KEYWORDS

Construction site; accident; safety

Introduction

There have been increasing numbers of construction projects undertaken in China since the beginning of the opening and reforming policy. The engineering quality and construction safety, however, are the two main problems affecting the construction industry. The Chinese government has been making efforts to avoid the stretching of these two problems by issuing laws and regulations, strengthening education and training, learning advanced experience from abroad, etc. The Construction Law of Peoples Republic of China promulgated on March 1, 1998 is a milestone. It clearly demands that all construction activities must ensure quality and safety which is found in its Item 3 of Chapter I. Although the situation has improved, there are still many dissatisfactions of safety on site. The authors have collected 307 pieces of casualty information on construction sites in southern China. The aim is to find the main causes of accidents, places with high occurrence, dangerous types of work, etc, by statistical analysis. Based on that, several improvements are attempted to suggest better safety management in the future.

Distributions and Analysis of the Statistical Information

The research collects information through sending questionnaires, visiting managers on sites and asking for records from government department. 136 companies were being investigated, with 307 safety accidents reported, including 209 wounded and 98 death The statistical results are as follows.

Age distribution of persons involved in accident

The labourers and workers on construction sites are mostly in the age range of 20-50 years old. The age distribution of the persons involved in accidents as shown in Figure 1 is quite the same as that of the total worker on site. This indicates that there is no significant relationship between the accident and the age. The probabilities of accident occurrence at any age ranges are almost equal. Therefore, safety education should be introduced to all workers on site.

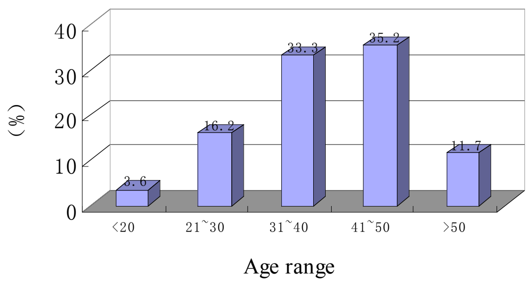

Figure 1 The age distribution of the accidental person concerned

Work experience of persons involved in accidents

Theoretically, the longer of work time and experience on construction sites, the lower rate of accident probability. However, the statistical diagram shown in Figure 2 shows that most accidents involved persons with 1 to 10 years of work experience. The accidents happened at a lower rate for workers with shorter than 1 year and longer than 11 of experience. The reasons are likely to be self-assured capability, paying no attention to safety regulations and carelessness, etc.

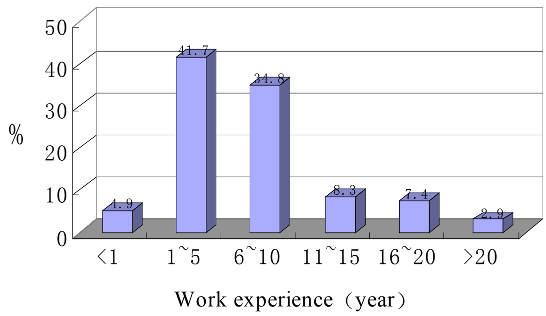

Figure 2 The work experience distribution of the accidental person concerned

Weeks on site before accidents occurrence

It needs a period of time to suit the situation in a certain site even if the worker is experienced. So, there would be connections between the entering time on the site and the accident occurrence. Figure 3 shows the statistical relation. Most accidents occurred between 1-30 weeks of entering site. Nearly half of the total ranges between 1~10 weeks. In contrast, the accident occurrence rates are relatively low within shorter than one week and longer than half a year. This gives a phenomenon that new comers on sites are usually very careful to suit the circumstance and old workers are familiar to the sites. Both types of workers are unlikely to be involved in accidents. The safety managers should pay much attention to workers having served for one to two months on the site. Their accidental probability is relatively high.

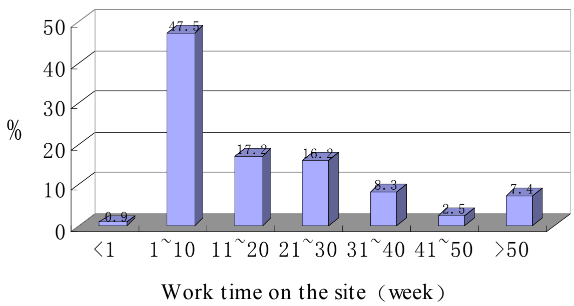

Figure 3 The distribution of work time on the site of the person concerned

Types of a*ccident*s

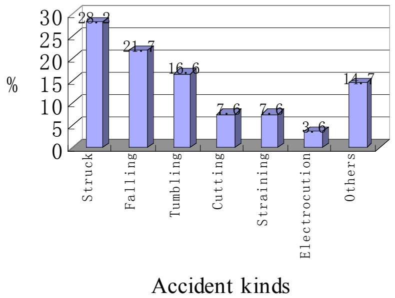

Figure 4 The distribution of accident kinds

Types of accident is one of the analyses because it reveals the causes of accident to some extent. From Figure 4, it is known that half of the accidents involved being struck by objects and falling from height. The other types of accidents are tumbling, cutting, straining and electrocuting in frequent orders. These causes are the main threats to workers' lives on construction sites. The precautions and education are necessary to be taken by workers.

Location of accident

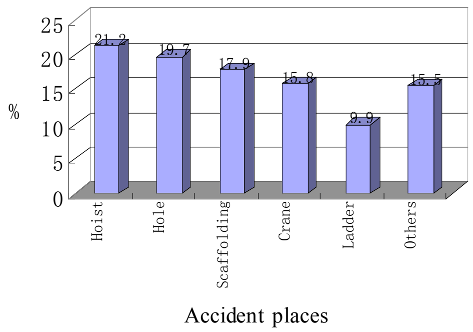

Figure 5 The distribution of accident places

Analysis of accident locations is also important. It is shown in Figure 5 that most of the accidents occurred at hoists, holes and wells, scaffoldings, cranes and ladders. So warning boards should be erected at these places to call attention to workers of possible dangers. Besides, detailed instructions of works relating to these areas are suggested for regular management to lower accidental possibility.

Kinds of Work

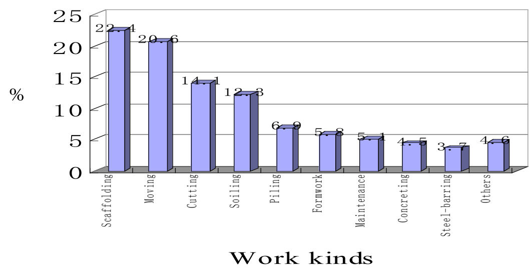

Figure 6 The distribution of work kinds relating to accidents

Lastly, it is worthy to analyse the kinds of work relating to accidents. The statistics shown in Figure 6 suggest that the vulnerable work kinds are scaffolding work, earth work, piling work, framework, concreting work and mechanical maintenance. Special technical training to the workers involving in those works is recommended to ensure that all workers are qualified.

Suggestions

Based on the statistics and analysis above, several advices are suggested for improving the safety on construction sites.

- First of all, the governmental department should pay much attention on the safety on construction sites as roles of guide, educator and inspector. It is necessary to organize activities such as technical training, discussion and seminar on safety, exhibition and public education, experience exchange, workshop, etc.

- Second, management of the industry needs to be strengthened. The legal regulations should be perfected step by step. An atmosphere concerning safety problem should be built in the society of construction industry. The rewards and punishment of companies should link with their safety records.

- Emphasis of precautionary idea on safety. Contractors should understand that safety is an important prerequisite to pursue profit.

- Spread knowledge of advanced experience and technology on safety. Provide protective utilities such as safety net, helmets, boots, gloves, goggles, ear-stoppers. This encourages the creation and innovation of new techniques on construction safety.

- Bring in life insurance mechanism for workers on sites. Education and protection are one part of the safety issue. On the other hand, accidents are inevitable. So the preparation of handling accidents is necessary. This is an important approach to minimize the economic risk of construction.

Concluding Remarks

The results of this paper give an understanding of safety issue on construction sites in southern China. The ages of casualties have insignificant relation to the accidents. The most dangerous period is likely to involve workers with about 5-year work experience and 1-30 weeks on certain sites. The kinds of accident are struck by objects, falling from height, tumbling, cutting, straining and electrocuting in frequent orders. The occurrence points are at hoists, holes and wells, scaffoldings, cranes and ladders, etc. The works involved in accidents are usually scaffolding work, earth work, piling work, framework, concreting work and mechanical maintenance. Therefore, the authors suggest strengthening the supervision role of government, to execute self-discipline in the industry, to educate the workers with awareness of safety, to change contractors' idea, to spread safety protective measurements, and to bring in life insurance mechanism for better handling of accidents.

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Reference

Safety Management in the Construction Industry – Asia Experience, Safety Specialist Group, Hong Kong Institute of Engineers, 2000.

Green Cross, Occupational safety and health council of Hong Kong, Vol 11, 2000.

The Guidelines on Occupational Health and Safety Management Systems for the Construction Industry of Japan, Japan Construction Safety and Health Association.

http://www.kensaibou.or.jp

Construction Site Safety, A guide for managing contractors, R. Hislop, Lewis Publishers, London, 1999.

RESTRICTION OF THE MULTI-LAYERS SUBCONTRACTING PRACTICE IN HONG KONG – IS IT AN EFFECTIVE TOOL TO IMPROVE SAFETY PERFORMANCE OF THE CONSTRUCTION INDUSTRY?

Wong, Francis Hong Kong Polytechnic University, Hong Kong
So, Lawrence Quality & Safety Department, China Harbour Engineering Company (Group)

KEYWORDS

Multi-layers subcontracting, safety performance, alternative safety improvement measures, and Hong Kong

Introduction

In 1998, the number of persons engaged in industrial activities constituted about 28 percent of Hong Kong's working population. However, the industrial sector recorded 43,034 loss-time industrial accidents in 1998 representing 68 percent of all worked-related loss-time injuries. Of these, 19,588 loss-time accidents or 45.5 percent happened in construction industry. This accounted for an accident rate of 248 per thousand workers. The safety record of the construction industry was poor and much worse than other industries in Hong Kong. The reasons of the poor safety record may correlate with many factors such as complexity of the work or system, risk nature of works, management style, safety knowledge and commitment, and personal behavior (Stranks 1994). Surprisingly the multi-layers subcontracting practice is unique to the Hong Kong construction industry and has been the most common practice being used with long history. When a principal contractor secured a project from a developer, usually it would break down the project activity into different trades and then sublet each category to individual subcontractors with the lowest bid (Lee 1991). These subcontractors would normally further subcontract their work without the consent of their principal contractor to several smaller firms in order to minimize their overheads.

The problems of multi-layers subcontracting practice have long been an issue and a controversial subject in the industry. Recent researches (Linehan 2000a & Tong 2000) have all suggested having legislation for restricting the subcontracting practice in the construction industry for better safety performance. Although such restriction may help to improve the safety performance, it would be extremely difficult to implement in the workplace due to the traditional work practice. On the other hand, some people including Lee (1999a) and So (2000) had disagreed to restrict the multi-layers subcontracting practice. They considered that the subcontracting practice has great market values for the industry, which ought not be interfered by restriction in the form of legislation.

Previous Studies

Safety performance of the Hong Kong construction industry

It is generally acknowledged that poor safety performance of the Hong Kong construction industry is an unenviable fact. The Census & Statistics Department (1999) found that the construction industry had the highest fatalities and accident rate than other industries in Hong Kong such as the manufacturing industry, catering, transportation, storage, communication and utilities industry in the past ten years. Also, Rowlinson (cited in Lo 1997) identified that the construction industry accident rate was exceptionally high in Hong Kong, the fatality rate was 10 times higher than UK, 8 times than USA, 4 times in Japan and 2 times than in Singapore. Thus construction should be one of the most important target areas of study for accident prevention in Hong Kong.

Subcontracting practice of the Hong Kong construction industry

Recent researches (Wong 1999 & Lee 1996) have indicated that the high accident rate of the Hong Kong construction industry was related to the multi-layers subcontracting system. Lai (cited in Lee 1991) found that the number of subcontractors in one construction site might be ranged from 17 to 54. The principal contractors' direct labour force in a project was small, and the subcontractors' workforce might actually carry out construction work without the knowledge of the principal contractor. Managing safety was a problem in terms of communication and monitoring. Lee (1999b) commented that the multi-layers subcontracting practice is common and excessive in Hong Kong. The most extreme case quoted by Lee was subcontracting up to 15 layers.

Problems of subcontractors

The structure of subcontractors is usually simple and small in size. They had neither time nor inclination to keep abreast with legal requirements or technological developments in safety. Shaw (1998) found that small business faced with specific health and safety challenge, many firms lack of adequate resources and were often struggling to survive. Furthermore, they lack an understanding of their obligations and the health and safety issues of their processes. Poon (1998) commented that the major cause of accident was that subcontractors were rewarded according to work done. They were working under tremendous time constraint, which caused higher possibility of construction accidents.

Advantages of subcontracting

Lee (1999a) however disagreed that subcontracting practice was the major cause of poor safety performance of the Hong Kong construction industry. He commented that the multi-layers subcontracting system was worth to exist in the market. Wong (1997) found that subcontracting practice could be employed to cope with long term demand uncertainty, allowing the firm to avoid the employment of a stable workforce and investments in fix resources under conditions of the fluctuating demand, serving as an external buffering mechanism, absorbing uncertainties arising from availability of resources and operational conditions.

Research Method

In order to achieve quantitative and qualitative result, both questionnaire and interview survey methods were used for the various concerned parties of the construction industry. Questionnaire survey was used for the contractor and non-contractor groups in order to collect quantifiable data to reflect the fact and norm of the industry. Thereafter, face-to-face interview was carried out to the professionals in the construction industry who have not participated in the questionnaire survey in order to provide qualitative and objective explanation for the data collected from the questionnaire survey.

Survey Results

Totally 55 out of 250 questionnaires were received, which represents a return rate of 22%. In addition, 15 numbers of professional which included 7 project managers, 4 consulting engineers and 4 safety professionals were interviewed.

Current status of the Hong Kong subcontracting practice

From the questionnaire survey, the majority of respondents expressed that they would sublet 80-90% of their works to subcontractors. None of the respondents would carry out construction works that fully rely on their own effort, at least 30% of works would be subcontracted out. The main reasons for them to subcontract works out were cost control and commercial purposes.

A contractor would normally employ over 100 numbers of subcontractors. In the current construction market, about 80-90% of construction workers are employees of subcontractors. If the subcontracting practice was restricted or regulated, it may cause a great impact to the society due to unemployment of the subcontractors and their construction workers.

The survey also reflected a common industrial practice that majority of the contractors would allow their subcontractors further sublet works to other subcontractors without controlling the number of subletting levels. They would normally not consider their subcontractors' subletting status and therefore the culture of multi-layers subcontracting practice is fostered.

As shown in Table 1, the accident rates per thousand workers of the respondents were ranged from 33 to 200. These accident figures would be used for providing trend for analysis of factors, which were affecting the safety performance.

Accident Rates provided by the respondents						
33	35	42	45	47	55	55
60	61	63	77	83	91	95
100	121	160	191	200		

Table 1 – Accident Rate per thousand workers

Factors affecting safety performance

The regression analysis technique in the SPSS computing software has been used to determine the relationship among the accident rates and other variables in the survey. The calculation result of Pearson's R-value reflects the trend of factors affecting safety performance.

Number of employees vs accident rate

The number of employees in the organization is one of the factors affecting the safety performance. The calculated R-value of the accident rate and the number of employee was at – 0.52, which represented that there was negative correlation between them. That is to say a higher number of employees, a lower figure of the accident rate.

Percentage of subcontractor employees vs accident rate

The percentage of workers employed by subcontractor and the accident rate do have a positive correlation. The calculated R-value was at + 0.41, which implied that more subcontractors' workers in an organization, poorer would be the safety performance.

Percentage of works sublet vs accident rate

The scales of works being sublet and the accident rate have positive correlation. The calculated R-value was at + 0.42, which implied that more works being sublet to subcontractors, poorer safety performance may result.

Perception of the Industry

Most of the respondents agreed that multi-layers subcontracting practice is one of the major causes of poor safety performance and the performance of subcontractors is difficult to control. Reduction of subcontracting could help improve the safety performance of the construction industry.

However, the multi-layers subcontracting practice has been widely adopted by the industry, majorities of the respondents believed that restriction of this practice is impracticable. It is because a great impact to the local construction industry was expected as well as the free market approach by Hong Kong would be damaged.

Whether restricting the multi-layers subcontracting practice is the best solution for improving the safety performance is arguable. However, the survey indicated that most of the respondents disagreed with it.

Discussion

Problems caused by multi-layers subcontracting

The multi-layers subcontracting practice was considered as one of the major reasons for poor safety performance. The interviewees explained that subcontractors are normally small in size and simple in structure. They usually lack safety commitment because of limited budget, time and human resources. It resulted in insufficient provision of on-the-job safety training to the employees, who have very limited knowledge to deal with safety matters.

Subcontractors would rarely employ safety professional and they had no interest in safety matters because most of them believed that safety should be the responsibilities of the principal contractors. It could be explained by the fact that in Hong Kong subcontractors are usually not accountable for serious accident or for violation of safety regulations. Principal contractors would usually be responsible for workmen compensation and penalized for safety offenses.

The short contract period and multi-layers subcontracting of works, which resulted in subcontractor who is at the lowest subcontracting level, will not have realistic profit. Hence they have to resort to sub-standard works, which will increase the possibility of accident occurrence (Leung 1997). High mobility of construction workers is also one of the major causes for poor safety performance. Simo (1995) found that subcontractors usually employed short-term workers. These short-term workers were strangers to the hazardous conditions on site and they would not take care of other workers because they do not know each other.

Assurance of subcontractors' quality and performance

It is considered that subcontractors' quality and performance were difficult to control. Subcontractors are operating as individual firms. They would have their own culture, structure, management style and business strategies. Most of the small size subcontractors have not been formed formally and most of them have only a few staff or workers. They are not well organized and therefore communication between the principal contractor and subcontractors might have problems. Meanwhile, if the principal contractor provides too much effort on supervising subcontractors, the objective of minimizing the use of limited resources would be lost.

Under the current subcontracting practice, the lowest bidder would get the contract and as a result the financial return is trivial but the risk is huge. Subcontractors have to shorten the completion time and resort to lower standard or to use unskilled or semi-skilled labour in order to save construction cost. As a consequent, the quality and performance are being affected accordingly.

Some interviewees opined that if the expected standards could be listed out clearly onto the subcontract documents, assurance for quality and performance would not be a problem. Furthermore, a suitable selection procedure for subcontractors such as pre-tender qualification is being considered as an effective tool to control subcontractors' quality and performance.

Restricting the multi-layers subcontracting practice

Most respondents considered that restricting the multi-layers subcontracting practice was impracticable. The interviewees suggested that even if the proposed strategy of restricting the multi-layers subcontracting practice was adopted, there would have no effective and reliable method to monitor whether the contractors have sublet the work out or how many layers of subcontract are being truly sublet. In addition, the expected financial impact and risk to principal contractors would be too great to be affordable if the multi-layers subcontracting practice is restricted.

Expected impacts

Over 80% of the respondents expressed that impact to the industry was expected if the multi-layers subcontracting practice has been restricted. The industry will be adversely affected. If the subcontracting practice is drastically restricted or the subcontracting levels is highly regulated, principal contractors have to employ extensive direct employees so that a large amount of routine turnover was required, and the operation cost would be greatly increased. Some contractors may be forced out of business. The society would also be affected because the construction cost would be increased and the increase in cost would eventually be transferred to end-users.

Free Market Approach

Based on the questionnaire survey, it is considered that the free market approach adopted by Hong Kong would be damaged by restriction of the multi-layers subcontracting practice. Most medium and small size contractors could not survive. If the multi-layers subcontracting practice is allowed to operate continuously, it could provide more tender opportunities and allow more subcontractors to join the competition. So that tender price would be more competitive and the construction cost could be maintained at an affordable level.

Proposed Alternative Measures to Improve Safety Performance

Strengthen the control of subcontractors

As previously discussed, safety training is considered as a key factor affecting safety performance. It is recommended that sufficient safety training should be provided to employees at all levels. Subcontractors should be held accountable for safety and they should be encouraged to employ safety professionals in managing safety matters.

Careful control and selection of subcontractor is essential that pre-qualification process should be adopted to assess subcontractor's quality and ability. The expected standards and safety requirements should be listed onto the subcontract documents as detailed as possible, and to correlate subcontractors' past safety performance with tendering opportunity.

It also suggests to replace the current practice of awarding the contract to the lowest bidder. The tender price should be assessed with special criteria. Contracts should only be awarded to those contractors or subcontractors who have submitted tender at a reasonable price.

Legislation and enforcement

It is suggested that tightening the requirement of registered safety officer such that at least one registered safety officer should be employed for each construction site. The current legal requirements of one safety officer to be employed when the total workforce is at 100 or more should be tightened. Small construction sites usually have no safety officer to carry out safety supervision.

The current Pay for Safety Scheme operates by the Works Bureau is an effective way to improve construction safety. It is an incentive scheme to compensate the safety cost incurred by contractors. Under the conditions of contract, the contractors are entitled to pay on monthly basis if they have completed the specified safety items as stated in the contract. It is suggested that extending this incentive scheme to other Government and private contracts.

The enforcement of occupational health and safety regulations is suggested to hold individual subcontractor or worker accountable. The enforcing department should prosecute those safety offenders directly.

It is recommended to implement tradesman-licensing system. Special tradesmen must gain recognized licenses before they are allowed to carry out high risk activities such as operation of plant, bend and fix steel bar, gases welding and working in confined spaces. The licensing system could ensure that high-risk tradesmen have received sufficient safety training before they start to work.

Chan (2000) commented that there was very little social security to workers, and everyone puts in extra to ensure that they can feed their family. As a result, workers either ignore or accept the danger, and in some cases they are being forced to take risk. A better safety culture for the construction industry is required. It is recommended that the Government should enhance the legal status and the negotiation ability of the labour unions and to educate workers to demand for the provision of safer plant, equipment and safer working environment from their employers.

Technological changes

The construction industry should be encouraged to widely adopt the use of pre-cast construction technique instead of using traditional labour intensive construction methods. Chudley (1985) found that the tradition cast-in-situ concrete construction method used to occupy large working area, consume more labour forces and construction materials and produce large amount of construction wastes.

Wong (2000) opined that occupational health and safety issues were often the results of lacking safety as an element or inadequate safety consideration in the design of buildings and planning of building works. Remedial safety measures are often technically more difficult, less ideal, less acceptable to employees, and cost more money than well-planned safety measures, which have been considered at the design and planning stage. Tang (2000) recommended introduction of the 'Construction Design Management' concept from Europe to the Hong Kong construction industry. Also, to request architects put considerations of design safety, construction safety and the safety of subsequent maintenance into account at the design stage. It is believed that this new management concept could help improve construction related occupational safety and health.

High mobility of construction workers is the major cause of poor safety performance. These short-term workers are strangers to the hazardous condition on site. It is therefore recommended to employ as many long-term employees as possible.

Linehan (2000b) commented that much could be achieved in quality, costs and safety through attempting to develop longer-term partnership between contractors and subcontractors. Longer term partnership enable both parties to work for good safety standards, to formulate effective means for working safely, and to develop a proper understanding of the reciprocal duties and responsibilities which exist on site.

Conclusion

The research, which was based on the perception of the survey respondents had concluded that restricting the multi-layers subcontracting practice might bring with it great impacts which is not acceptable by the majority of the contractors in Hong Kong. Without their full support and cooperation, implementation of such idea would encounter tremendous difficulties that would make the regulation not applicable. Meanwhile, the subcontracting practice has its values and advantages for the construction industry, which should not be under estimated. Linehan (2000b) commented that certain subcontracting by professional trades was unavoidable though excessive subcontracting should be minimized. Thus, the proposed alternative measures, as well as the reduction of excessive levels of subcontracting are recommended for improving the safety performance of the Hong Kong construction industry.

References

Census & Statistics Department, 1999, 'Industrial Accident Figures and Rates of All Industries 1989-1998', Census & Statistics Department, Printing Department, HKSAR Government, Hong Kong.

Chan A., 2000, 'Tragedy in the use of Oxy-acetylene torches', A Hong Kong journal of Safety Bulletin, Vol.18, No.4, p.8.

Chudley R., 1985, Construction Technology Volume IV, Longman Singapore Publishers, Singapore.

Lee H.K., 1991, Safety Management-Hong Kong Experience, Lorrainelo Concept Design, Hong Kong.

Lee H.K., 1996, Construction Safety in Hong Kong, Lorrainelo Concept Design & Project Management Ltd., Hong Kong.

Lee S.S., 1999a, 'An article of interview by Labour Department', A Hong Kong journal of Construction Safety Newsletter, Labour Department of HKSAR, Vol. 4, p.4.

Lee K.M., 1999b, 'An article of interview', A Hong Kong journal of Construction Safety Newsletter, Vol.4, Nov 99, p.3.

Leung P.C., 1997, 'A Review of the Report of Construction Safety by the Hong Kong Construction Association', A Hong Kong journal of Green Cross, Vol.7. No.5, p 4.

Linehan A.J, 2000a, 'Subcontracting in the Construction Industry', A speech presented in Safety + Health Conference in Hong Kong, 22-23 March 2000.

Linehan A.J., 2000b, 'The safety implications of subcontracting in the construction industry', A Hong Kong journal of Green Cross, Vol.10, No.4, pp.12-20.

Lo A., 1997, ' A Talk of Safety Experience', A Hong Kong journal of Safety Bulletin, Occupational Safety and Health Association, Vol. 14, No. 5, pp6-7.

Poon T.C., 1998, 'Workers Have No Choice to Work Under an Unsafe Working Environment', A Hong Kong journal of Safety Newsletter, Labour Department, Hong Kong, Vol. 2, p.3.

Shaw M., 1998, 'Promotion of Occupational Safety and Health for Small and Medium Sized Enterprises – Canadian Experience', A Hong Kong journal of Green Cross, Occupational Safety & Health Council, Vol.8. No., pp.40-45.

Simo S., 1995, 'Serious occupational accidents in the construction industry', A journal of Construction Management and Economics, Vol 13, pp.299-306.

So K.C., 2000, 'The Multi-layers subcontracting system', An article of interview from the Hong Kong newspaper of Hong Kong Economic Post, 12 May 2000.

Stranks J., 1994, Health & Safety in Practice - Management System for Safety, Bell & Bain Ltd, Great Britain.

Tang W.S., 2000, 'Establish safe construction culture from work designs', A Hong Kong journal of Green Cross, Vol.10, No.4, p.2.

Tong Y.C., 2000, 'Scrapping of rotten subcontracting system urged', An article of interview by South China Morning Post, http://www.scmp.com/News/Hong Kong/Art…/FullText_asp_ArticleID-20000411015846713.as., 11 April 2000.

Wong Y.Y., 1997, 'Safety Experience', A Hong Kong journal of Safety Bulletin, Occupational Safety and Health Association, Vol. 15, No. 3, pp.12-13.

Wong H.W., 1999, 'Health and Safety Management System', A Hong Kong journal of Green Cross, Occupational Safety and Health Council, Vol.9, No.1, pp.20-21.

Wong W.Y., 2000, 'Occupational Safety and Health at the Workplace', A Hong Kong journal of Safety Bulletin, Vol. 18, No.5, pp.4-6.

MANAGEMENT OF CONSTRUCTION SITE SAFETY DURING PROJECTS: THE USE OF "5S" SYSTEM

Yang, Xiang School of Management, Tianjin University, China
Zhang, Lianying School of Management, Tianjin University, China
Zhang, Jie School of Management, Tianjin University, China

Background

It is well known that worldwide accident statistics are not available, therefore, in order to explore the background of the safety problem, statistics from one nation must be considered. In this paper the statistics refer mainly to the United Kingdom (UK), but studies show that similar trends are apparent throughout the world although, in many cases, the accident figures are considerably higher outside the UK. In the UK the Health and Safety Commission (HSC) produces annual reports on accident statistics throughout the industry. The surveys show that construction is one of the most dangerous industries with 581 fatal accidents between 1986 and 1992. There is no doubt that maximum effort is required to significantly reduce these statistics.

One particularly worrying observation is that almost identical situations continue to cause death and injury. The construction industry seems unable to learn from its past mistakes. There is a tendency to blame external factors for the poor safety record. Factors [1] such as:

- The transient nature of the industry;
- The complete disregard for safety of many of its employees;
- The need to use a partially completed permanent structure, or a regularly changing temporary platform, to access works at a higher level;
- The constantly changing hazards as the project is constructed.
- In general every corporation has its own safety policy. A corporate safety policy will include:
- Policy statement: states what the organization will do.
- Operation of the policy: explains how the organization will ensure that the policy is adhered to.
- Organization: states who is responsible for safety at different levels of the organization; explains how the policy affects departments, sections or projects within the organization.
- Communication: explains how the policy will be communicated throughout the organization, and how senior management will be briefed on its implementation.

There is a danger that, once compiled, the safety policy is filed out of sight. The safety policy must be a working document, used regularly to monitor site practice. If practice begins to device from the policy, the major contractor must act immediately.

The Major Contractor's Role in Making Projects Safer

In 1988, the UK's HSC published a guide to managing health and safety. The guide described [2] the roles and responsibilities of the various parties under the following types of construction contract; management contracting; design and manage; construction management.

The major contractor's responsibilities for managing health and safety [3] include:

- to help the design team identify information on major health and safety matters which will be passed no to the package contractors;
- to contribute construction and health and safety expertise to the design team. This should lead to design futures which are easier and safer to construct;
- to identify high-risk activities during the pre-contract planning stage and to formulate site-wide method statements for dealing with them. These will be included in the contract documents for the package contractors. High-risk activities will differ from contract to contract, but are likely to include: confined spaces and excavation; demolition including asbestos removal; cranes and hoists; scffolding and temporary works; multi-storey frames; clandding and roofing; hot-works (welding/buming/cutting, etc.); substances hazardous to health;

- to identify essential, separately priceable health and safety items (for example, access scaffolding, edge protection and welfare facilities) which could be included in contracts with package contractors;
- to shortlist package contractors who will be invited to tender, taking account of their skills in managing health and safety;
- to produce a site safety policy that includes rules and conditions, procedures, guidance notes and codes of practice. The policy should incorporate client requirements, where appropriate, and be included in the contract documents for the package contractors;
- to set up the site organization for the management of health and safety taking into account the following factors:

  (1) overall programme for the project;
  (2) planned procedures;
  (3) arrangements for coordination, liaison and communication;
  (4) safety representatives' functions and arrangements for joint consultation;
  (5) arrangements for monitoring site health and safety;
  (6) arrangements for training, instruction and information;
  (7) policy on the use of common facilities, plant and equipment;
  (8) arrangements for record-keeping and statutory examination;
  (9) extemal liaison;
  (10) responsibilities of package contractors;
  (11) responsibilities of individuals.

- to ensure that package contractors are briefed about anticipated construction method, site/design factors, relevant hazards, precautions, general site safety rules and conditions, and are clear about divisions of responsibility. Similarly the package contractors should inform the major contractor, and interfacing package contractors, about possible hazards arising from their own activities;
- to ensure that package contractors have made plans to work safely, have priced their bids accordingly and have the necessary resources. Each package contractor should produce a contract-specific safety policy;
- to ensure that package contractors produce detailed method statements for high risk activities, to monitor the package contractor's performance against the method statements and take action where necessary. It is good practice to consider safety as the first item on the agenda of the regular package progress meetings;
- to manage health and safety on site by coordinating activities, ensuring that planned procedures are implemented and monitoring performance so that revised arrangements can be made as necessary. The major contractor should ensure that he does not become remote from day-to-day problems on site;
- to consider the creation of a joint safety committee operating on a site-wide basis and involving representatives of management and operatives from all package contractors;
- to convene regular, site-wide coordination meetings, attended by both the major contractor's staff and each package contractor's site management. Safety is one of the key aspects of coordination;
- to make site-wide arrangements for emergencies, fire prevention, safe access, lighting, etc.

However, the advice given is applicable to all major construction projects, especially those where the major contractor has some influence over detailed design and employs package contractors to construct some, or all, of the project.

"5S" SYSTEM

- The source of "5S"

  "5S" is a series of management activities canonized in Japan. It includes: tidy (seiri), dight (seiton), clean (seiso), clear (seiketsu), attainment (shitsuke). The five items begin with "s" in Roman pronunciation of Japanese, so they are called "5S". "5S" is so frondose and actuality that employee can understand as they look at this. The purpose of "5S" is creating a clean, comfortable, suitable and tidy environment for the employees.

- The three stanchion of "5S"

The activities of "5S" are implemented one by one and can be divided into three stanchions:

1. Firstly creating a disciplinary process of project. "5S" changes the way of people's behavior, so it is very important to train each person to be responsible.
2. Secondly, creating a clean environment, that is cleaning every cant and gap, getting rid of dust to make the site look brand-new and exciting. This is a revolution of mind.
3. Lastly creating a visual management project. Observe by eyes to discover where the abnormity is, to help each man finish his work very well, to avoid making mistake. This is the standardization of "5S".

- Tidy (seiri)
  1. Definition: to distinguish whether the object is necessary or not and get rid of the unnecessary.
  2. Purpose: to make place for other utility.
  3. Essentials: to examine all work concourse including the visibility and invisibility, establish the criterion to justify the necessary and unnecessary, get rid of the unnecessary objects, investigate the utility frequency of the necessary and determine everyday dosage, formulate the way of dealing with the castoff, and examine selves every day.

- Dight (seiton)
  1. Definition: to place the necessary according to the rule to allow easy identification.
  2. Purpose: orderliness, nameplate and do not waste time to look for something.
  3. Essentials: arrange the flow and determine the concourse to placing, rule the way of placing, draw and pitch, and identify the objects there (the emphases of visual management).
  4. Emphases: dight to formulate the state that anyone can find the objects in need at once; look on the side of the abecedarian or other occupation to make it explicit that something should be somewhere; as for placing concourse and placed objects, the measure should be taken to use them immediately; besides it can be recovered easily after use and understand immediately if not recovered or placed by mistake.

- Clean (seiso)
  1. Definition: to get rid of the dust in concourse and prevent pollution occurring.
  2. Purpose: to eliminate the "dust" to keep the concourse clean and bright.
  3. Essentials: to set up the responsible field for cleaning (indoor and outdoor), execute and routinely sweep and clean up the dust, investigate the source of pollution and stop it, establish the benchmark of cleaning and look at it as a criterion.
  4. Emphases: make the concourse free of dust and pollution. After the tiding and dighting the necessary can be made available immediately but can they be used normally? The first purpose of cleaning is so that the equipments can be used normally. Especially when high qualification and worth are needed it is forbidden to have dust and pollution. It should be known that cleaning is not only sweeping but an important part of the project and it is executed by heart.

- Clear (seiketsu)
  1. Definition: to institute and standardize the activities of frontal 3S, fulfil and keep the production.
  2. Purpose: to keep the production by system and show where the "abnormality" is.
  3. Essential: to fulfil the frontal 3S; formulate the benchmark of visual management and colour management; formulate the way of auditing; formulate the system of rewards and punishment and execute it seriously; keep the mind of "5S"; the super director should usually take the initiative to go on a tour of inspection.

- Attainment (shitsuke)
  1. Definition: everybody performs in accordance with the rule and form the good custom.
  2. Purpose: to change people's attainment and form the custom of serious work.
  3. Essentials: to keep on promoting the frontal 4S customary; formulate the related rule and regulation and abide by them; formulate the convenance regulation ; educate and train; promote all kinds of spirit activities(morning meeting, smile sports, etc.).
  4. Emphases: attainment is not only the last result but also the ultimate purpose aspired by director in enterprise. If every employee has good custom and abide by the rule the director must be very comfortable, the work order can be fulfiled, the spot law can be united, and all activities can be fulfilled.

- "5S" and safety

The safety committee should be founded in lots of projects and issue safety regulations because safety is the most important to the project. If there is no exhorts every day the safety can be neglected. [5] Although it is necessary that everyone should be told to work with safety helmet and shoes, to notice the movement of objects and assure the road open. It is well known that "5S" is not only the indispensable activities to stead qualification and raise efficiency but also the base of preventing the accident. A project which fulfils "5S" completely[6] will reduce many disasters, so it is usually said that "5S" is the mother of the safety and qualification".

The embedding and fulfilling of "5S"

In the case of fire and accident occurring without "5S", attention should be paid to the following:
(1) place something in or out of the passage;
(2) place something nearby the entrance or safety passage;
(3) place something in the front of the hydrant or switchboard;
(4) the layout and tubing is not steadfast;
(5) pile up the sharp things irregularly;
(6) the flammable things not in the directed vessel with lid.

The virtue of fulfilling the "5S"

The achievements of "5S" are great on the preventing accidents; be good to tidy the site, stead and raise the qualification; make the flow[7] orderly, fault discovered easily and efficiency improved; the work space can be increased and used effectively; reduce the damage of the things; in favor of health and sanitation; in favor of forming comfortable air; make the concourse bright and clean; conducive to preventing the fire.

The emphasis of work safely

(1) work clothes
- keep clean usually;
- if the fastener fall off or damage;
- if the heel of work shoes disrupted, bootlace loose (baboosh forbidden);
- put on the safety helmet in the appointed work;
- if schlep sharp things.

(2) the things for safeguard(glasses, respirator, earplug, and safety helmet etc.)
- put on glasses and earplug;
- put on respirator correctly, not chin;
- filter things;
- get store at any time;
- determine the spot for storage and keep correctly.

(3) passage
- place anything in the passage;
- if there is there any accident and hazard;
- if sprinkle the oil or water;
- if there is any dangerous situations that the wire and tube cross the passage;
- determine the height and width of the entrance.

(4) the floor of the concourse
- if is there any unnecessary appliance;
- assure wire and tube safety;
- keep the sweep appliance and store in directed place;
- do not put anything nearby the switch, hydrant, fireproof equipments, and safety gate;
- if is any problem about the tidy and dight.

(5) organic acid and tinder[8]
- mark the content and functionary of the things at the custodial place, and tidy them by class;
- prevent evaporation by the lid of vessels, avoid overfalling and leaking;
- ensure the exchange and discharge equipments run normally in the work concourse;
- examine the keeping warehouse termly, prepare the hydrant and sign "fire forbidden";
- keep the scrap cotton yarn in the fireproof vessel;
- if oil is spilled it is clean up immediately;
- survey if is there any fire or fume nearby;

- do not execute the work with fire (belt etc.) near the tinder.

The emphasis of visiting and examining at concourse

The safety guideline [9] should be fulfilled and strengthen everyone's safety mind includes: to make the safety sign board, the safety record, and calendar; plan the safety advertisement and selves' purpose; sign the items that can almost become accident and constitute the examination team.

Master the affairs to resolve hazard problems include: to illuminate what degree has the action reached; ensure to use the safety clamp practically and determine the spot for placement obviously; examine every team, patrol and record the items that may be accident.

Confirm if there is any dangerous state includes: to take the measures[10] that settling the equipments' safety cover, interlock and transducer etc. consummate the safety installation of equipments, especially notice the temperature of drier, manipulator and auto running equipments.

Conclusions

As the major contractor, it is necessary that much attention should be paid to the construction site safety. Though by now "5S" system has not been applied in the field of construction, in other fields it shows very strong functionality, especially in Japan it is usually used by many directors of enterprise. Through the discussion in this paper, "5S" system must become one of the most effective means to resolve the problem of site safety.

References

[1] The Establishment and Implement of Assurance System for Safety Producing in Construction Site, The Supervise Seminar of Project Construction in Shanghai, The Press of Construction Industry in China, Beijing, 1999.

[2] Health and Safety Commission Annual Report (UK), 1991/1992,HMSO, London, 1992.

[3] Project Management Institute. A guide to the project management book of knowledge, Project Management Institute, Upper Darby, PA, US, 1996

[4] A.M. Levitt and H.W. Parker: "Reducing construction accidents—Top management's role", in Journal of the Construction Division, ASCE, Vol,102,No.3,Sep.1976.

[5] Total project management of construction safety, health and environment, Thomas Telford Services Ltd. London, ISBN 0-7277-1923-8,1993.

[6] Shaoxiong Shun, How to Push 5S,The Press in Xiamen University, Xiamen, 2000.

[7] Morris PWG, Hough GH. The anatomy of major projects, John Wiley, Chichester, UK, 1987.

[8] Adapter from Managing health and safety in construction: Management contracting, Construction Industry Advisory Committee, HMSO, London, 1988.

[9] Cooper KG. The rework cycle: benchmarks for the project manager. Project Management Journal 1993; 24(1):000-111.

[10] Major Project Association Beyond 2000: a source book for major projects. Major Projects Association, Oxford, UK, 1992.

A SURVEY OF CONSTRUCTION SITE SAFETY IN CHINA

Zeng, S.X. Aetna School of Management, Shanghai Jiaotong University, P.R. China
Wang, H.C. Aetna School of Management, Shanghai Jiaotong University, P.R. China
Tam, C.M. Department of Building and Construction, City University of Hong Kong, Hong Kong

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Introduction

The issue of construction site safety has engaged both practitioners and researchers for a long time. Some relevant research on this issue has been extensively reported. Hinze (1981) investigated the relationship between the safety performance of individual workers and individual worker attitudes. Hinze and Raboud (1988) explored several factors that apparently influencing the safety performance on Canadian high-rise building projects. In some studies, the usefulness of behavioral techniques to improve safety performance in the difficult construction setting was examined. The study by Mattila and and Hyodynmaa (1988) revealed that when goals were posted and feedback was given, the safety index was significantly higher than when no feedback was given. Fellner and Sulzer-Azaroff (1984) analysed the industrial safety practices through posted feedback. In a study carried out on Honduras construction sites, Jaselskis and Suazo (1994) demonstrated a substantial lack of awareness or importance for safety at all levels of the construction industry. In addition, Laufer and Ledbetter (1986) assessed various safety measures. Some researchers examined costs of construction accidents to employers (Leopold and Leonard, 1987; Levitt and Samelson, 1993). With regards to construction site safety in Hong Kong, Lingard and Rowlinson (1994) investigated the theoretical background to commitment at the group and organizational level and presented a site-level research model which is illustrative of the possible effects. A more recent study by Tam *et al*. (2001) explored the attitude change in people after the implementation of the new safety management system in Hong Kong.

By international standards, the construction industry in China performs very badly in the area of safety. In 1999, 923 site accidents above IV level occurred in countryside construction, in which 1,097 employees sustained fatal injuries and 299 serious injuries (China Statistical Yearbook of Construction, 2000). However, there is no research, to our knowledge, that tries to examine construction site safety in the Chinese construction industry in international literatures. The study in this paper conducted a survey to explore the factors affecting construction site safety. A description of the methodology, results and analysis, and conclusion are provided in the sections that follow.

Methodology

A structured questionnaire was sent to senior management reprehensive of one hundred large construction firms. Up to the time when the authors write this paper, twenty completed questionnaires have been received.

All the twenty construction firms are state-owned. In China, large construction firms are state-owned establishments under the traditional planned economy system. These firms employ a larger number of staff. Moreover, the construction firms fall into two professional categories: housing building, and civil & municipal engineering.

Results and Analysis

Site accidents

There are two categories of site accidents including: 'more serious accidents' and 'less serious accidents'. In more serious accidents, some labors sustain injuries or fatal injuries in the accidents. The 20 % of the respondents claimed that there were records of more serious accidents before. All the respondents claim that less serious accidents occasionally occur.

Effects of site accidents

This survey lists four aspects of effects of accidents on construction sites including 'order of production and operations', 'reputation of firms', 'psychology of labors', and others. Table 1 lists the respondents' views.

Effects of site accidents	Number of firms	Proportion (%)
Order of production and operations Reputation of	6	30
firms	14	70
Psychology of labors	0	0
Others	0	0
Total	20	100

Table 1 Effects of accidents on construction sites

In Table 1, 70 % of respondents choose the answer 'reputation of firms' and 30% choose 'order of production and operations'. It indicates that the significant effect of site accidents is on reputation of construction firms.

Causes of site accidents

There are some causes of accidents on construction sites including 'throwing from high-rise projects', 'dropping from high-rise projects', 'improperly operating equipment', and others. Respondents were asked to choose an answer, and the results are listed in Table 2.

Causes of site accidents	Number of firms	Proportion (%)
Throwing from high-rise projects	2	10
Dropping from high-rise projects	10	50
Improperly operating equipment	4	20
Collapse of scaffold and framework	4	20
Others	0	0
Total	20	100

Table 2 Causes of accidents on construction sites

In Table 2, 70% of respondents ranked 'dropping from high-rise projects' the first cause of site accidents. According to China Statistical Yearbook of Construction (2000), the accidents due to dropping from high projects resulted in 207 (18.87%) employees' death.

The OHSAS18000 system

The respondents were asked whether they would implement the OHSAS 18000 system for safety and health. The 50% of the respondents are going to adopt the system, and the others are not to adopt it.

Factors resulting in site accidents

The respondents were asked to provide their opinions on the importance of the factors affecting construction site safety by scores from 1 to 5, where '1' represents the least important and '5' the most important.

To determine the relative ranking of the factors, the scores were then transformed to importance indices based on the following formula.

$$\text{Relative importance/difficulty index} = \frac{\sum w}{AN} \qquad (1)$$

where w is the weighting given to each factor by the respondents, ranging from 1 to 5, A is the highest weight (i.e. 5 in the study) and N is the total number of samples. Based on equation (1), the relative importance index (RII) can be calculated ranging from 0 to1. Table 3 shows the relative importance index of each factor affecting construction site safety.

Ranking	Factors affecting site safety	Relative importance index
1	Lack of attention from leaders	0.92
2	Reckless action	0.90
3	Poor safety conscientiousness of managers	0.88
4	Non-certified skill labor	0.87
5	Lack of emergency measure	0.87
6	Poor equipment	0.85
7	Lack of training	0.80
8	Poor equipment maintenance	0.80
9	Non-rigorous enforcement of safety regulations	0.76
10	Non-definite organization commitment	0.75
11	Lack of experience of managers	0.75
12	Non-effective operation on safety regulation	0.75
13	Poor of education of laborers	0.74
14	Poor safety conscientiousness of laborers	0.73
15	Not-strict operation procedures	0.70
16	Lack of technique guide	0.70
17	Lack of personal protective equipment	0.68
18	Non-perfect of safety and regulations	0.67
19	Overtime work for labor	0.65
20	Lack of protection in material carrying	0.65
21	Lack of protection in material storage	0.64
22	Lack of teamwork	0.63
23	Shortage of safety management	0.60
24	Poor information flow	0.60
25	Lack of innovation technology	0.55

Table 3 Relative importance index of each factor affecting construction site safety

In Table 3, the respondents rank the first and the third, with a relative importance index of 0.92 and 0.88. It indicates that leaders play a very important role in safety management in construction.

'Reckless action' is graded the second, with a relative importance index of 0.9. According to China Statistical Yearbook of Construction, fatal employees were 46 (4.19%) resulted from reckless action in 1999.

'Non-certified skill labors' is graded the fourth, with a relative importance index of 0.87. In construction, some activities are professional, such as tower crane and gantry operation, and framework and scaffold erection etc. In 1999, the fatal employees were 102 (9.3%) and 46 (4.19%) resulted from gantry and framework erection respectively.

'Lack of emergency measure' is ranked the fifth, with a relative importance index of 0.87. In general, construction firms have no emergency measures in China. This is relative to the factor 'lack of attention from leaders' and 'poor safety conscientiousness of managers'.

The respondents grade 'poor equipment' and 'poor equipment maintenance' is ranked the sixth and the eight respectively, with a relative importance index of 0.85 and 0.80. In 1999, the fatal employees were 95 (8.66%) resulted from the problems of construction equipment.

'Lack of training' is ranked the seventh, with a relative importance index of 0.80. One of the characteristics in China construction is that there are a large number of peasant-workers in the first line, who have low education level. The percentage of peasant-workers trained in the construction industry is very low, that is, 3% of peasant-workers have been trained and gained professional certification; 7% trained for short-term; and 90% non-trained (Zhang, 2001). Being lack of necessary training easily results in site accidents.

The respondents rank 'non-rigorous enforcement of safety regulations' the ninth, with a relative importance index of 0.76.

The respondents grade 'non-definite organization commitment' the tenth, with a relative importance index of 0.75.

Conclusion

By international standards, the construction industry in China performs very badly in the area of safety. All the construction firms have records of site accidents. The significant effect of site accidents is on reputation of firms. The obvious cause of site accidents is dropping from high-rise projects. Although there are factors resulting in construction site accidents, the main factors include 'lack of attention from leaders', 'reckless action', 'poor safety conscientiousness of managers', 'non-certified skill labor' and 'lack of emergency measure'.

References

Fellner, D.J. and Sulzer-Azaroff, B. (1984) Increasing industrial safety practices and conditions through posted feedback. *Journal of Safety Research*, **15**, 7-21.

Hinze, J. (1981) Human aspects of construction safety. *Journal of the Construction Division*, ASCE, **107**, 61-72.

Hinze, J and Raboud, P. (1988) Safety on large building construction projects. *Journal of Construction Engineering and Management*, ASCE, **114**, 286-293.

Jaselskis, E.J. and Suazo, G.A.R. (1994) A survey of construction site safety in Honduras. C*onstruction Management and Economics*, **12**, 245-255.

Laufer, A. and Ledbetter, W.B. (1986) Assessment of safety performance measures at construction sites. *Journal of Construction Engineering and Management*, **112**(4), 530-542.

Leopold, E. and Leonard, S. (1987) Cost of construction accidents to employers. *Journalof Occupational Accidents*, **8**, 273-294.

Levitt, R. and Samelson, N.M. (1987) In Post, N.M. and Young, N. (eds), McGraw Hill, NewYork.

Lingard, H and Rowlinson, S. (1994) Construction site safety in Hong Kong. *Construction Management and Economics*, **12**, 501-510.

Mattila, M. and Hyodynmaa, M. (1988) Promoting job safety in building: an experiment on the behavior analysis approach. *Journal of Occupational Accidents*, **9**, 255-267.

Tam, C.M., I.W.H.Fung and A.P.C.Chan (2001) Study of attitude changes in people after the implementation of a new safety management system: the supervision plan. *Construction Management and Economics*, **19**(4), 393-403.

Tang, S.L., Lee, H.K. and Wong, K. (1997) Safety cost optimization of building projects in Hong Kong.

Construction Management and Economics, **15**, 177-186.

SAFETY MANAGEMENT IN INTERNATIONAL PROJECT: PROBLEMS ENCOUNTERED AND RECOMMENED SOLUTIONS

Zhang, Jie School of Management, Tianjin University, China
Zhang, Lianying School of Management, Tianjin University, China
Yang, Xiang School of Management, Tianjin University, China

Introduction

Every year there are thousands of accidents happening around construction sites worldwide. From the accident statistics of United States and United Kingdom, the trends of construction accidents throughout the world can be seen: the construction industry has more accidents happening than the average level of other industries and the figure of fatal injuries is much higher than the average figure of other industries[2]. So the construction companies need safety management to improve their efficiency and competence.

The interest in safety awareness among construction companies has greatly increased in the past decade. This increased awareness in safety can be attributed to many factors: the relation between risk management and return on investment, the ever-increasing cost of medical treatment, convalescent care, and the potential for lawsuits. Also the companies with has bad safety records are often prohibited from bidding on a certain kind of work.

Responsibility for Safety[5]

In general, every party involved in a project has a responsibility for safety, including the owner, the designer, the engineers, the major contractor and the subcontractors. The owner and the project designer have an indirect impact on the safety practices encountered on the job site. In fact, there is a trend in the construction industry to enhance safety by design because the designers clearly can and do influence construction worker safety through their design decisions. Therefore, if the design process takes the safety of the workers into consideration, the overall safety of the project can be impacted in a positive manner. It is the owner's responsibility to ensure the implementation of this design standard from project initiation, and to make safety a priority for the duration of the project. If this method of design is accepted, the overall safety of the project will be undoubtedly enhanced.

Different with the owner and the project designer, the engineers and the contractors have a direct impact on the safety of the job site. The engineers have a professional and moral obligation to take safety, health, and welfare under construction. It is their duty to superintend the contractors to carry out safety management policy. To ensure project safety, the contractors should play the most important role among all the parties. The Occupational Safety and Health Administration (OSHA) specifically requires that employers such as contractors are responsible for providing workers a place of employment free from recognized hazards. The contractors should produce their own safety policy and carry it out throughout the duration of the project. The major contractor has the responsibility of managing the safety of its own employees as well as the employees of the various subcontractors utilized for the project. This often places the major contractor in an awkward position and a lot of problems may be encountered during the project, since the company may not be competent in managing the safety of all subcontractors on the job site. The subcontractors are also faced with similar problems that they employ a lot of workers, it is their duty to ensure the employees' safety. Also, since the subcontractors may be small-to medium-sized company, their safety program may not satisfy both the requirements of the major contractor and the standards produced by OSHA. This paper will focus on the problems which may be encountered by the subcontractor of a international project and recommended solutions are given. Also, what the major contractor should apply in its safety policy is mentioned.

Safety in International Project

To most of the domestic powerful construction companies, they need to enter international project market. A lot of international project's characteristics make safety management to be one of the most important aspects that the contractor need to pay much attention to. To most of international projects, the job site may be in another country and they are operating in a social, economic and physical environment that is quite different from that on which the construction companies are based. In the job site of the project, there are employees from different countries. They are quite different in their living habit, working style and ideology. In this type of people, working accidents may have strong negative impact on the project. The death of those people due to working accidents or ill will bring great hurt to their family and friends, and the influence on the job site will last a long period of time. An international contractor will suffer economic loss and degrade of reputation in his field if working accidents happen on the job site.

Another character of international projects is that the major contractor often comes from the country different from the project's country. This foreign major contractor will employ large quantities of domestic workers to decrease the cost of project. In such case, the relationship between the employer and employee becomes a sensitive problem, especially in some countries. If the employer (foreign construction firm) can discreetly deal with the affair of safety and health of the employees, it will get the support and appreciation of those domestic employees. On the contrary, if the foreign construction firm does not respect domestic workers and pay little attention to their safety and health, once working accidents happen on the job site, the consequence will be very serious which may lead to strike on the job site.

The importance of safety in international projects is also emphasized in world wide use of FIDIC contract conditions. In the second part of the fourth edition of Conditions of Contract for Works of Civil Engineering Construction, [3] there are many conditions talking about the safety and health of employees, some are listed below:

(1) The Contractor shall have on his staff at the Site an officer dealing only with questions regarding the safety and protection against accidents of all staff and labor. This officer shall be qualified for this work and shall have the authority to issue instructions and take protective measures to prevent accidents.

(2) Due precautions shall be taken by the Contractor, and at his own cost, to ensure the safety of his staff and labor and, in collaboration with and to the requirements of the local health authorities, to ensure that medical staff, first aid equipment and stores, sick bay and suitable ambulance service are available at the camps, housing and on the Site at all times throughout the period of the Contract and that suitable arrangements are made for the prevention of epidemics and for all necessary welfare and hygiene requirements.

(3) The Contractor shall at all times take all reasonable precautions to prevent any unlawful, riotous or disorderly conduct by or amongst his staff and labor and for the preservation of peace and protection of persons and property in the neighborhood of the Works against the same.

Safety Practices and Problems Encountered

The safety practices and problems encountered on construction sites are as varied as the sites themselves, all construction sites have their own unique aspects of safety which must be considered. Most international projects are large sized projects and the major contractor usually is the world famous firm from developed country. These companies have reputations to uphold as well as safety records to maintain, also they are generally better prepared to manage the safety aspects of a project. But this does not mean that they will not encounter safety problems during a project because as the major contractor of a project, they are responsible for the safety of the whole project including the subcontractors' part. In general, those companies as subcontractors may not have enough experience and knowledge to ensure their safety policy. One of the problems the major contractor need to solve is that the major contractor itself does not have thorough knowledge of the subcontractors' safety procedures and will easily assume the burden of implementing a safety program for every subcontractor. As a result, the major contractor often leaves the responsibility of safety to the individual subcontractors and may never take an active part in ensuring that the subcontractor is actually exercising all measures necessary to provide a safe working environment.

Although more and more Chinese construction firms enter into the first 225 international contractors of the world, most of the contracts they win are located only in the developing countries and the contract value are relatively small. To enhance the competence in international project market, our construction company should try their best to win the chance of cooperating with those famous companies as subcontractor. Now most of Chinese construction firms can not fully satisfy the requirements outlined by OSHA.

A construction company's emphasis on safety is proportionate to the size of the company. As an example, smaller companies may not place as high a priority on safety as larger companies. While there are smaller firms with excellent safety programs and records, and while there is no doubt that smaller firms would benefit from a more comprehensive safety program, it is nonetheless a difficult process for them because of the expense incurred in implementing such a program. Safety training is often left to an on-the-job learning exercise or taught by the employees' union or trade organization. But the best training is often acquired through experience, on-the-job training, and continuing education.

Some small sized construction firms may not have an adequate safety program. Implementation of their safety management programs is usually left up to the foreman or the project superintendent. Because of their normal work load, neither of these have time to put the best effort toward the program. As a result, the method employed is often a "just get by" approach, satisfying only the minimum requirements.

Most of the construction companies have special personnel and safety department to take charge of safety affairs of companies' all projects. This method is useful to domestic projects, but if the project is outside of the country, the job site may not be visited by the safety officer and the project team will receive little assistance from the headquarter.

One difficulty encountered by the subcontractor is that they can not, at times, place the proper emphasis on safety. At the beginning stage of the project, the quantities of workers on the job site may be a few, and some traditional safety management methods, such as daily "tool box" safety talks, [6] may have good effects. While when the project schedule is tight or at the summit stage of the project, these traditional methods are not enough.

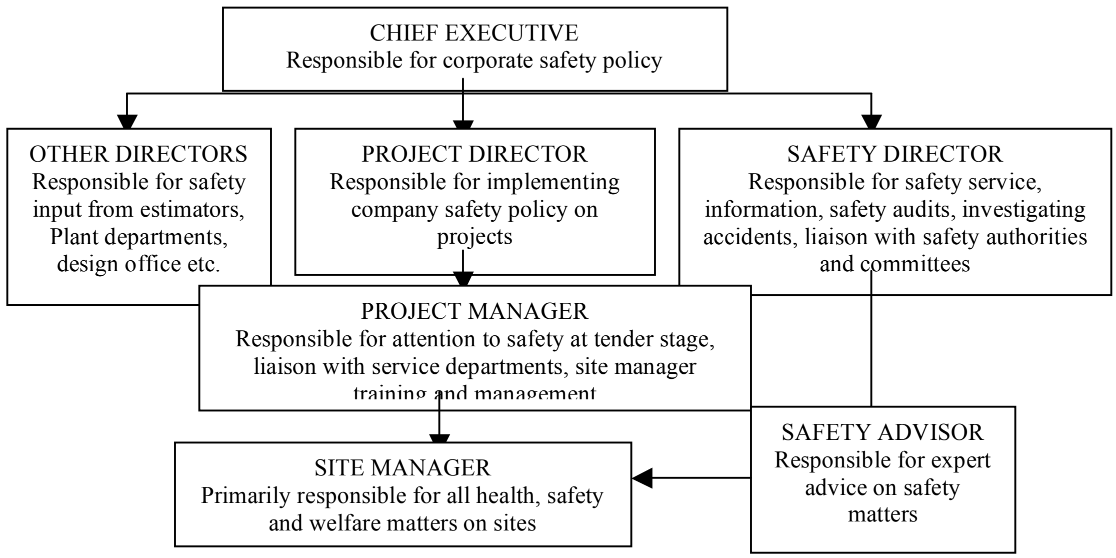
Another problem is how to deal with domestic labor. Managers are often dispatched from company's own country, they may not have the experience to deal with domestic affairs.

Suggestions And Solutions

On the job site of every project, the project manager shall establish a safety system to avoid any working accident. This work has four aspects of job:

(1) Establishment of safety organization

Each project needs a safety organization under the direct leadership of project manager. The typical construction organization is described in the figure below:[4]



It is important that the company has a full-time safety director or at least one person who is responsible for the company's safety program. Having full-time safety personnel relieves the pressure, somewhat, on the onsite construction project team. This allows the project personnel to focus their efforts on the project itself.

(2) Safety inputs storage[11]

In the financial system of international projects, the costs of ensuring safety are regarded as indirect cost. Some contractors regulate that safety cost be divided into two parts: the first part is withdrawn by the headquarter and used as accident treatment fare, when there are more accidents happening, this part will increase proportionately. The second part is retained by the project team and used as accident treatment fare on the job site. In such case, the project manager is obligated to take measures to avoid working accidents to decrease the cost of the project.

The project manager shall retain abundant money to make enough safety equipment and instruments available to deal with the emergencies that happen on the site. This equipment include:

a. First aid equipment and stores. When there are injured worker, the urgent treatment will be available, if the worker is seriously injured, suitable ambulance service should be available.
b. Enough safety instruments and equipment. For example, safety helmet, safety belt, special suit, special operating tools etc.
c. Enough extinguisher, special pipes and faucet to avoid fire disaster. Flammable materials need special storage and custody. Dynamite used in construction need full-time guard to ensure its safety.

(3) Establishment of safety regulations

First of all, the safety regulation of the project must correspond to the safety policy, law and specification of project's country, and the labor protection standard and safety technical regulation must be carefully carried out. Worker must abide by the safety operation regulation of his work species. So the management staff involved in an international project must study laws and regulations that relate to safety construction and labor protection and carry it out rigidly to avoid working accidents happening.

Every work aspect has its own safety regulation and special requirements. Training to all labors in the job site is necessary. Through training, workers on the site can get a complete knowledge of safety requirements and safety technique of their work aspect and enhance their ability of self-protection.

During the construction of an international project, other than the safety regulation and specification mentioned above, a complete safety system must be established which can be divided into four subsystems:

a. Safety conference should be held at intervals. At the various stages of the project, this interval can be changed relatively. A weekly safety meeting is recommended to the company and at this weekly meeting, appropriate safety information, project scheduling and cost are reviewed by the project manager. The importance of safety should be placed as well as the schedule and cost. Some potential hazards should be analyzed and pointed out to draw the attention of the foremen and site managers, the measures to avoid these hazards should be discussed and carried out during the following week's construction. The overall results of this method of safety conference are proved to be excellent by last international project practices.

b. Safety inspections should be carried out. In the job site of the project, the site manager and foreman usually put their best effort into the control of the progress and have no time to think about the safety affairs. So it is recommended that all staff should be involved in the safety inspections. Therefore, instead of the project manager being solely responsible, the enforcement of safety is to be shared. Workers can conduct self-inspection, foremen and site managers should inspect safety of their own part before the weekly safety conference of the project and listen to the suggestions and safety concerns of the workers. This is important so that at the weekly safety conference, these suggestions are discussed and solved by the project manager. Also the project manager, with his safety advisor, should inspect different parts of the project and get the first-hand safety information of the project. At the weekly safety conference, he should criticize the site manager who has safety problems and working accident and praise the one who has excellent safety performance and record. The above mentioned method has many advantages. One is that this method involve the workers on the job site with the safety issues of the job, once their problems are solved or their suggestions are adopted by the site manager or project manager, their working enthusiasm will be markedly increased. Another benefit this method provides is to educate employees on the various safety concerns of the different parts and how they may affect the project.

c. Putting the avoidance of working accidents the first place of safety construction. Every construction company should believe the policy that "construction must be safe and the safety is for construction". During the construction of a project, the project manager must abide by the thought that "the safety is at the first place and precaution is most important". The construction practices prove that if there are two job sites that have similar working conditions and scale, the one which carry out the principle of "precaution is the most important" has better safety performance and records and the working accidents are much less than another one. Safety training is the most effective method to carry out this policy. The facts prove that the lack of formal safety training is commonly the weakest part of accident prevention in construction. All personnel must receive formal safety training. This training should relate specifically to their responsibilities and should be repeated whenever their responsibilities or environment changes. In any case, the training should be repeated at regular intervals – ideally annually – to act as a refresher and to include changes in legislation or methods of construction. At the workface, site managers and foremen should receive short and specific safety instruction at regular intervals – ideally weekly, called "tool-box talks" and cover aspects of safety that will be encountered on a day-to-day basis. However, these short refresher talks should not take the place of more formal "off the job" training. The majority of accidents occur to people within their first few days on site, therefore prior to commencing work on a new site, or even visiting a site, each employee should receive a safety induction that will cover specific risks and location of hazards on that site, at that time. It is considered good practice to issue all personnel a safety handbook during their induction. This will enable them to take away a readily available guide to the safety aspects of the site. A typical safety handbook is covered by contents such as site rules, what to do in an emergency, how to respond to an accident, correct safety equipment, a site plan showing medical facilities and muster points, examples of typical warning signs and details of the safety award schemes etc.

d. Get a domestic safety expert as safety consultant. To most of the international projects, contractors come from different countries. Though the principles of safety management are universal, however, construction practice varies from country to country – furthermore each country has its own safety legislation. Before considering trading in another country it is essential that the full requirements of that country's safety legislation are understood. Because of the complex nature of much of the legislation and the significance of correct interpretation of the law it is advisable to obtain specific advice from a national safety consultant.

(4) Establishment of reward and punishment rules

During the construction of an international project, the happening of a working accident will result in great economic loss. If all the personnel are concerned about the safety construction, a lot of money will be economized. So it is helpful to enhance the safety of construction that reward the job team with excellent safety performance and records, at the same time, the one with bad safety performance will be punished.

The specific rules should be regulated according to the character of the project. To a international contractor, the following two rules are recommended:

a. The headquarters of the company should decide whether or not to reward a project team according to their safety performance and records. Usually different project team had various safety performance and records due to the different emphasis on it and the different ability of the project manager. So it is necessary to decide reward or punishment and how to implement them. The benefit of this method is that it will form the competence among the project teams and consequently develop the safety management ability.

b. Inside a project team, the project manager also should decide whether or not to reward a job team according to their safety performance and records. A safety inspection is recommended that the job team's safety records can be filed and the overall records are the safety performance of that job team. The reward or punishment should be regular, and the ideally intervals is quarterly.

Some Useful Suggestions for Major Contractor

Some useful suggestions to improve safety of an international project are listed below:

(1) Produce a site policy that includes and conditions, procedures, guidance notes and codes of practice. The policy should incorporate client requirements, where appropriate, and be included in the contract documents for the subcontractors.

(2) Set up the site organization for the management of health and safety.

(3) Ensure that subcontractors are briefed about anticipated construction methods, site/design factors, relevant hazards, precautions, general site safety rules and conditions, and clear about divisions of responsibility. Similarly the subcontractors should inform the major contractor, and interfacing subcontractors, about possible hazards arising from their own activities.

(4) Ensure that subcontractors have made plans to work safely, have priced their bids accordingly and have the necessary resources. Each subcontractor should produce a contract-specific safety policy.

(5) Ensure that subcontractors produce detailed method statements for high risk activities, to monitor the subcontractor's performance against the method statements and take action where necessary. It is good practice to consider safety as the first item on the agenda of the regular subcontractor progress meetings.

(6) Manage health and safety on site by coordinating activities, ensuring that planned procedures are implemented and monitoring performance so that revised arrangements can be made as necessary. The major contractor should ensure that he does not become remote from day-to-day problems on site.

(7) Consider the creation of a joint safety committee operating on a site-wide basis and involving representatives of management and operatives from all subcontractors.

(8) Carry out inter-inspection among subcontractors in turn. Each subcontractor has the chance of being the inspector of safety along with the major contractor's safety staff, and the records will be filed.

(9) Convene regular, site-wide coordination meeting, attended by both the major contractor's staff and each subcontractor's site management. Safety is the key aspects of coordination.

(10) Make site-wide arrangements for emergencies, fire prevention, safe access, lighting, etc.

References

[1] The establishment and implement of assurance system for safety producing in construction site, The supervise seminar of project construction in Shanghai, The publishing company of construction industry in China, Beijing, 1999.

[2] Health and Safety Commission Annual Report (UK), 1991/1992,HMSO, London, 1992.

[3] FIDIC, Conditions of Contract for Works of Civil Engineering Construction, Fourth Edition 1988, & Third Edition, 1977

[4] R. Neale Managing international construction project: An overview, International Labor Office, Geneva, 1995

[5] Tony Baxendale and Owain Jones, "Construction design and management safety regulation in practice—progress on implementation", in International Journal of Project Management, PREGAMON, 18(2000)

[6] Joe M.Wilson Jr. And Enno "Ed" Koehn, "Safety management: problems encountered and recommended solutions", in Journal of Construction Engineering and Management, ASCE, 77-79, 2000

[7] A.M.Levitt and H.W.Parker: "Reducing construction accidents—Top management's role", in Journal of the Construction Division, ASCE, Vol,102,No.3,Sep.1976.

[8] Total project management of construction safety, health and environment, Thomas Telford Services Ltd. London, ISBN 0-7277-1923-8,1993.

[9] Adapter from Managing health and safety in construction: Management contracting, Construction Industry Advisory Committee, HMSO, London, 1988.

[10] Major Project Association Beyond 2000: a source book for major projects. Major Projects Association, Oxford, UK, 1992.

[11] Jian Liang, Construction Operating Management of International Project, Hydraulic and Power Press, Beijing, 1994.