

Design for Construction Health, Safety, and Ergonomics: Encouraging Architectural Designers

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Abstract

A prior exploratory survey demonstrated, inter alia, that architectural designers: perceive H&S to be the contractor's problem; do not adequately conduct hazard identification and risk assessments during the design process; concur that appropriate design and specification can mitigate health, safety, and ergonomic risks; concur that design education is inadequate in terms of construction health, safety, and ergonomics, and further concur that associated risks can be mitigated through improved design education.

This paper presents the findings of a quantitative pilot study conducted among a regional group of architectural designers registered with the South African Council for the Architectural Profession (SACAP) to determine what would encourage architectural designers to proactively mitigate construction hazards and risks through design.

The salient findings are: architectural designers need 'designing for construction health, safety, and ergonomics' competencies; a guiding approach or model should be developed and incorporated into architectural education and ongoing training; the guiding approach or model should be technologically grounded and should not stifle architectural freedom.

The findings, although arising from a pilot study, will contribute significantly toward questionnaire development for a PhD study, which ultimately aims at mitigating construction health, safety, and ergonomic risks through architectural design.

Keywords: architectural designers; construction: health, safety, and ergonomics.

1. Introduction

The South African construction industry, as worldwide, is dangerous. The outdated Compensation for Occupational Injuries and Diseases (COID) report (Compensation Commissioner, 1999) suggests that of the listed 24 industries, Building and Construction ranks ninth in terms of accident frequency rate, fifth in terms of accident severity rate, and third in terms of accident fatality rates.

The South African Construction Regulations were promulgated in 2003 and require a multi-stakeholder approach to construction health and safety, inclusive of designers (Republic of South Africa, 2003), while SACAP expects "... registered persons to competently carry out their duties with integrity." (Goldswain & Smallwood, 2009) The impact on 'designing for construction health, safety and ergonomics' remains questionable. The traditional 'cost, quality and time' project success measurement tool is no longer applicable and needs to embrace construction health, safety, and ergonomics (Mroszczyk, 2005; Schneider, 2006; Smallwood, 2006). Numerous studies suggest that half of construction accidents can be eliminated through proactively 'designing for construction health, safety, and ergonomics' (Health and Safety Executive (HSE), 2003; Beam, 2006; Toole and Gambatese, 2006).

The literature review considers a range of factors, which can exacerbate construction hazards and risks leading to accidents. It identifies predominant accident types leading to construction related illness, injuries and fatalities. A discussion on 'mitigation of hazards and risks through design' suggests that up to half of construction accidents could be avoided through design, and entertains separate discussions on construction health, construction safety, and construction ergonomics. Approaches toward mitigation of construction hazards and risks are exposed in the form of lists of recommendations and models which have been devised to engage, inter alia, designers in the process of 'designing for construction health, safety, and ergonomics'. In closing, relative perceptions of architectural designers are exposed through a prior exploratory survey.

This qualitative pilot study forms part of a PhD (Construction Management) study, which ultimately aims to realise a paradigm shift relative to construction health, safety, and ergonomics. The objectives are to determine the perceptions of architectural designers as to:

- Whether they engage in 'designing for construction health, safety, and ergonomics' or not, and to establish the need for development of competencies;
- What mechanisms could be introduced which would promote engagement and commitment to the process, and
- What format the introduced mechanisms should take.

2. Review of the literature

Accident factors and causes of illness, injuries and fatalities

A convergence of factors leads to construction accidents. Firstly, ‘proximal factors’, which include the attitude, ability, awareness, health and fatigue status of workers, as well as site hazards created in the absence of suitable planning, management and supervision. Secondly, ‘distal factors’ include issues surrounding design, in terms of choice of material and equipment and the application of the design situation. Similarly, these factors can be grouped as worker factors, site factors and material / equipment factors, which stem from ‘originating influences’, such as permanent works design, *inter alia*, which in turn are affected by client requirements, economic climate and the education, knowledge and experience of the people involved (Health and Safety Executive (HSE), 2003; Gibb *et al.*, 2006).

The main causes of illness, injuries and fatalities in South African construction and internationally are ‘falls onto different levels’, ‘motor vehicle accidents’, ‘struck by’, ‘inhalation, absorption and ingestion’, and ‘work-related musculoskeletal disorders’ (WMSDs) or ‘body stressing’ (The Health and Safety Executive (HSE), 2006; Penny, 2007; Weitz and Luxenberg, 2008; Bureau of Labour Statistics (BLS), 2008; Construction Industry Development Board (cidb), 2009; Safe Work Australia, 2010).

Mitigation of hazards and risks through design

Toole and Gambatese (2006) suggest that mitigating hazards and risks can be achieved by conducting reviews at various stages of the design process, while Beam (2006) suggests that one third of the hazards and risks “... could have been eliminated or reduced if design-for-safety measures had been implemented”. The HSE (2003) suggests that up to 50 of 100 studied cases could have mitigated the hazards and risks through alternative design.

Construction health hazards and risks include inhalation, absorption and ingestion of hazardous chemical substances (HCSs), which can lead to a range of illnesses and ultimately death (Smallwood and Wheeler, 1999). Cowley *et al.* (2000) advocate Bender and Hadley (1994) and suggest more pressure be applied on manufacturers of HCSs to improve hazard information on packaging to make ‘upstream target groups’ more aware of the risks presented by using specific products.

Construction safety hazards and risks include ‘motor vehicle accidents’, ‘falls onto different levels’ and ‘struck by’ possibilities, as well as electrical contact, contact with moving parts of machinery and vehicles, fire and explosion, excavation collapse, and working in confined spaces (Deacon and Smallwood, 2010). Cowley *et al.* (2000) advocate The Consultancy Company (1997) suggesting that by the time hazards are assessed it is usually too late to intervene.

Deacon and Smallwood (2010) suggest that construction ergonomic hazards and risks include repetitive movements, working in awkward positions, climbing, heavy equipment and material handling, bending or twisting, reaching overhead or away from one's self, noisy and vibrating tools, use of body force, working in limited space, reaching away from the body, working in a varied range of weather conditions, and working while injured. Rotation of activities and rest periods can alleviate problems, however ultimate risk mitigation can be achieved through avoidance of labour intensive construction (Deacon and Smallwood, 2010).

Approaches toward mitigation of construction hazards and risks

Beam (2006) presents a list of design suggestions originally developed by Gambatese (1996) suggesting modifications to permanent features of projects. For example: *Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance.* Beam (2006) created a new list of design suggestions. For example: *When design features, such as ventilation systems, trash chutes, chimneys, and elevators, cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors;*

Numerous researchers contend that up to half of construction accidents can be mitigated through design, which can be enhanced by conducting construction H&S reviews throughout design stages (Toole *et al.*, 2006; Toole and Gambatese, 2006; Beam, 2006; HSE, 2003). To this end two models come to the fore, namely the United Kingdom's Gateway model (HSE, 2004) and the Australian CHAIR model (WorkCover NSW, 2001). These differ and are not elaborated here, but focus on a multi-stakeholder approach requiring interim assessments of designer's work, inter alia, with construction health, safety and ergonomics being an inclusive factor.

Perceptions of architectural designers

A prior quantitative exploratory survey was conducted to determine the perceptions of architectural designers with regard to the mitigation of construction health, safety, and ergonomic risks through appropriate design (Goldswain and Smallwood, 2009).

The paper is not elaborated here, but the most significant findings include: *architectural designers do not adequately conduct hazard identification and risk assessments during the design process; appropriate design and specification can mitigate health, safety and ergonomic risks; design education inadequately prepares architectural designers in terms of construction health, safety, and ergonomics and associated risks can be mitigated through improved design education.*

It recommended additional research with regard to 'designing for construction health, safety, and ergonomics', which should be fully integrated into appropriate tertiary education design programmes, as well as Continuing Professional Development (CPD) courses.

3. Methodology

A quantitative pilot study was conducted among a regional group of architectural designers registered with the South African Council for the Architectural Profession (SACAP) to determine what would encourage architectural designers to proactively engage in mitigation of construction hazards and risks through the design process.

The process involved development of thirteen semi-structured interview questions in order to determine the perceptions of architectural designers as to:

- Whether they engage in ‘designing for construction health, safety, and ergonomics’ or not, and to establish the need for development of competencies;
- What mechanisms could be introduced which would promote engagement and commitment to the process, and
- What format the introduced mechanism should take.

Approximately 60 telephone calls were made to set up interviews. Of these, twelve interviews were secured and only 10 took place due to two cancellations. Interviews were recorded and corresponding hand written notes were captured.

4. Findings

The data gathered is too rich for inclusion in a concise paper, but will serve toward the greater PhD study. Only responses to the more pertinent questions are included here.

To the question ‘*Do you believe that construction hazards and risks can be mitigated through alternative design?*’ 80% of respondents confirmed their belief, with commentary suggesting that:

- Everything has risks, which can be minimised through design and material choice;
- It is the responsibility of the architect to understand construction technology;
- Risks need to be identified and managed correctly;
- There are definitely ways, but the form of buildings should not change;
- Construction methods should take safety and worker ability into account;
- Risks can be reduced by pre-manufacturing and spending less time at high levels;
- One should mitigate risks, but this should not become a driver for design, and
- There is a lack of awareness and the profession should advise and set out preambles.

20% of respondents do not believe that mitigation of hazards and risks is a design issue. Commentary includes:

- It doesn’t really matter as the risks and dangers are contractor responsibility, and
- It is not so much design as management of site procedure.

To the question *‘Do you actively engage in ‘designing for construction health, safety, and ergonomics’? (Please support your answer with an explanation of ‘how’ or alternatively with ‘reasons’ for not engaging)’* 60% of respondents suggested that they do actively engage, yet the responses suggest that the understanding and level of engagement is minimal. Some selected commentary suggests:

- Some design occurs with health and safety in mind but it cannot be specified on drawings;
- Not when taking form into account, but maybe when starting to detail things;
- It is kept in back of mind, but is not a sole reason;
- To a certain extent, risks are noted and sorted out;
- I think I do ... it’s not at the forefront of one’s mind, and
- One does or should ... we don’t think about it enough.

40% responded to the negative, with commentary including:

- I don’t think one can ... don’t consciously think about it;
- I wouldn’t say we actually design for it ... the challenge is to look at how it can be done;
- Inspectors check on how a contractor manages his staff, and
- Not specific, it depends on the project.

To the question *“Is there ‘something’ which could be introduced that would encourage architectural designers to engage in ‘designing for construction health, safety, and ergonomics’?”* 60% of respondents offered positive suggestions, which include:

- Educating people ... tedious to implement ... should not limit design;
- Ongoing education to keep it at the forefront of one’s mind ... it’s becoming more visible as a topic;
- It is more a case of awareness, even at university level ... it stems back to Architectural School days;
- One may be able to make up manuals ... needs to be brought to our attention ... an awareness is needed;
- Training should include on site experience ... mentorship is lacking, and
- Architects should have hands on knowledge of what the contractor encounters.

40% of respondents were less forthcoming with suggestions and commentary including:

- Nothing specific ... think it’s logic;
- Wonder if it happens in high architecture ... nothing off hand;
- No – dangers come more from under-design by engineers, and
- Can’t think of anything off hand ... would hate design to be stifled. Is there a design criteria? ... I don’t think there can be.

To the question *“In terms of your recommendation, is there any specific means or format which could be integrated into the design process in order to promote ‘designing for construction health, safety, and ergonomics’?”* 80% of respondents offered positive input, while 20% did not respond. Commentary includes:

- Find out how to do it safely ... stipulate how it’s got to be done;
- Education ... consulting agents or representative visits ... buy-in is required;
- An ongoing process to sensitise people ... CPD makes it easier to introduce;
- Some sort of methodology is crucial ... a method or awareness of the building programme;
- Not sure of a format (earlier suggested manual) ... it should make a worthwhile contribution ... something which reminds one to think about it all the time;
- More time spent on the design development stage could benefit ... to build it in, we do Advanced Technologies as part of our design course ... it’s glanced over ... we don’t fully understand how things are put together;
- It should be integrated into the training process ... in terms of the architect going through six years of training, and
- Architects need to understand how buildings are put together and how methodologies are spelt out ... but the contractor is the expert in building.

To the question *“How could the aforementioned means or format be integrated into your everyday design process?”* 70% of respondents offered positive commentary:

- It should be part of integral thinking ... part of design and documentation;
- Architects should build up specialist knowledge over time;
- It is up to the professional... we need to educate the client to trust the professional;
- The fundamentals of health and safety should be discussed, even at university, and should be monitored and recorded;
- Keep it real and honest – practical and buildable. Do not simplify form and make architecture less exciting and stimulating ... methodology should check and double check your decisions as you proceed;
- Education must be relevant and must address the real problems of design, and
- What must not happen ... we must be very careful with any manual ... it must not be prescriptive and must invite deeper thinking ... if you start closing doors, your design process will be stunted and you can’t have that.

30% of respondents did not contribute effectively:

- Never really thought of it;
- We do specify that contractors should conform to safety standards; and
- Accidents seen are due to on site carelessness ... no problems where architectural designs are not safe.

To the question *“Do you feel you have the necessary competencies to ‘design for construction health, safety, and ergonomics’, and how could these competencies be*

enhanced?” 40% of respondents felt that they have the necessary competencies, although commentary suggests otherwise:

- Must do ... most definitely ... working with an engineer the combined effort must cover those sort of things;
- I believe I've got the competencies ... to enhance those competencies one would need to interact with contractor to find out how things could be improved;
- Yes, but we must understand our limitations ... ask for help when we need it and consult with specialists. Experience helps – and do the research, and
- We have the competencies because we are designers ... we can design anything. The only way to enhance those competencies is by being made more aware.

50% of respondents did not feel they had the necessary competencies, while 10% of responses could not be deemed valid. Commentary received includes:

- I don't believe any of us do – we were never taught. What is known is purely through experience – if a detail causes a big problem it won't be used again;
- No, I'm not a health and safety 'fundi'. Aware, but learning as we go;
- No ... interaction of the team to thrash out ideas. Awareness is needed ... goes back to 'varsity' days;
- Not something we factor in enough ... but we don't want it to govern form totally. Architects take thousands of different influences to determine form ... this needs to be one of them, and
- It would be arrogant to say that – maybe adequate but never enough. Education is needed to enhance competencies ... there's a chasm between the two. We actually need to marry the thought processes.

To the question “*If 'designing for construction health, safety, and ergonomics' could somehow be incorporated into tertiary education for architectural students, then how do you think it could be integrated?*” 80% of respondents offered a way forward:

- It needs to be instilled from basics. It's difficult, but there must be a way to define objectives ... to fit into Building Construction – the nuts and bolts – not into Design ... must be non-restrictive;
- Alternative construction usage could be enhanced ... risks are not clear. It could form a module with OHS incorporated ... or a subsection of Materials and Methods – what materials, how to use them ... what to use where;
- It will have to fit somewhere between Building Design and Construction, which run parallel ... the Building Construction component. How do we put a building together and how do we document it? It needs to be an integral component – a separate course won't receive the emphasis it deserves. In the early years of architecture it needs to create awareness for architects;
- There must be a rational way of thinking ... even as simple as once drawn, imagine building it. Architectural education discourages it ... forget how, it doesn't matter how it gets built ... at what point do we bring it into detail technology ... the subject Building Technology;

- It should be taught by an architectural professional, not a health and safety officer;
- It should start at root level – day one. Design and methodology go hand in hand like form and structure ... ‘varsity’ projects – how is it going to be built ... feasible, viable or too risky?;
- Incorporate it into Design and Construction courses – how to put it together. Architects can become more aware, but are not health and safety officers, and
- We need the correct packaging ... there is too much emphasis on spatial rather than detail. Incorporate it into a design problem – link into the detail – talk to the curriculum to decide what year to introduce it.

20% of respondents did not offer a way forward, with comments such as:

- Wouldn’t know, and
- It relies on common sense.

To the final question “*Do you have any other comments or ideas in general with regards to ‘designing for construction health, safety, and ergonomics’?*” 70% of respondents offered commentary:

- It’s important ... an awareness needs to be made;
- One does not really think about it – it needs to be taught and awareness raised;
- The trade is becoming more aware of the problems;
- We need to understand alternative methods of construction. Recycle and re-use ... reduce manpower and reduce risk;
- Awareness and fairness – people doing a hard job – how do we make their day more comfortable. If teams are happy, they will be more aware and careful;
- Something can be developed. Hopefully we’re doing it anyway ... it’s something we need to be aware of, and
- It’s a new field ... not widely explored. We need research and new ideas brought to us. Information needs to be increased at tertiary education level and workshops held for the professionals.

5. Conclusions

Given the objectives and methodology of the study, it is likely that the more committed architectural designers made themselves available for interviews.

80% of respondents believe that construction hazards and risks can be mitigated through alternative design and 60% of respondents suggested that they do actively engage in designing for construction health, safety, and ergonomics, yet commentary suggests that the understanding and level of engagement is minimal. This is supported by the responses received relative to having the necessary competencies.

In terms of encouraging architectural designers to engage in designing for construction health, safety, and ergonomics, and the possible means or format thereof, the arising themes strongly suggest the need for appropriate and ongoing education and training to

create awareness and that designers need ‘hands on knowledge of what the contractor encounters’. It was also suggested that a manual could be introduced to guide designers through the process, which would make a worthwhile contribution.

The responses to the question of how designing for construction health, safety and ergonomics could be incorporated into education, as well as into the everyday design process, position themselves somewhere between design and technology, with the majority leaning toward the nuts and bolts – as suggested, ‘how do we put a building together and document it?’ When to introduce this into education remains questionable, but suggestions of creating awareness ‘in the early years of architecture’ is inspiring.

An additional important theme running throughout the responses is that designing for construction health, safety, and ergonomics must not stifle the design process and should ‘invite deeper thinking’, rather than being prescriptive.

6. Recommendations

In order to encourage architectural designers to design for construction health, safety, and ergonomics, further research is necessary. Such research should focus on development of a guiding approach or model – or a manual – suitable for integration into architectural education and continuous professional development (CPD) programmes. The approach or model should be geared toward the early years of architecture and related technologies, and should invite deeper thinking, rather than stifle architectural freedom.

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