Designing for Safety – Applications for the Construction Industry

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Abstract

While the rate of serious injuries and fatalities for construction workers in the United States has been improving as indicated by some statistics, there are major challenges in construction safety towards meeting a long-term goal of zero injuries. To achieve that goal, a variety of different approaches to safety should be considered and implemented. This paper will examine one such approach which involves designing for safety with consideration given to the safety of construction workers in particular. The paper will explore a current designing for safety initiative known as Prevention through Design (PtD) which seeks to implement design solutions to address hazards in construction along the lifecycle safety continuum for a construction project, beginning in the conceptual design phase and continuing through to completion. The paper describes the activities that are educating the broad construction audience (owners, designers, and contractors) and the efforts to increase partnership involvement in designing for construction safety. The objective of designing for construction safety is to eliminate the construction hazards with deliberate assessment of potential hazards and incorporation of design solutions within the project. The paper will describe this approach, and will provide examples of the application of designing for safety such as: structural design layout to reduce exposure to falls and the use of value engineering in the preliminary project phase.

Keywords: preliminary design phase, education, hazards, Prevention through Design (PtD)
1. Introduction and background

1.1 Hazards and their consequences in the construction industry

In the United States, the construction industry employs roughly 7.5% of the nation’s workforce yet accounts for over 20% of the nation’s occupational related deaths. Despite the fact that morbidity and mortality statistics mark a steady improvement in safety conditions for the construction industry, the records serve as reminder of the need to address hazards and provide for the safety and health of construction workers. In a little over a decade, the fatality rate has decreased from 14.7 per 100,000 workers in 1995 (Toscano and Windau, 1996) to 10.5 per 100,000 workers in 2007 (BLS, 2008). However, each year more than 1000 workers are killed in the construction industry, and the industry accounts for a disproportionate percentage of all workplace fatalities compared to employment across all industries.

Workers in the construction industry are involved in trades that are inherently dangerous because of the potential for exposures to multiple hazards. Despite the existence of well-characterized and effective solutions to these hazards, many known for decades, too frequently they are insufficiently implemented. It is estimated that 7 - 10% of the global workforce works in the construction industry, but the sector counts for at least 60,000 fatal accidents or 30 – 40% of all fatal accidents (Murie 2007; ILO 2005). Given these realities, and building upon a wealth of research characterizing hazards and proven solutions, an approach for anticipating, evaluating, and minimizing or removing the hazards prior to initiating work is warranted. This approach begins with the recognition that influence over the safety and health environment of the construction industry and its workers extends much broader than historically acknowledged.

1.2 Responsibility for safety in construction

Traditionally, safety was widely viewed as the responsibility of the contractor. Yet, the goal of zero injuries is not compatible with this view. Rather, the inclusion of owners, designers, and all parties involved in construction projects from planning to completion, is required to ensure that hazards are eliminated and workers are protected. A key component to reducing construction accidents through design and planning is the involvement of construction users and project owners. There are owners who recognize this possibility as an effective method to reduce accidents and accident producing situations, as evidenced when consideration is given to the lifecycle system of a construction project from the conceptual phase to completion. Who influences the safety of construction workers? There is no single influence, as the safety of the worker is influenced by other workers, supervisors, contractors, subcontractors, owners, and designers. Recognizing this string of influences is essential for impacting construction safety, and includes involvement of designers and engineers.

Previous research in Europe in the area of designing for safety has led many European Union (EU) countries to adopt legislation requiring architects and design engineers to implement design for
construction safety (ILO, 1985; European Foundation for the Improvement of Living and Working Conditions, 1991). The effect of these European Directives on safety and health conditions in the construction industry has recently been studied and publicized elsewhere (Aires, Gámez, and Gibb 2010); that study indicates that in a little more than a decade since the Directives were implemented, at least 10 EU countries have experienced significant reductions (~10%) in workplace accident rates. The study authors acknowledge the need for the next phase of the study to evaluate the extent to which reductions can be traced to better planning and design. In the United States construction worker safety is solely the responsibility of construction firms and is reinforced by the Occupational Safety and Health Administration (OSHA) standards and contracts specifications.

Among the pioneers in this effort, the National Safety Council Institute for Safety Through Design established in 1995 sought to advance workplace safety and health in its core mission: To reduce the risk of injury, illness, and environmental damage by integrating decisions affecting safety and health, and the environment in all stages of the design process (Christenson and Manuele, 1999). Within that mission statement are elements of issues that remain relevant and timely – sustainability, occupational safety and health, and the influence of design. Another noteworthy development in efforts to explore and promote discussion about this topic occurred in September 2003, with the convening of a symposium entitled Designing for Safety and Health in Construction. That event represented a “broad collaboration involving scholars and practitioners; the multiple disciplines involved in construction, design, and workplace safety and health; and different countries and continents (Hecker, Gambatese, and Weinstein, 2004).”

2. Prevention through Design (PtD)

2.1 Making the case for design solutions

It starts with planning, and as with any project, this is the stage at which safety and health issues can be addressed most efficiently. Consequently, NIOSH and its partners have created a National initiative, known as Prevention through Design or PtD, to prevent or reduce occupational injuries, illnesses, and fatalities by including prevention considerations into all designs that impact workers. One of the best ways to prevent and control occupational injuries, illnesses, and fatalities is to "design out" or minimize hazards and risks early in the design process.

Many examples of design solutions for challenges such as these exist, and many more remain to be discovered. The objectives of PtD are to promote this concept and its application in all industries, highlighting its importance in all business decisions. (Please refer to http://www.cdc.gov/niosh/topics/PtD/) One construction specialty area with possible applications of this approach relates to the increased emphasis of Green buildings and sustainable resources. The use of specialty roofing materials, insulation, and even installation of solar panels and skylights could all be associated with attendant hazards, in particular working at heights and risk of falls. Based upon the common recognition of this hazard, adopting safer work practices and modifying activities to protect
workers could be achieved through better coordination between manufacturers, facility designers, building owners, roofers, and construction engineers to

- determine the best designs for addressing fall hazards
- provide barriers or appropriate anchor points for fall protection
- design skylights to provide greater strength and durability or include metal coverings to prevent falls through them
- limit exposures to hazardous energy sources during installation and maintenance of solar panels (Lentz et al. 2009).

In particular, falls through skylights can be a significant hazard for roofers, other construction workers, and facility maintenance engineers. The occurrence of such events indicates a need to increase hazard awareness and introduce designs to control fall hazards. Possible design solutions include:

- skylight screens capable of safely supporting the greater of 400 pounds or twice the weight of the employee plus his equipment and materials
- guardrails around the skylight at least 45 inches in height with a top rail and mid rail which should be halfway between the bottom surface and top rail. The rails should be able to withstand a live load of 20 pounds per square foot.

In some cases it is realized that these design solutions are not feasible, and consequently other options including personal fall protection should be utilized. A personal fall protection system consists of a body harness, lanyard and anchor points.

Another example of planning to avoid hazards involves structural design layout that affects erection and hoisting such that the sequence of erection could reduce exposure to falls when connections are made. Increased communication between designers, engineers, project owners, and construction project managers is essential for performing a safety constructability review during preliminary project phases.

Architects and designers are able to prepare plans with greater accuracy, efficiency and speed utilizing computer-aided-design (CAD) systems. A recently introduced technique and movement in design and construction is Building Information Modelling (BIM). BIM provides a vehicle whereby continuous learning is possible throughout all phases of a construction project, from conception to completion. CAD permits the visualizing of conflicts of building components. BIM has the potential during early design phases and during construction to reveal situations that involve risk management attention. There are case examples of BIM that show applications for planning, scheduling, improved conflict control, and hazard recognition in buildings (Ku et al., 2008). BIM then provides the possibility for designers to conceive hazard recognition during design and provide this information to constructors.
2.2 Harmonizing national PtD efforts

The interest in and knowledge of the role of design for workplace safety and health predate efforts and activities today. Yet the two related initiatives described here are intended to guide national efforts in the United States: the Prevention through Design (PtD) National initiative developed by the National Institute for Occupational Safety and Health and promoted through the National Occupational Research Agenda (NORA); and the NORA Construction Hazards Prevention through Design (CHPtD) objectives. Although these efforts are harmonized, the former has a scope which encompasses all industry sectors and work practices, while the latter is more focused on unique characteristics of the construction industry.

It should also be noted that many of the concepts and objectives related to PtD and CHPtD are not exclusive to these programs; rather they may include elements which have evolved either as a continuation of earlier efforts or objectives being pursued in concert with other groups based on a common recognition of their importance. Education can have a broad impact for informing designers, owners, and engineers about construction worker safety and how to develop and promote safe design solutions.

To catalyze and harmonize efforts to explore and promote the role of design in the broad field of occupational safety and health, NIOSH and its partners convened the first PtD Workshop in Washington, DC in July 2007. The intent was to launch a National Initiative aimed at eliminating occupational hazards and controlling risks to workers “at the source” or as early as possible in the life cycle of items or workplaces. PtD includes the design of work premises, structures, tools, plants, equipment, machinery, substances, work methods, and systems of work. The workshop attracted approximately 225 participants from diverse industry sectors and disciplines. Viewed as a collaborative endeavor, initial partners included the American Industrial Hygiene Association, the American Society of Safety Engineers, the Center to Protect Workers’ Rights, Kaiser Permanente, Liberty Mutual, the National Safety Council, the Occupational Safety and Health Administration, ORC Worldwide, and the Regenstrief Center for Healthcare Engineering. Others have joined and continue to do so since.

The central tenet of this initiative is as follows:

Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment (NORA, 2008).

The approach to develop and implement the PtD National Initiatives framed by industry sector and within four functional areas: Research, Education, Practice, and Policy. Goals for each of these areas, and an additional focus area of small businesses, were established at a subsequent meeting of the NORA PtD Council in September 2008. The education goal for the National PtD Initiative is:
For designers, engineers, health and safety professionals, and business leaders to understand principles of PtD and apply knowledge in the design and re-design of facilities, processes, equipment, tools and organization of work (with 5 sub goals).

A comprehensive description of the PtD initiative is documented in an issue of the Journal of Safety Research (Volume 39, Number 2, 2008) dedicated to proceedings of the 2007 PtD National Workshop.

2.3 NORA Construction Hazards Prevention through Design (CHPtD) goals

The NORA Construction Sector Council was formed in 2006, and is comprised of invited stakeholders and subject matter experts from government, academia, industry groups, organized labor, and private consulting. During its initial face-to-face meetings, the Construction Sector Council identified priority topic areas through a series of discussions and multi-voting processes. Among the resulting topic areas identified, safety by design, later renamed Construction Hazards Prevention through Design (CHPtD) for harmonization and consistency with the broader PtD initiative, was determined to be a priority area for assessing research needs as well as the translation and dissemination of best practices for preventing hazards in construction through design and engineering solutions. A core CHPtD workgroup was formed from volunteers on the Sector Council with interest and experience in this topic area. Additional corresponding members were recruited through the Sector Council in February 2008.

To apply the concept of designing for safety to the construction industry the NORA Construction CHPtD workgroup was given the task of providing leadership to develop goals and priorities. The main idea was to utilize engineering strategies in the design phase of projects to reduce accident producing situations. This is to be accomplished by the formation of partnerships, coordination of efforts, and facilitating networking between the construction industry and associated groups of design organizations.

These activities were performed through a series of facilitated discussions, face-to-face meetings, and multiple teleconferences throughout a three-year period (2006-2008). An overall strategic goal (Goal 13) was established for the CHPtD topic:

**Strategic Goal 13** – Increase the use of “prevention through design (PtD)” approaches to prevent or reduce safety and health hazards in construction.

**Performance Measure** – Increase the use of CHPtD by 33% over the next 10 years.

The intermediate goals and associated performance measures were established to support the strategic goal and describe specific research or research-to-practice (r2p) activities identified as priority activities for this topic area. The draft goals, first disseminated in February 2008, were later revised.
in October 2008 and have been released elsewhere (see
http://www.cdc.gov/niosh/nora/comment/agendas/construction/).

2.4 Outcomes and early indications of PtD implementation

Since the establishment of the vision and motivation for PtD, activities have started to accelerate. A
PtD plan for the National Initiative was established by NIOSH and stakeholders in April 2009 (see
Society of Safety Engineers (ASSE) recently published a technical paper and will begin developing a
standard for the American National Standards Institute (ANSI) dedicated to addressing occupational
risks in design and redesign processes (ASSE 2009). Further, in December 2009, the Acting Assistant
Secretary of Labor at OSHA addressed the Advisory Committee for Construction Safety and Health
(ACCSH), the advisory body established by statute that provides advice and assistance in construction
standards and policy matters to OSHA. He specifically charged the ACCSH Roll-Over Protection
work group to include Prevention Though Design issues in its approach to considering hazards. The
intent is for ACCSH to provide OSHA with assistance developing products that will make design
industries more aware of the value of design decisions that can help reduce hazards to construction
workers. Another of the ACCSH workgroups has been formed and given a related task: to consider
Green Jobs in Construction and how the roles of engineering, design, and planning can help prevent
hazards. These activities will continue to build upon the already mature efforts of the OSHA Alliance
Program Construction Roundtable and its Design for Safety work group. Among the guidance
developed by the latter were construction Design for Safety training materials, web-based guidance,
and design solution case studies for fall protection in construction.

2.5 Conclusions

The impact of addressing challenges related to design, and conducting additional research and
evaluation, will ultimately be judged against measures that translate into fewer injuries and fatalities
by eliminating or mitigating hazards. A reduction in the occurrence of accidents and injuries will not
only save lives and improve the quality of life for workers, it can also result in lower workers’
compensation claims and other financial expenditures for contractors and owners of construction
projects. In order to recognize hazards that can be eliminated before construction commences a need
exists for additional tools in the form of PtD. As with the experience in the EU stemming from the
establishment of preventive measures and guidance to address construction hazards, the increased
recognition, validation, and dissemination of design solutions for the U.S. construction industry is
expected to impact the safety and health conditions during construction activities. Disclaimer

The findings and conclusions in this paper have not been formally disseminated by the National
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References


