Safety in Design:

Enhancing Construction Safety by Implementing Safety in the Design Phase

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Abstract

Construction remains the most dangerous industry for workers, who suffer illness, injury, and death in far greater proportions than other industries. Traditionally, safety in construction is the primary responsibility of general contractors and subcontractors, and not designers and construction managers. Data collection through a literature search, review of OSHA regulations, and review of health and safety statistics indicates that construction safety is substantially improved when qualified designers practice Safety in Design. Safety is enhanced when Construction Managers perform design review and constructability review in the design phase of a project, with the objective of building safety into the design. There are barriers to the implementation of Safety in Design in the United States and where it has been embraced abroad. Similar barriers to full implementation remain. These barriers can be overcome through an emphasis on training and education, Safety in Design awareness, changes in perceptions and practices in professional liability insurance, and a rethinking of the emphasis of safety responsibility in the OSHA and other applicable safety regulations. This paper provides a discussion of the state of the art in the practice of Safety in Design, including progress, barriers to full implementation, and best practices.

Safety in Design is an effort that is made in the design phase of a construction project to consider the safety of workers who will be constructing the project. Safety in Design is a structured process in the planning and design phases of the project. In the United States, such a focus on worker safety in the early stages of a project is neither a part of the traditional aspects of design nor a part of the traditional aspects of construction safety practices. The focus of designers is on the safety of the end users of the facility: its occupants, its maintenance personnel, and the public who utilize the facility, and not the worker who builds it.

There are reasons why construction worker safety has not been addressed adequately in project design. The fact is that construction workers experience death, illness and injuries on the job more than nearly every other industry in the United States (Bureau of Labor Statistics, 2003). Construction is one of the most hazardous of professions. In recent years there has been a much greater emphasis on safety. However, construction safety requirements fall primarily on general contractors and subcontractors. The safety emphasis is on the means and methods practiced in the construction phase. Perhaps there are other effective ways of addressing construction safety, in addition to proactive safety management during construction. The key to improving construction safety is to make the working environment safer before construction begins.

This paper summarizes a body of literature and statistics that show clearly that the United States has not achieved Safety in Design practice. Other countries have taken initiatives to implement Safety in Design through legislation, formation of organizations that develop design models to implement Safety in Design, and education and training of designers to enable them to perform Safety in Design. Yet the forces in the United States that prevent barriers to implementing Safety in Design are also at play where the initiatives are being implemented elsewhere.

At the 14th Annual Conference and Exposition in Rosemont, IL several years ago, John Gambatese and Steve Hecker (2004) of the University of Oregon discussed the reasons why Safety in Design as a concept has not fully taken hold in this country: (a) The Occupational Safety and Health Administration (OSHA) through its regulations and enforcement, places responsibility for safety on the general contractor and subcontractor; (b) The education and training of designers limits their ability to perform Safety in Design; (c) There is a lack of Safety in Design tools, guidelines, and procedures; (d) Designers are not fully integrated on the project team after the finalization of design documents; (e) Traditionally, designers do not view their role as promoting construction worker safety since this is in the bailiwick of the contractor; and (f) Concerns about professional liability although there still remains associated liability.

The Association of Civil Engineers (ASCE) Code of Ethics states that “the lives, health and welfare” of the general public are dependent on engineering judgment (ASCE Code of Ethics). Note the omission of “construction worker” in the above phrase. Review the OSHA standards and you will see that they place the primary safety responsibility for construction workers on those who employ them. The OSHA regulations (OSHA 20 CFR 1926.16c) state that “In no case shall the prime contractor be relieved of overall responsibility for compliance with the requirements of this part.” The regulations further state that, "With respect to subcontracted work, the prime contractor and any subcontractor or subcontractors shall be deemed to have joint responsibility." (OSHA 29 CFR 126.16(a))

The United Kingdom (U.K.), Australia, and some other countries moved away from this concept of safety responsibility when they implemented their respective regulations placing Safety in Design responsibilities on architects and engineers. In the U.K., design engineers are required by law to specify in detail, the safety of construction workers in their design. This has been in place for more than 10 years (Bennett, 2008). The Australian government has also taken a leadership role in requiring design in construction (Australian Safety and Compensation. Council, 2006).

There are a number of ways that the Safety in Design paradigm can shift in the United States. This requires a different approach to safety by architects, engineers and construction managers. It also requires a change in the perspective of private and public owners. There are many human and financial cost benefits to the practice of Safety in Design, and owners need to understand that these benefits outweigh the additional costs that are incurred in design to implement safety before construction. Construction managers, as agents of the owner, have vast construction knowledge and experience that could be brought into the design phase, not only from within the construction manager's organization, but through collaboration with trade contractors. The owner benefits from the value that the construction manager can bring to the table to promote safety in the very early stages of planning and subsequently in design (Gambatese & Hecker, 2004). Construction managers can mentor designers in identifying safe alternatives in formulating design and construction contract documents.

The notion that Safety in Design has been completely ignored in the United States would be a misconception. There certainly has been some progress in shifting the paradigm, and it can continue to be shifted in a meaningful way. The active involvement of designers will have a positive impact on reducing site safety hazards further by shifting the paradigm and introducing Safety in Design. Many safety hazards on construction sites exist mainly because they have been designed into the project's physical features (Gambatese, 2005).

Objectives of this Paper

Through a review of the literature, a study of existing safety regulations, and statistics of construction worker safety, this paper addresses: (a) Causal link between Design and Construction Accidents and Health Incidents; (b) Status of Safety in Design initiatives in the United States and elsewhere and barriers to full implementation; and (c) Examples of Safety in Design models that can be implemented to dramatically improve construction safety.

Literature Review

A text based electronic search of Safety in Design practice in the United States and world wide was performed. Practices in the U.K. and Australia were reviewed for comparative purposes because these countries have enacted legislation to mandate safety in design practices. The findings were used to determine if Safety in Design can make construction sites safer for workers, and reduce deaths, accidents and illnesses suffered by workers in this industry, as well as to identify specific models of safety and design that would have a positive impact on safety.

Safety Statistics

A review of safety statistics provided by the U.S. Department of Labor, Bureau of Labor Services and other sources reporting on safety was undertaken to compare safety performance in the United States and internationally, where safety in design is mandated by law, to determine if safety in design practices abroad has had a mitigating affect on injuries, deaths and illnesses.

Review of OSHA Standards

The construction standards contained in the OSHA regulations (29 CFR 1926, Safety and Health Regulations in Construction) were studied in order to identify those standards that specifically apply to designers, and to identify standards that can be readily incorporated into Safety in Design criteria and that can be applied by construction managers in reviewing design and construction documents to determine safer means and methods of construction. Changes in design methodology through the adoption of certain OSHA standards was examined and identified.

Causal link between Design and Construction Accidents and Health Incidents

The European Foundation for the Improvement of Living and Working Conditions (1991) concluded that about 60 percent of fatal accidents in construction arise from decisions made upstream from the construction site. These were attributed to shortcomings in design and organization of the work. This was an early claim that the design and the design process are linked to construction accidents (Behm, 2005).

The construction industry in the United States presently employs about 7 percent of the workforce, but its workers still experience 21 percent of its injuries (Zarges & Giles, 2009). Decisions made in design influence the number of safety incidents that occur during construction. Studies of fatalities in construction showed a clear link to design for construction safety. Forty-two percent of fatalities examined in 224 fatal incidents at construction sites were shown to be preventable if Safety in Design practices were in place (Behm, 2005).

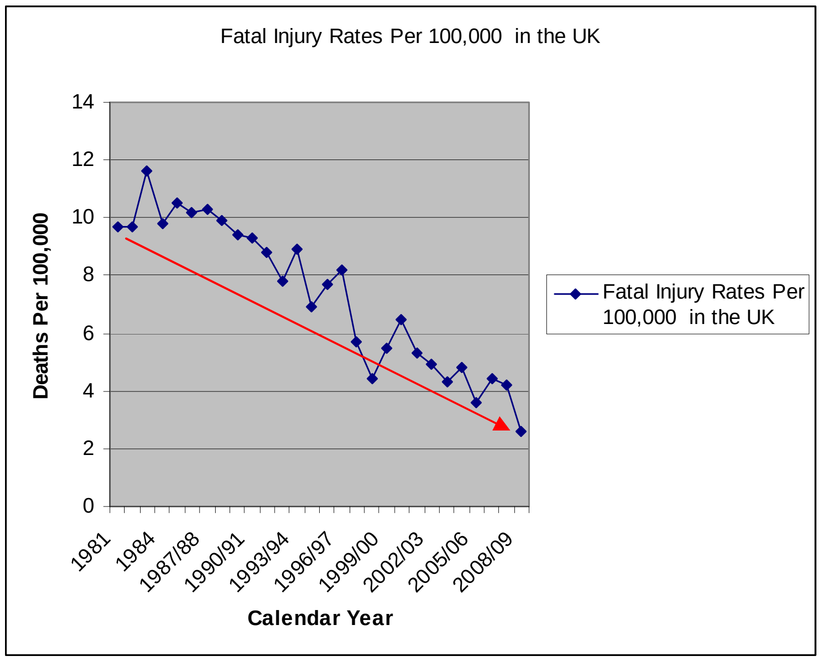
In 2002, the construction industry experienced 1,121 total deaths, or 20 percent of all work-related fatalities in the United States (Bureau of Labor Statistics, 2003). A study by Behm (2005) provides statistical evidence that the safety of any operation is determined well before construction begins. By addressing safety during the design process, hazards will be eliminated or reduced during construction. Behm used the National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment Control and Evaluation (FACE) program with the random selection of 230 cases that provided sufficient data to make a determination of the causal link between safety and Safety in Design practices. A model was created to perform this assessment, built around: (a) whether the permanent features of the construction project were causal factors in the fatalities; (b) whether previously developed best practices (i.e. Safety in Design suggestions) could have been implemented to eliminate or reduce hazards that contributed to the fatal incident; and (c) Whether design processes could have been modified to prevent the fatal incident. Behm used these three criteria to form the model by which each fatality was evaluated as to whether it could be linked to the design for construction safety concept. If any of the three questions developed around these criteria were answered in the affirmative, then the fatality was determined to be linked to the design for construction safety concept. If all questions were answered negatively, then the fatality was not linked to the design for construction safety concept (Behm, 2005). The research demonstrated that 42 percent of the fatalities were linked to the design for construction safety concept. Behm (2005) also tested the hypothesis that certain fatalities linked to the Safety in Design concept are related to the designer's discipline. Some disciplines are more prone to safety incidents during construction than others. He applied a Chi-square methodology in the study of 207 cases. Chi-square says that there is a significant relationship between variables, but it does not say just how significant and important this is. He therefore used Cramer's V to post-test his analysis to confirm the association between variables. Findings indicated that 29 percent of construction safety incidents were linked to the civil engineering discipline. Twenty-five percent were linked to architectural design. Twenty-four percent were linked to structural engineering. Seven percent were linked to mechanical engineering, and 7 percent to electrical engineering. Behm concluded that design professionals are in a position to make decisions about construction safety and reduce or eliminate certain identifiable risks before those risks reach the construction site. Design decisions, placed in the hierarchy of safety controls will result in hazards that are "designed out" in a way that will result in their elimination or reduction before workers are exposed to them or have to react to them. He concluded that design was linked to 42 percent of 224 fatal accidents from the period of 1990-2003. These results make a strong case for adopting the concept of designing for construction safety in the United States.

There is other causal evidence that demonstrates that fatalities are related to design issues. Research commissioned in Australia by the National Occupational Health and Safety Council in 2005 found that the design of machinery and equipment had an influence on the incidence of design as the probable cause of construction fatalities 37 percent of the time, when 210 identified work site fatalities were examined. It was also found that at least 30 percent of work related serious non-fatal injuries are attributed to design. These were industry-wide findings. In construction, the study found that at least 50 percent of incidents of accidents and fatalities were attributed to design issues (Australian Safety and Compensation Council, 2006).

Further corroboration that Safety in Design would reduce fatalities comes from another study performed in Australia. A study commissioned by the National Occupational Health and Safety Commission considered the role of design issues in fatal work related injuries, studying a two-year period ending in June 2002. The main finding was that design was a significant contributor to fatalities at work. The study included any aspect of the construction of structures, equipment, plant, and tools. The study considered whether fatal injury would have occurred if a design issue was not present. The design issues considered were: problems with rollover protective structures, inadequate guarding, inadequate fall protection, and inadequate protection mechanisms. Across various accidents, it was found that poor design contributed to 37 percent of workplace related industries in Australia, and that, for the construction industry, 43.9 percent of fatalities were directly linked to design (Bradley & Newson, 2008). In the United States, in a review of one hundred construction accidents, it was found that in 47 percent of the cases, changes in permanent design would have reduced the likelihood of an accident (Gibb, Haslam, Hide,& Gyi, 2004).

In the U.K, where the government has promulgated regulations to require that designers incorporate safety into their design for construction, statistics released by the Health and Safety Executive (HSE) for 2005/06 show the rate of fatal and major injuries in the construction industry is continuing to fall. The HSE has never completed a specific study to determine the impact of the CDM regulation on construction related accidents and fatalities (H. Phillips, Personal Communication, SE Email Communication, November 27, 2009). However, the HSE's Health and Safety Statistics 2005/06 report shows that fatal injuries in that year declined 36 percent compared to the number of fatal injuries in the period of 1999/2000. A comparison of major injuries suffered by construction workers in the same period shows a reduction of about 22 percent. The rate of reported major injuries to employees in construction between 1999/00 and 2005/06 has been reduced by around 22 percent. The rate of reported over three-day injuries to employees in construction between 1999/00 and 2005/06 has been reduced by around 31 percent. For the first time, the proportion of major injuries due to falls from height has been overtaken by those resulting from slips, trips, and falls on the same level. Injuries due to slips and trips and manual handling have risen steadily over the past few years while those from falls from height and being struck by an object at height have been reduced substantially. While the sustaining of any type of injury is not good news, the good news is that the types of injuries that are preventable through Safety in Design, which includes falls from heights and being struck by objects are decreasing, providing circumstantial evidence that Safety in Design measures implemented in the U.K. are effective. Commenting on the statistics, HSE's Chief Inspector of Construction Stephen Williams said: "My congratulations go out to the industry on the progress it has made so far. I am particularly pleased to see the encouraging signs that it has taken ownership of its health and safety performance, and worked hard to achieve the lowest incidence rates ever for fatal, major injuries and over three-day injuries." (Health and Safety Executive, 2006)

An analysis of fatal injuries reported in the U.K. for the construction industry in the years ranging from 1981, when the CDM regulations were not in effect, and 2008/2009 shows a downward trend since their introduction, as depicted by the line chart. Although these statistics are not conclusive, it is instructive to note that construction in the U.K. continues to have the largest incidence of fatal injuries of the main industry groups. In 2008/2009, there were 53 fatal injuries, or 2.5 per 100,000 workers. The rate of fatal injuries in construction over the past decade has trended downward. In a comparable period in 2000/2001, there were 5.9 fatal injuries per 100,000 workers in construction, and in the past three years the rate declined a total of 34 percent. The reports of fatal injuries have steadily fallen, but the rate of major injury is still the highest among the U.K.'s industries at 254.1 per 100,000 employees. In the opinion of the author, this is an indication that the resources must be provided to the HSE for the full enforcement of the CDM regulations, and that education and training to promote the benefits of compliance needs to be continued (HSE Statistics, 2009).



The U.S., in the period from 1989 to 1995, experienced approximately 14 fatalities per 100,000. In a comparable period, from 1988/1989 to 1993/1994, leading up to the implementation of the CDM regulations by the U.K, the fatality rates per 100,000 ranged from 9.9 to 8.9. However, after the implementation of the CDM regulations, the fatal injury rate per 100,000 in the U.K., with the exception of the period 1996/1997, declined from 6.9 in the CDM regulations implementation year, to 2.6 in 2008/09 (HSE Statistics, 2009).

In comparison, the U.S., the Bureau of Labor Statistics reported that in 2009, there were 9.6 fatalities per 100,000 in the U.S., or a total of 969 fatal injuries (BLS, 2009). Fortunately, in the United States, there has been an increasing emphasis on the enforcement of safety regulations, albeit not Safety in Design, and the United States has therefore experienced a significant reduction in its construction death rate since 1992, when it was 18.6 per 100,000 workers. As has been the trend for many years, the leading causes of these fatalities have been falls from elevation, electrocution, struck by falling objects, and other causes, many of which would be further mitigated by the practice of Safety in Design (eLCOSH, 2007).

Fatal Injuries reported in the U.K. for the Construction Industry, 1981 – 2008/2009

YEAR	No. Fatal Injuries	Fatal Injury Rates Per 100,000		YEAR	No. Fatal Injuries	Fatal Injury Rates Per 100,000
1981	105	9.7		1995/06	62	7.7
1982	100	9.7		1996/07	66	8.2
1983	118	11.6		1997/08	58	5.7
1984	100	9.8		1998/09	47	4.4
1985	104	10.5		1999.00	61	5.5
1986/7	99	10.2		2000/01	73	6.5
1987/8	103	10.3		2001/02	60	5.3
1988/9	101	9.9		2002/03	56	4.9
1989/90	100	9.4		2003/04	52	4.3
1990/01	96	9.3		2004/05	55	4.8
1991/02	83	8.8		2005/06	43	3.6
1992/03	70	7.8		2006/07	54	4.4
1993/04	75	8.9		2007/08	53	4.2
1994/05*	58	6.9		2008/09	33	2.6

Source: HSE Statistics for fatal injuries in the U.K. in construction, 2009.

* Year CDM Regulations went into effect.

Safety in Design Abroad

As we have shown, countries abroad have taken the lead in implementing design for construction safety. This includes enacting laws, rules, and regulations that require the designer to proactively design for safety, and in developing best practices models for designers to use to incorporate into design. The U.K. and Australia, and to a lesser extent certain European nations, have embraced this concept and have taken a leadership role in worksite safety through proactive design. Australian health and safety law and supporting guidelines for industry practice have been established. Requirements have been imposed on designers to ensure health and safety in design and construction of buildings, facilities and infrastructure. Professionals in design, and others including the owner, and the developer, are all under the jurisdiction of Australia's Occupational Health and Safety Laws. The laws require a process of interaction between designers and the end users, manufacturers, suppliers, and contractors (Australian Safety and Compensation Council, 2006).

In the U.K., the Construction Design and Management Regulations of 2007 require every designer preparing a design for construction to "avoid foreseeable risks to the health and safety" of workers on construction projects. The designer is required to eliminate hazards that may cause safety risks and reduce the risks of remaining hazards. Designers are required to incorporate the requirements of Workplace Health, Safety and Welfare Regulations (OPSI, 2007). These regulations address hazards that are created by design when a construction process is being specified. To prevent a hazard potentially caused by design, designers in the U.K. are required to identify prohibited practices, such as allowing for the lifting of loads over a large radius, or painting steelwork on site, exposing workers to toxic vapors. Designers are expected to propose safer alternatives. Designers are also required to assist contractors in meeting safety requirements through safety policies. These include, for example, the provision of holes in steelwork to anchor lanyards, lifting points in pre-cast or pre-assembled panels, and use of lightweight blocks. *Safety in Design*, a non-profit organization in the U.K. that exists to assist designers and contractors in complying with safety in design and construction, likens safety in design to a traffic system of red, amber, and green lights. Red means "do not specify"; amber means "specify with caution and provide further information to others"; and green means "actively select where possible." (SID, 2009)

Although the CDM regulations were hailed as a milestone in Safety in Design, there has been some resistance by owners to comply with the regulations. A large factor is added cost for compliance and the need to cut costs and meet schedules, which can result in compromising safety. Also, the HSE has been under-funded to provide inspections to ensure compliance. In 2005/2006, there were 59 fatal injuries on construction sites in the U.K. Fatalities rose to 77 in the next year. Recent inspections of sites by the HSE resulted in findings of non compliance in one in three sites, and one in four contractors inspected were found to be working below acceptable standards. The main drawback is in resources – the resources to police sites and to make owners more aware of the benefits of Safety in Design and compliance with HSE regulations (Lee, 2009).

Safety in Design in the United States

The implementation of Safety in Design is likely to be a part of the evolution of the construction industry in the United States. Much like the embracing of Green Construction, which has taken many years to take hold, Safety in Design is a concept whose time has come. Safety in Design is highly complementary to Green Design principles. Both concepts speak to a choice of processes in engineering and architectural design that lead to safer and healthier environments. The Green Design movement has been slow in its implementation but is now gaining momentum. In some respects, Safety in Design has been slow in its implementation, particularly in the United States. However, there are many signs that Safety in Design not only reduces accidents and illnesses, but is cost effective.

The implementation of Safety in Design in the United States is in the early stages, as will be seen by examples cited below. When the Hoover Dam was constructed, more than 120 workers were killed, and this was an acceptable cost of construction. When the Verrazano bridge was being constructed, initially there were not safety nets for workers at heights, until three fatalities caused a job action in 1963 and safety nets were installed. These are human costs based on practices that would not be tolerated today. There is growing evidence that the construction industry is becoming more aware and more receptive to safety and health requirements on the job. This awareness is not only motivated by the concern for the well being of the construction workforce. Increasing costs associated with accidents and illnesses, lost productivity, and legal liability have combined to increase awareness (Gambatese, 2000).

Long standing resistance to Safety in Design is well documented by the literature. Studies by Hinze, n.d., and Wigand, 1999 (as cited in Gambatese, 2002) found that only one third of major design firms took credit for performing any type of Safety in Design function in the preparation of plans and specifications. As costs of litigation and liability insurance increase, along with the concern for construction worker safety, there is recognition that improved safety can improve worker productivity and the quality of construction (Gambatese, 2000). It is not easy for designers to embrace Safety in Design, and Best Practices have been slow to evolve for widespread use by designers and construction managers who perform design and constructability reviews. The current notion is that liability should remain in the province of the general contractor. The general contractor is rewarded for the risks it takes. The design community fears that the embrace of Safety in Design will increase their professional liability (Gambatese, 2000). While the fear of litigation may be the biggest deterrent in implementing Safety in Design, there are also other factors. There is also great reluctance by Architects and Engineers to interfere with, recommend or suggest construction means and methods to Contractors, and great reluctance by Contractors to accept them. This is because it goes against the culture, custom, and norms of the practice of construction in the United States.

Behm (2005) reported that the construction contract procurement processes in use in the United States presents more barriers to the implementation of designing for construction safety. The processes separate design from construction, and herein lays the barrier. Contract language between the designer and the owner, and between the owner and the contractor clearly mandate the responsibility of safety to the contractor, who is solely responsible for job site safety, means, methods, techniques, sequences, and procedures. Alternative means of construction procurement, such as design build, could promote the implementation of design for construction safety faster than the more traditional procurement models (Behm, 2005).

Another Safety in Design barrier, ironically, is the federal OSHA regulations. The role of contractors in providing safe work conditions and practices is clearly established by the OSHA standards. While the standards provide that a professional engineer or designer provides input in safety, this is not a mandated requirement. The safety provisions in OSHA, as they relate to designers, speak to the safety of the general public, and not the construction site worker. In a text-based electronic search of OSHA construction standards to identify provisions containing references to “design professional,” “engineer,” and “designer,” it was found that the OSHA standards addressed such operations as scaffolding, material hoists, hazardous locations, cranes and derricks, and protective systems, but defined the role of the professional engineer as an inspector or designer for the Contractor, providing no role to perform prevention through design services before the start of construction (Gambatese, Hinze, & Behm, 2005).

The typical roles of owners, designers and contractors have been established by tradition, and each entity has its own distinct responsibility and does not generally interfere with the role of the other parties. The position of professional associations on Safety in Design is presently compatible with the silence of the OSHA regulations on the designer's role in safety. The official position of the National Society for Professional Engineers, an organization that promotes professionalism and ethics in engineering, is reflected in the Engineer's Creed in the NSPE Engineer's Code of Ethics: "As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare." The engineer pledges to place "the public welfare above all other considerations." The creed is silent on worker safety, and it appears that construction workers are not considered to be part of the general public. The preamble to the NSPE Code of Ethics states only that the services provided by engineers "must be dedicated to the protection of the public health, safety and welfare" and that they "shall hold paramount the safety, health and welfare of the public in the performance of their professional duties."(NSPE Code of Ethics)

Various other portions of the Code of Ethics mention the engineer's obligation as it relates to the safety, health, and welfare of the public. Unfortunately, the construction labor forces are never mentioned. It would be difficult to defend the assertion that the engineer's obligation is to "the public" and that this specifically excludes any obligation to the construction workers. Hinze (n.d.) suggests that it is not reasonable that engineers should be concerned about the safety of the public, protecting individuals who may have an incidental presence on the project, while not having a similar concern about construction workers who are physically on the project during construction.

As stated previously, there has been some Safety in Design initiatives taken in the United States that are noteworthy:

- The ASCE has entered into discussions with OSHA to improve construction worker safety, which would more directly involve design engineers in the process at a future time. The purpose of the ASCE/OSHA alliance is to raise the awareness of safety issues within the construction community and to promote the resources offered by OSHA to promote this initiative. A key initiative is to develop model safety programs that can be used by engineers and architects in their designs (Toole 2005).
- The Department of Energy has taken concrete steps to incorporate safety into the design phase for nuclear power plant facilities. The Department issued an operating standard known as DOE-STD-1189, which requires that sound safety related decisions are incorporated in design by performing a hazard analysis. In testimony before the DOE's Defense Nuclear Facilities Safety Board, the project director of the Department's Chemistry and Metallurgy Research Facility Replacement Project at Los Alamos, stated that his project was a model of safety through design because safety was integrated early during design due to federal regulations that require the evaluation of hazards associated with building the facility. All project participants, including designers, contractors, and safety contractors followed a well documented process of identifying and addressing safety issues on a daily bases through the interface of designers and safety professionals. This was supplemented by monthly formal design meetings and safety committee

meetings for review and debate of issues identified and means to resolve them. Procedures and guidelines for safety relating to construction and maintenance were developed (Ledoux, 2007).

- Some professional consulting firms have also made progress in promoting Safety in Design. One project identified in the research is a project undertaken by Washington Group International (now the Washington Division of URS Corporation). The project, known as the Advanced Mixed Waste Processing Facility, was a design build project for the Department of Energy for radioactive waste management. A core mission was to integrate safety input into the design, engineering, and planning stages of the project. Washington believed that designing for safety in the engineering phase would have a great impact on safety during construction of the project, and later on in the operation of the facility. Thus, safety measures were built into the design, construction, operations, and future decommissioning and demolition stages. A formal process was developed to identify ideas that would enhance safety. Design managers incorporated safety concepts early in the design. These inputs were reviewed for their appropriateness and effectiveness by other team members. A design safety review team was given the responsibility to train design team members in OSHA Safety requirements. The design safety review team was responsible for OSHA and other federal safety regulatory training, and ensuring participation by health and safety personnel with field experience in construction, and establishing periodic design review incorporating safety measures. Safety in design measures included construction and operation of the facility. During construction, design took into account hazards of electric shock, confined space, fire, toxic substances, vehicle traffic, falls, and rigging for heavy lifts. On the operational side, some of the safety in design measures included the design of a waste handling system that would be remotely handled by operators. Processes and controls were designed to minimize exposure of employees to waste (OSHA Washington Group, 2008).

Best Practices for Implementing Safety in Design

Best Practices for implementing Safety in Design rely on: (a) Education and training of designers in Safety in Design practices and project safety; (b) Diffusion of models of Safety in Design for adaptation by designers; and (c) Advocacy by professional societies to increase awareness of the need to address construction safety in the design phase of the project.

By examining design for safety suggestions, designers can gain insight of the ways that they can address construction worker safety in their designs. The designer cannot simply plug design safety models into their designs, but need to think about construction worker safety when they are in the process of making design decisions. By consciously addressing construction safety as part of the design routine, true Best Practices will be implemented. This requires designers to make the effort to address construction worker safety in all of the aspects of their design. It is a proactive role that needs to be an integral part of the design and construction phases of the project (Hinze, n.d.).

Professional societies have a definite role in advancing Best Practices by increasing the awareness of the impact of construction safety during the design phase. These professional societies need to consider how their members can be made more aware of the positive impact they can have on safety, and to advocate that professional liability can be reduced, and not increased by embracing Safety in Design, simply because sites will become safer. Once again, public and private owners must also be a partner in Safety in Design. For example, if a large construction agency of a state or municipality embraces this approach, it will have a great impact on finally focusing safety efforts in the front end of a project.

There are many Safety in Design Best Practices models that have been developed for use by designers in order to incorporate designing for safety. In the U.K., the non-profit organization, Safety in Design, has developed models to assist designers in the U.K. and elsewhere to incorporate these measures before construction begins (SID, 2009).

The Australian government has issued guide documents to assist architects and engineers in the elimination of construction hazards in the design stage as well. These guidelines integrate hazard identification and risk assessments early in the design phase of a project with the goal of eliminating or minimizing risks of deaths and injury throughout the life of the project, extending into the user and demolition phases of the constructed facility (Australian Safety and Compensation Council, 2006).

The Best Practices models guide designers in making choices which still allow design objectives for the project to be met, but with promoting safety as well. The principles of the Best Practices for Safety in Design start with the premise that persons in control of design decisions are best able to promote health and safety in the preconstruction stages. Safe design must apply to the project life cycle, from conception to demolition. Designers who are able to develop an awareness and understanding typical common hazards of a construction site, the hazards associated with construction and demolition processes, means of providing safe temporary works, an understanding of how materials that are specified can harm workers because of the release of harmful agents during application, and other likely hazards that require special design considerations reflects the qualities of a designer who can perform Safety in Design in a meaningful way (Australian Safety and Compensation Council, 2006).

Following are examples of Best Practices for designers that have been identified in the research of existing literature on this subject.

1. <u>Prefabricated Components</u>

The design of prefabricated components reduces the number of activities that must be performed at heights and therefore reduces the risk of fall related and struck by related injuries (Toole, Hervol & Hallowell, 2006).

The consideration of prefabricated components has been advocated not only as a safer means of construction, but one that can be cost effective, less time consuming and labor intensive, and provide more quality because of fabrication under controlled conditions. The U.S. Department of Transportation, Federal Highway Administration, in conjunction with AASHTO, reviewed the use of prefabricated bridge elements and systems aboard and concluded that the use of prefabricated bridge systems would improve work-zone safety. They reviewed 35 different innovative technologies. In one case, for example, the casting of partial depth concrete decks in steel or concrete beams before the erection of the beams would reduce the danger of equipment falling to the roadway surface below, since a safe working surface would be already established (USDOT Prefabricated Bridge Elements, 2004).

2. Electrical Hazards

The contract specifications can specify the crane radii and sufficient vertical space required that is clear of obstructions such as overhead power lines, a major source of accidents when cranes come into contact with energized lines. In fact, electrical hazards are reduced or eliminated by requiring in the design the disconnection, reduction of voltage ore re-routing of power lines around the project site before work begins. Existing power lines can be located on contract drawings, in relation to the new structure, as well (Toole, Hervol & Hallowell, 2006).

3. Placement of Openings on Roofs and Floors

By considering where openings on roofs and floors are placed, structural designers can influence project safety by placing openings of roof skylights away from readily accessed areas by construction workers in proximity of the openings, to prevent falls and drop hazards.

Obviously, this can only be done when there is no conflict to the design intent of the architect. In those cases, standard industry safety safeguards need to be used. A consistent floor layout on each floor, where this can be achieved, gives workers a throughout knowledge of the floor layout and openings, so that they can become more aware of hazards presented on each floor (Toole, Hervol & Hallowell, 2006).

Other design solutions include the installation of permanent guardrails around skylights; the design of domed skylights instead of flat ones; furnishing skylights with shatterproof or shatter resistant glass; and designed skylight installation on raised curbs (Hecker & Gambatese, 2004).

4. <u>Shop Welded Connections</u>

Specified shop welded connections where feasible in place of bolt and field welds helps to avoid dangerous and awkward positions for welders and contractors (Toole, et. al., 2006).

5. <u>Upper Story Window Sills</u>

If these are designed at least 39 inches above the floor level, they will function as guardrails during construction (Toole, et. al., 2006).

6. <u>Parapet Wall Design</u>

OHSA 1926 Subpart M requires a 42-inch guardrail or other protection when working at elevated heights. If the parapet wall is designed to be below 42 inches, a temporary guardrail or other temporary fall protection is required during construction. If the designer specifies a 42-inch high parapet wall, not only will the design comply with the building code in regard to public safety but the risk of a fall injury during the lifetime of the structure is eliminated because fall protection will not be required (Mroszcyk, 2006).

7. <u>Underground Utility Design</u>

Use trench-less technology to eliminate hazards that result from trenching. Trenchless technology replaces the need for open cut excavation and conventional trenching methods through tunneling, drilling and boring methods that minimally disrupt surface areas, and eliminate backfilling, compaction and restoration of ground surfaces, along with the material and labor costs associated with conventional methods. Safety impacts include eliminating hazards for fall protection, cave-ins, and equipment operation hazards (Mroszcyk, 2006).

9. <u>Primers and Sealer Specifications</u>

Specify primers and sealers that do not emit noxious fumes. This reduces illnesses caused by contact or inhalation of toxic fumes (Mroszcyk, 2006).

10. <u>Work near Underground Utilities</u>

The danger posed by underground electrical lines and gas lines poses a substantial risk. This risk can be reduced, after the utility lines have been located, work conducted around such utilities can be mandated to be done by hand (Hinze, n.d.).

11. <u>Work Performed Near Traffic Arteries</u>

This is actually a Safety in Design component that is widely practiced on highway and bridge projects. The mediation of danger posed by traffic adjacent to construction sites is accomplished by lane closures, traffic detours, speed limit reductions, and other maintenance and protection of traffic measures that are designed for the control of traffic.

12. <u>Construction Loads</u>

The design loads on structures that do not take into account the expected construction load, or that underestimate these loads creates a hazardous condition. If design documents clearly identify the assumptions made concerning the construction loads, or if the design can specify the amount of loading that are allowable, this can result in a safer project (Hinze, n.d.).

13. <u>Renovation Involving Existing Structures</u>

Whenever renovation work involves wall systems, the existing load-bearing walls should be clearly noted. It may be necessary to specify the explicit nature of the temporary shoring or support system that might be required. Any unique hazards that are observed during the design phase should be identified in the design documents (Hinze, n.d.).

14. Pre-assembled Rails

Design steel structures so that construction guardrails can be fabricated integrally with the structure. When the steel structure is erected, the guardrail will not have to be erected as a separate component, further reducing fall hazards (Hinze, n.d.).

15. Fire Safety

Schedule the underground firewater system to be constructed early in the construction phase. Similarly, in high-rise construction, schedule the firewater protection system to be operational early in the construction phase. Permanent emergency exit signs should be required to be erected as early as possible (Hinze, n.d.).

16. Demolition

When a project requires demolition of existing buildings or structures, the design should clearly show the fire walls and load-bearing walls, with scheduling to keep the firewalls in place as long as possible. If safety systems such as sprinklers and smoke alarms are operational, the design should try to keep the safety systems operational as long as possible (Hinze, n.d.).

17. Mechanical Systems

Design mechanical systems to be operational as soon as possible so use by construction forces is possible. Ventilation systems should be operational early in construction, whenever possible, especially where coatings with hazardous emissions will be applied (Hinze, n.d.).

18. Performing Tests

Require concrete test results to be obtained prior to removing forms and shoring on selected structural members. Where concrete placement loads impact the design, specify the procedure for placing the concrete. Similarly, in piping systems and structural steel systems, perform weld tests at the critical locations (Hinze, n.d.).

19. Slip And Trip Hazards

The entire design should reflect a sensitivity of the need to reduce falls resulting from irregular surfaces, steep slopes on ramps and roofs, and slippery walking surfaces. Additionally, design covers for sumps, outlet boxes, drains, hatches, etc. to be installed flush with the floor surface (Hinze, n.d.).

While many of the above Safety in Design suggestions appear simple or obvious, they have been shown to greatly enhance project safety. The point is that once the designer begins to approach design with safety in mind, such as in considering the design examples cited above, these ideas can be shared within the design community, promoted by professional member organizations such as the CMAA, AIA, and ASCE, and public and private owners. This in turn will generate more ideas and innovation. This is how Best Practices for Safety in Design can take a greater hold.

Conclusion

Safety in Design is a non-traditional approach to reducing illness, injury, and accidental death in the construction industry, an industry that has a disproportionate amount of safety incidents compared to other industries. The causal link between a safer construction site and the practice of Safety in Design is well documented. Safety in Design is the logical progression in the movement to improve construction worker safety. The full implementation of Safety in Design is hampered by barriers to its full embrace by the industry. The focus on construction safety continues to be on the contractor, and this is reinforced by the form of contract used by owners and advocated by professional societies, the OSHA safety regulations, professional liability practices, and an educational and training system for architects and engineers that largely does not teach Safety in Design techniques and construction safety in its curricula.

We have discussed initiatives abroad that have begun to institutionalize Safety in Design. The CDM regulations enacted in the U.K. and other measures that provide for criminal penalties for non compliance with safety requirements have only been partially successful. In the view of John Gambatese, some of whose works have been cited in the paper, many of the barriers in place in the United States also have impacted the ability of the U.K.'s Health Secretary Executive to fully implement Safety in Design. In an interview with the writer, John Gambatese, several of whose works have been cited in this paper, in observing the initiatives in the U.K., stated that legislation alone is no panacea to implementing Safety in Design (Personal Exchange, September 7, 2009).

Dr. Gambatese believes that Safety in Design has gained interest in the United States over the past 15 years. This paper has cited examples where Safety in Design has started to gain traction, particularly with some federal projects and through initiatives of some major design and construction management consultants.

The fact remains that many construction incidents that result in illness, injury, and death could be avoided if there were better design choices. Construction accidents are often caused by the lack of proper training, the failure to comply with safety regulations and safety programs and plans that have been developed for a construction project, the use of unsafe equipment, unsafe construction methods, and the use of improper or defective tools and equipment.

Some of the Safety in Design models that could immediately used by designers has been illustrated in this paper. Innovative professionals here as well as in the U.K., Australia, and elsewhere continue to develop valuable tools for the implementation of Safety in Design. The road to Best Practices in Safety in Design is a long and bumpy one. It was Confucius who once said, “A journey of a thousand miles begins with a single step.”

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