Investigation of the Viability of Designing for Safety

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Construction workers historically have experienced more deaths from injuries and more injuries and illnesses requiring time off than workers in any other industry. (The *rate* of fatal injuries is higher in agriculture, mining, and transportation.) In recent years the construction industry has taken many steps to ensure safe working conditions and enable safe work practices, yet construction work remains a hazardous occupation. Addressing safety in the *project design*, before construction begins, has been proposed as an additional method for improving construction worker safety and health.

However, consideration of worker safety is not traditionally part of the project designer’s role. This study investigated the viability of addressing construction worker safety and health in the project’s design, known as “designing for safety.” Research activities included a review of the literature on designing for safety, an examination of the federal Occupational Safety and Health Administration (OSHA) construction standards containing references to design professionals, and a pilot survey of architects and engineers employed as construction design professionals.

Background

U.S. Bureau of Labor Statistics data show that, in 2003, construction workers were about 7% of the nation's workforce but suffered nearly 1,166 deaths from work-related injuries, just under 21% of the total. That same year, 155,400 injuries and illnesses requiring days away from work ergonomic and head-knocker risks (Hecker, Gambatese, and Weinstein 2004). However, addressing worker safety is not traditionally part of the design professional's role, and formal implementation of the concept is not part of standard design practice. Additional investigation and development of the concept are needed to fully realize the benefits of designing for safety.

Study Objectives and Research Methods

The goal of this study was to determine the viability of designing for safety as an intervention for improving construction worker safety and health. The researchers considered viability to be related to the practicality of implementation, given the nature of design practices and the delivery of construction projects. The project sought to assess design professionals' knowledge and acceptance of the design-for-safety concept, and to identify the potential effects of designing for safety on construction project characteristics, such as costs, productivity, and quality. As a small, pilot-level effort, the study was intended to be the starting point for a more comprehensive research project. Three primary activities were undertaken: a literature review, a review of OSHA construction standards containing references to design professionals, and a pilot survey of design professionals. These activities are described below.

Literature review

A literature review identified previous research on a variety of topics related to designing for safety, including its significance to worker safety and health, as well as descriptions of safety-in-design programs, processes, and tools. The findings were used to develop the survey questionnaire and to provide background material for evaluating the survey results.

OSHA standards review

An examination of OSHA construction standards (29 CFR 1926, *Safety and Health Regulations for Construction*, online at www.osha.gov) aimed at identifying provisions for the following:

- The services of a licensed professional engineer or designer that are specifically mandated
- Professional engineer or designer input that is recommended but not mandated
- Design modifications that would mitigate a hazard and thereby eliminate the need for additional on-site safety measures.

The authors conducted a text-based electronic search of OSHA construction standards to identify provisions containing references to "design professional," "engineer," and "designer." Another review sought to identify OSHA provisions for which the required temporary, on-site safety measures could be omitted if a design modification were made, even without specific reference to a design professional. For this effort, the authors evaluated the database of suggested design modifications developed by Gambatese, Hinze, temporary safety measure, or to minimize the instances in which the safety measure was required.

Survey of design professionals

The authors surveyed construction design professionals to determine the extent of their knowledge of construction safety, as well as their capabilities in designing for safety and their willingness to implement the concept. The survey sought also to determine designers' perceptions about the feasibility of specific design modifications intended to improve construction worker safety.

The number and type of design firms employed on a project depend on many factors, including the size, complexity, and nature of the project; the intentions and capabilities of the owner; and the availability and cost of design services. One or more firms may be hired to develop a design, each working on the portion related to a particular specialty. Firms may concentrate on a design discipline (design only), or they

Literature Review

Approaches to designing for safety

Eliminating the hazard is widely recognized as a far more effective way to improve safety than reducing the hazard or providing personal protective equipment to workers. For instance, Manuele (1997) lists approaches to safety in the following order of decreasing priority and effectiveness:

1. Design to eliminate or avoid the hazard.
2. Design to reduce the hazard.
3. Incorporate safety devices after the fact.
4. Provide warning devices.
5. Institute training and operating procedures.

Andres (2002) developed a similar “safety hierarchy,” presented in order of decreasing effectiveness as follows:

1. Eliminate the hazard.
2. Provide engineering controls.
3. Warn.
4. Train.
5. Provide personal protective equipment.

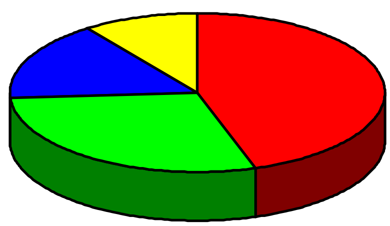
There is a prevailing belief that the construction industry’s safety problems have been around for too long (Korman 2001). Korman reported on breakthrough approaches to safety that are needed to break the cycle and reduce the number of construction injuries and fatalities. One of the ideas described in Korman’s report is to require and motivate architects and engineers to become involved in worker safety considerations so that safety can be designed into the project.

Implementing the design-for-safety concept

Design firms do not commonly address construction worker safety in their design, according to a 1992 survey (Hinze and Wiegand 1992). Less than one-third of the 23 surveyed design firms addressed safety, and less than one-half of the independent constructability reviews included a review of construction worker safety. ("Constructability" reflects the ease and efficiency with which a project can be built. Constructability is in part a reflection of the quality of the design documents; that is, if the design documents are difficult to understand and interpret, the project will be difficult to build.) The study also found that design-build firms more often addressed safety in project designs than design-only firms.

Two construction marketing studies also found that most designers do not address construction worker safety (Hinze 1994a, 1994b). The studies surveyed 377 project owners in the United States. Although these studies had several different areas of focus, the owners were asked if the designers of their projects addressed construction worker safety in their designs. The studies were similar in their finding that many designers did not address construction worker safety (*see* figure 1). Only 16% of the owners surveyed indicated that they considered worker safety in their designs.

Figure 1. Distribution of designer activity in addressing safety (Hinze 1994a, 1994b)



An abbreviated search of the LexisNexis legal database (keywords “architect,” “construction,” and “safety”) identified one court case addressing a construction design professional’s legal responsibilities concerning worker safety. In that 30-year-old case, the architect was found responsible for the deaths of two construction workers who were killed by hydrogen sulfide gas during the construction of a sludge pit (*Evans v. Howard R. Green Co.,* Iowa Supreme Court, 231 N.W. 2d 907, 1975). It was established that the architect knew of the potential for hydrogen sulfide gas accumulation in the pit, because his design included a plan for dissipating the gas to ensure the safety of the facility’s final occupant. The Iowa Supreme Court found:

- An architect cannot ignore a duty to the general public for harm resulting from negligence in furnishing plans and specifications that result in damage during the work itself.
- An architect may be held liable for negligence for failing to exercise the ordinary skill of the profession, where such negligence results in the erection of an unsafe structure whereby anyone lawfully on the premises is injured (including construction workers).
- An architect’s liability for negligence resulting in personal injury or death may be based on his supervisory activities or defects in the plans.
- The liability of an architect is not limited to the owner who employed him. Architects can be sued by “third parties,” that is, parties with whom they do not have a formal contract.
- The claim brought against the architect in the Iowa case was that of a negligent design only.

An in-depth search of legal cases found that recent court decisions recognize a role for designers in ensuring construction workers’ safety (Behm 2004). These legal findings, when considered in combination with the codes of ethics of professional design organizations, can help motivate design professionals to embrace the concept of designing for construction worker safety.

Legislative actions addressing design for safety

Legislative efforts to give design professionals more responsibility for construction worker safety date back at least to the late 1980s, following the collapse of the L’Ambiance Plaza in

Table 3. Design experience of survey participants (in years)

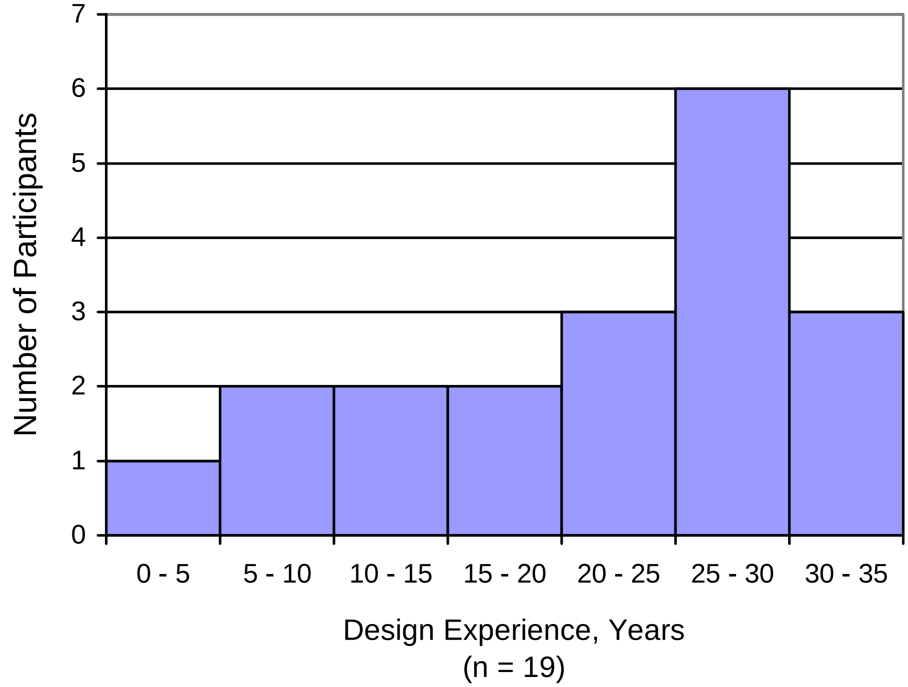


Table 4. Construction experience of survey participants (in years)

Total annual design fee revenue per firm ranged from $75,000 to $500 million, averaging about $155 million per year, according to information pr from the two sources were roughly equivalent. The size range reported by these firms is representative of the industry overall. However, this survey does not claim to be an accurate statistical sampling of the industry.

Knowledge of designing for safety

General knowledge of the design-for-safety concept was evaluated using the responses to questions 10, 20, and 25 (*see* questionnaire in annex A). At the beginning of the interviews, the respondents were asked to describe their understanding of the design-for-safety concept. Three of the 19 respondents referred to American Institute of Architects contract documents, which state that safety is the contractor's responsibility. Only one respondent showed an in-depth knowledge of the concept, mentioning topics such as Life Cycle Safety and communication of hazards to constructors, and stating that designing for safety is more than just designing to code requirements. (This participant personally participated in the development and implementation of the Life Cycle Safety process on a project and has spoken on the topic at construction industry conferences.) Four of the 19 respondents indicated that they had heard of the United Kingdom's CDM regulations. Two respondents reported taking coursework that included material on construction worker safety, but not specifically designing for safety.

Implementation of design-for-safety concept

Table 5 summarizes the responses to a variety of questions about designing for safety. Two respondents said they had attended constructor safety meetings, and two mentioned discussing safety as part of constructability reviews. (Constructability reviews implicitly address safety when taking into account the ease and efficiency3 Tc0.0016 byf thea19.42182.3730.0012 Tc0.0483 Tw60(titu) stated that the client (project owner) provided a safety checklist for use in the design phase. One participant, a structural engineer, pointed out that a revision to the American Institute of Steel Construction's *Manual of Steel Construction* recommends a specific design for steel connections to protect construction workers installing structural steel beams.

Design-for-safety modifications

Nine of the 19 respondents reported making at least one design modification with the intention of reducing safety and health risks to construction workers (questions 16 and 19). One participant cited the use of less hazardous chemicals to comply with green building design certifications. Designing pre-fabricated project components and built-in tie-off points for construction workers were also offered as examples of design-for-safety modifications.

Impacts of designing for safety

Several survey questions sought to obtain participants' views about the possible impacts of designing for safety (questions 15, 24, and 32). ("Impact" was defined broadly to apply to any aspect of a project, the design process, or the construction industry overall, including safety and other project characteristics.) Fourteen participants stated that designing for safety would result in increased project costs, and nine stated that it would lead to schedule delays and lowered productivity (table 6). The impact on construction worker safety was not mentioned, presumably because this outcome was implicit in the survey. Alternatively, failing to mention construction worker safety may reflect the prevailing work priorities for designers.

Table 6. Impacts of designing for safety (n = 19)

Impact

Two survey questions (37 and 39) were intended to assess the designers' general interest in and ease with the topic of construction worker safety. Eight of the 19 participants stated that they had been asked to give their opinion about safety (question 37). Most reported that they provided general suggestions while on site and during safety meetings. One respondent stated that, while on a project in Southeast Asia, he felt compelled to speak up about safety because of the extremely dangerous conditions he observed. All but one of the 19 respondents indicated that they felt comfortable talking about construction worker safety and health issues (question 39).

Feasibility of design-for-safety modifications

Table 10 below presents the participants' comments on the feasibility of implementing various design-for-safety modifications (*see* questionnaire in annex A). The proposal for a minimum window sill height of 42 inches to serve as guardrails during construction drew the largest number of objections. Nine respondents opposed the measure and three others felt it was feasible but would have to be requested by the owner.

Table 10. Responses to proposed design-for-safety modifications

Proposed design modification	Responses/comments
existing underground utilities and mark a clear zone around the utilities. No-0sia,tae drawings the source of information and level of certainty on the location of underground utilities.	• Already complete this to some extent (10 respondents) • Most do not mark a clear zone or provide a level of certainty for the location of underground utilities • No- part of an architect's work; should be completed in the field (4 respondents)
protection and eliminate the need to construct a maintenance.	• Modification woul by hiding rooftop r respondents) • Would diminish ae

Table 10. Responses to proposed design-for-safety modifications (continued)

Proposed design modification	Responses/comments
Design perimeter beams and beams above floor openings to support lifelines (minimum dead load of 5400 lbs.). Design connection points along the beams for the lifelines. Note on the contract drawings which beams are designed to support lifelines, how many lifelines, and at what locations along the beams.	• Modification is possible (4 respondents); not possible (4 respondents) • Would increase cost (6 respondents); extra time in the design phase (2 respondents) • Not feasible without constructor input (1 respondent)
Provide permanent guardrails around skylights.	• Feasible modification (5 respondents) • Would not implement or is not feasible (7 respondents) • Would increase costs (6 respondents)

Analysis and Discussion

The goal of this pilot study was to determine the viability of implementing the designing-for-safety concept as an intervention for improving construction worker safety and health. The concept is considered viable if it is feasible to implement and effective in producing desired outcomes (*see* table 11). If the concept is, for instance, relatively easy to implement, requires minimal additional resources, and complements other project goals, designers are more likely to implement it.

Table 11. Factors affecting implementation of designing for safety

Note: This table was developed by the authors and is based on their research and experience.

Designer knowledge and acceptance of design-for-safety concept

The researchers used the survey results to assess designer knowledge and acceptance of the

and insurance experts to assist in developing contracts and insurance policies that protect designers from excessive legal liability for incorporating safety features in their designs.

Recommendations

This research indicates that designing for safety is beginning to be recognized as a viable intervention for improving construction worker safety and health. However, the practice is still in its infancy and additional research is needed to demonstrate its effectiveness and to gain widespread acceptance among design professionals. Further study is needed in the following areas:

- *Effectiveness of designing for safety*. Demonstrable evidence will accumulate as more design professionals address worker safety in their projects.
- *Dangers of not designing for safety*. Case studies of the negative consequences of ignoring worker safety in building designs can help motivate designers to apply the concept in their building projects.
- *Benefits of design modifications.* Cost-benefit modeling can be used to create a database of cost-effective design modifications.
- *Tools and processes.* Design review and assessment tools are needed to assist designers in addressing safety. Research is needed on project delivery methods, design and construction contracts, and errors and omissions insurance.
- *Incorporation of the concept.* Research is needed on how the concept might be incorporated into building codes and standards, sustainability models, and the OSHA construction standards (29 CFR 1926).
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Annex A. Survey Cover Letter and Questionnaire

Civil, Construction and Environmental Engineering

Oregon State University
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Telephone: 541-737-4934 Fax: 541-737-3052

Dear Design Professional:

Oregon State University is conducting a research study of the feasibility of design professionals to address construction site safety through a project's design. The study is titled "Investigation of the Viability of Designing for Safety", and is sponsored by The Center to Protect Workers' Rights (CPWR Small Study No. 01-2-PS). The study involves: an examination of the OSHA standards for construction to determine the provisions that lend themselves to designer input; the development of design details that would capitalize on the identified provisions; and a survey of design professionals to obtain information regarding the barriers and limitations to incorporating safety in the design and the estimated impacts of designing for safety on a project. The outcomes of the study include recommendations for addressing safety in design practice and for further, expanded research on the topic.

As a design professional in the construction industry, we ask for your help with the study by answering some questions about safety in design practices. The interview should take no more than 45 minutes to one hour. To facilitate the interview, we have developed the attached list of questions which relate to your background and experience, current design practices, and design suggestions for improving safety. Your participation in this study is voluntary. Any questions

You are welcome to keep a copy of this letter and the questions for your r

Questionnaire

SECTION 1: GENERAL INFORMATION

1. What is your title/position? ____________________________

2. What is your typical role on a project team?

3. How many years of experience do you have as a design professional: _____

4. What kind of experience do you have that is related to construction?

5. How many years of experience do you have in construction: _____

6. Design firm discipline: (check all that apply)
   ___Architectural ___Structural ___Civil ___Elect. ___Mech. ___Other

7.

35. Have you ever been asked to address construction wo

11. Provide a guardrail along the perimeter of the tank roof.

A – 4: Skylights

12. Provide permanent guardrails around skylights.

13. Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires.

A – 5: Ladders/Stairways

14. Use consistent tread and riser dimensions throughout the stairway run and the project.

15. Provide access by means of a ladder or stairway when there is a change in elevation of greater than 19 inches.

A – 6: Other Safety and Health Considerations

16. Provide emergency showers and eyewash basins in areas where personnel might come in contact with highly toxic or poisonous materials.

17. Provide adequate illumination on projects to allow for work at night.

18. Allow for a large, unobstructed, open area (limited access zone) below elevated masonry work to minimize the risk of workers being struck by falling objects.

19. Require concrete test results to be verified before removal of the forms and shoring.

20. Require regularly scheduled site housekeeping to ensure a neat, clean work area.

Annex B. Construction (Design and Management) Regulation No. 13 (United Kingdom)

Annex C. Results of OSHA Construction Standards Review[1]

Section 1: OSHA Provisions Addressing Design Professionals

This section lists OSHA construction standards (29 CFR 1926)

Subpart R – Steel Erection

1926.751 – Definitions
1926.755(b)(1)
1926.756(a)(1)
1926.756(b)
1926.757(a)(7)
Appendix A – Guidelines for Establishing the Components of a Site-Specific Erection Plan – Non-Mandatory Guidelines for Complying with 1926.752(e)

Section 2: Suggested Design-for-Safety Modifications and Corresponding OSHA Provisions

Subpart L – Scaffolds

OSHA Provision	Design Suggestion
1926.451(e)(5)	Use a maximum ramp slope of 7 degrees.

Subpart M – Fall Protection

OSHA Provision	Design Suggestion
1926.501	Design window sills to be 42 inches minimum above the floor level. Window sills

OSHA Provision	Design Suggestion
	resistant material, or treated to minimize slipping.
1926.1053(a)(12)	Specify that wood ladders NOT be coated with an opaque material.
1926.1053(a)(20(i)	Design horizontal bands to be fastened

OSHA Provision	Design Suggestion
	to be between 7 and 8 feet.
1926.1053(a)(21)	Keep the inside of the well clear of projections.

Subpart Z – Toxic and Hazardous Substances

OSHA Provision	Design Suggestion
1926.1101	Specify materials that do not contain asbestos or other known hazardous substances.