

Increasing Engineers' Role in Construction Safety: Opportunities and Barriers

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Abstract

A number of factors suggest engineering and Construction professionals should discuss increasing designer's role in construction safety. Design civil engineer could contribute to construction worker safety by performing five tasks differently than current custom and practice: reviewing their designs, creating design documents, assisting the owner in procuring construction, reviewing submittals, and inspecting work in progress. However, four sets of major barriers would prevent designers from increasing worker safety through these tasks: lack of safety expertise, lack of understanding of construction processes, typical contract terms, and professional fees. Potential ways for reducing these barriers are suggested. Some regulation like The United Kingdom regulations requiring engineers to design for safety are summarized, but it is concluded that similar legislation in the United States would not be appropriate.

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Introduction

There are several indications that design engineers' involvement in construction safety warrants continued critical examination by engineering and construction practitioners and academic researcher. Design engineers have been cited by OSHA or sued in civil court for construction worker safety issues (Smith 1998). Respected academic researcher have contributed a number of journal articles on the topic over the past dozen years (Hinze, Wiegand, Hadikusmo and Rowlinson). Legislation implemented in the United Kingdom in 1995 explicitly requires designers to design for worker safety (Her Majesty). At a recent symposium entitled *Designing for Safety and Health in Construction* nearly 100 industry professionals discussed how to increase designing role for construction safety. The current ASCE policy statement on site safety States:

"Engineers have responsibility for: Recognizing that safety and constructability are important considerations when preparing construction plans and specifications".....

ASCE's Construction Institute and OSHA signed a formal alliance that included the following text:

"OSHA and CI therefore agree to form an Alliance to use their collective expertise and share information and technical knowledge to promote safe and healthful working conditions for construction employees. Through this Alliance, OSHA and CI will work together to encourage employers to increase employee access to safety and health information and training resources, especially in the area of crane safety, and to incorporate safety and health issues into the construction/constructability process".

It is clear from the above-listed safety-related events that design engineers' role in construction site safety is changing, but the direction of the change is not clear. It seems that design engineers stand at a crossroad with regard to their construction safety role. One way represents the status quo in which—for legitimate reasons discussed later in this paper—design engineers appear to follow a "Don't ask, don't tell" policy regarding safety. By pointing at the OSHA standards, which clearly ascribe primary safety responsibility for construction workers to their employers (Toole and Gambatese), and to the American Institute of Architects (AIA) and the Engineers Joint Construction Documents Committee (EJCDC) model contracts, which clearly state designers have no site safety responsibilities (Toole), design engineers can easily justify their continued non-involvement in site safety.

The other road facing design engineers is to adopt a larger role in site safety. They could embrace rather than ignore the ASCE Site Safety Policy 350 and ASCE/OSHA Alliance (both excerpted above) and interpret the following text from the ASCE Code of Ethics to include the safety of construction workers:

Canon 1. Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.

Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions and practices incorporated into structures, machines, products, processes and devices.

Should individual design engineers or the industry as a whole decide to follow the latter road—that is, a more active role in site safety, what specific changes in design-related tasks would be involved Several authors have discussed tools to help designers identify design decisions that can substantially improve construction safety without compromising architectural form or function (Gambatese). But designer engineers are typically involved in all stages of engineering and construction projects, not just during design.no authors have addressed how designers could play a larger role in site safety in designer tasks other than the design stage.

This paper is relevant to practitioners because it provides practical insights into the opportunities and barriers facing design and design-build engineers who wish to increase their role in site safety. The paper first identifies five tasks currently performed by designers in which they could contribute to increasing worker safety. The paper then discusses the real and substantial barriers relating to custom and practice that would prevent designers from contributing to worker safety by changing how they perform the five tasks. Finally, the paper discusses how the barriers could be eliminated or navigated around over the long term.

This paper is relevant to non-design construction professionals (contractors, subcontractors, etc.) because they will almost certainly be affected by any change in the safety role of design engineers. Construction professionals currently interact with design engineers through the request for information (RFI) and submittals processes, and occasional site visits. These interactions could be affected if design engineers increase their role in safety. Moreover, the growth of design-build has made it more likely that construction personnel will eventually have a design engineer as a design-build partner. It is important that construction personnel understand the safety role that a design engineer partner might consider playing and the factors influencing how effective they could be in that role .

It is important to note that this paper discusses the expansion of design engineers' safety role should individual engineers or the industry as a whole choose to expand their current role. This paper focuses on the potentially “could” not on the “should” or “shall” aspects of construction site safety.

How Could Designers Increase Their Role in Worker Safety?

To examine how designers could increase their role in worker safety, it is appropriate to examine how designers might increase worker safety in several of the major tasks they perform. Based on the background of industry experience in engineering and construction, this section describes the tasks in

which designers could potentially increase their safety roles and identifies relevant requirements facing design engineers. The discussion of each task is brief because the ideas presented are relatively simple and straightforward. The potential barriers to increasing designers' safety roles in these tasks are discussed in a later section of the paper.

Review for safety

The design process involves applying engineering and architectural principles to design a physical facility. Designers typically perform this process keeping key design criteria, such as cost and functionality, in mind as they make detailed design decisions. The work product of this design process (i.e., the construction documents) are plans (or blueprints or drawings) and technical specifications, which contractors use to erect the design. After the design is complete, some sort of peer review is typically performed to ensure the design reflects the proper application of engineering principles and that goals for cost and quality are met. It is need to (author's perception) that construction worker safety is rarely considered during the detailed design or the peer review process for design-bid-build projects.

One way designers could increase safety would be to have the peer review of the completed design include ensuring the design provides an acceptable level of worker safety. That is, the review could ensure the design is not inherently more dangerous to build than necessary. Safety would thus join cost, functionality, and Constructability as key design criteria that are part of the peer review process. (Some industry professionals assume the term "constructability" includes construction safety. The term is used here to refer to construction documents that do not conflict with one another or require materials or methods that are not cost effective.) This review could be accomplished either by qualified professionals within the firm or by an outside consultant. This would seem to be in accordance with the previously quoted excerpt from ASCE policy statement 350 that site safety should be considered when preparing construction plans and specifications.

The plans and specifications reviewed during the peer review process would be no different from typical construction documents; however, the final design may be improved over a design produced through a process that did not address worker safety. For example, the risks of fall injuries could be reduced by limiting roof pitches to a reasonable level or by ensuring that the bottom of window openings are at least 42in. above the floor, eliminating the need for temporary guardrails during construction (Gambatese). Of course, design changes identified during peer review of construction documents may be costly or annoying to implement due to their being identified in such a late stage of the design process. There is also the risk that the suggested changes conflict with the aesthetics, functionality and/or budget desired by the client. Notwithstanding the previous risks, peer review for safety has the potential to

contribute meaningfully to worker safety without significantly increasing the design budget or duration. The U.K. CDM regulations require that designers ensure that the safety of not only construction workers but also future maintenance and repair workers is considered in their design process. Specifically, designers shall:

“Ensure that any design ... includes among the design considerations adequate regard to the need, to avoid foreseeable risks to the health and safety of any person at work carrying out construction work.....”[Part 13, paragraph 1in her Majesty]

Create design documents for safety

Rather than explicitly considering worker safety only during the peer review process, as suggested earlier, worker safety could be considered throughout the design process. Thus, decisions about roof pitches and wall opening heights and steel column splice heights, for example, would be made earlier in the design process, when it is easiest to modify the design to maximize worker safety. Also, rather than having typical plans and technical specifications, the construction documents would include special details and technical specifications that would facilitate worker safety. For example, technical specifications could reference or include the actual text from OSHA and ANSI safety standards.

Fig. 1. Modified from Szymberski

Drawings could include locations on the structural framing that would provide sufficient strength to serve as tie offs for fall protection. Drawings related to trenching operations could indicate benching or sloping requirements based on the excavation depth required for foundations or site utilities and the designer’s knowledge of site soil conditions.

Designer-generated documents could also include erection sequencing sketches for large prefabricated concrete or steel components. These examples illustrate how designers could enhance worker safety by applying their specialized technical knowledge and skills and/or by using information technology to improve the construction documents. Designers could therefore increase worker safety by supplementing, not replacing, contractors’ knowledge of means and methods.

Gambatese and others have discussed how the ease and effectiveness of designing for safety depends heavily on the stage of design in which designing for safety is first considered. As shown in Fig. 1, the ability to affect worker safety exponentially decreases over the design process.

The U.K. CDM regulations include regulations relevant to this task. As mentioned under the first task, review for safety, the CDM requires that designers give adequate consideration to safety of construction and maintenance workers. A clarifying publication by the United Kingdom’s equivalent to OSHA (HSE 2002) suggests that designers take the following specific steps:

“Identify the significant health and safety hazards likely to be associated with the design and how it may be constructed and maintained; consider the risk from the hazards which arise as a result of the design being incorporated into the project; if possible, alter the design to avoid the risk, or where this is not reasonably practical, reduce it”.

The requirement to reduce unavoidable risks includes “combating risks at the source “by ensuring” that the design includes adequate information about any aspect of the project or structure or materials (including articles and substances) which might affect the health and safety of any person at work carrying out construction work”[Paragraph 13(1) (b) in her Majesty] HSE (2002) further states that designers must ensure construction documents adequately communicate the designer’s suggestions for dealing with specific risks, such as ensuring “the design details of items to be lifted include attachment points for lifting”.

Procure for safety

Designers frequently assist the owner in soliciting and reviewing bids from contractors. Specifically, designers often create not only technical drawings and specifications, but also requests for proposals (RFPs) or bids from contractors. Such RFPs often require bidders to provide evidence of their ability to complete the project they are bidding on, such as information about the scope, quality, cost, and timeliness of past projects, along with their bid price and completion time (Russell). Designers often review this information and recommend to the owner which bidder should be awarded the contract typically the lowest “responsive bidder”.

As suggested in the ASCE Site Safety policy statement and as occasionally occurs in industry, designers could recommend that safety be one of the criteria for selecting the winning bidder. RFPs could require bidders to submit information about their safety program and safety performance data (e.g., OSHA 300 accident logs or experience modification factors associated with workers compensation insurance) with their bids (Jaselskis) Designers could include satisfactory recent safety performance as one of the requirements to be considered a responsive bidder.

The U.K.’s CDM requirements address designers’ involvement in procurement Designers are explicitly required to inform owner clients of the clients’ duties regarding safety and health on the project, which includes ensuring that the contractor chosen to perform the construction is competent in safety. It should also be mentioned the CDM requires several relevant actions by a new entity created by the CDM, the Planning Supervisor, which seems to be similar to a Program Manager on large projects, the Planning Supervisor role is performed mostly by firms who specialize as planning supervisors, quantity surveyors, or by designers. The CDM requires that planning supervisors ensure a preliminary project health and

safety plan is created for the project before it goes out to bid. This pre-tender health and safety plan provides bidders with safety information required to adequately prepare a bid that reflects safe construction methods, as well as allows the owner client to better evaluate the safety competence of each bidder.

Review submittals for safety

Nearly all contracts between owners and designers require the latter to review design-related documents submitted by the contractor, referred to as submittals. Submittals typically include shop drawings that indicate the specific materials, layout and, occasionally, procedures the contractor and/or subcontractors intend to use. Designers review these documents to ensure the intended functionality and quality of the design will be achieved by the contractor. Because submittals provide information about the inherent risk of the construction process to workers, designers could review submittals to increase the chances that the intended safety goals of the project would be met, particularly for items that involve the application of engineering principles. Notwithstanding the barriers discussed in the following section, it should be noted that contractors would need to start including safety-related information in submittals and designers would need to review contractors' safety plan for this task to be implemented.

The CDM does not address designers reviewing submittals; however, planning supervisors (a role often filled by design engineers) are required to advise owner clients on the adequacy of chosen contractors' safety and health plan if requested by the owner client.

Inspect site operations for safety

Many contracts between owners and designers require the designer to periodically inspect the construction site to ensure the work in progress complies with the plans and technical specifications. Designers could theoretically also monitor the site for compliance with the safety requirements indicated in the contract documents

(Plans, technical specifications, and general conditions), submittals, owner standards, and/or OSHA standards. Designers could thus not only be an extra set of eyes for spotting potential hazards to workers, they could use their expertise to spot hazards associated with the improper application of engineering principles, such as with retaining walls, false work, and scaffolding systems. It is relevant to note that 30% of the 75 U.S. design engineering firms surveyed in 2002 reported that employees in their firms sometimes or often failed to report hazards that they observed on construction sites (Toole and Marquis).

One of the benefits of having designers involved in site safety issues when they are on site is that they could increase compliance with portions of the OSHA construction standards (Title 29, volume 1926 of the Code of Federal Regulations). Specifically, OSHA standards include several instances where the services

of a professional engineer are required for the analysis and design of temporary construction structures such as scaffolding, shoring, and earth-retaining structures (Toole and Gambatese). Although the standards do not indicate whether these services are retained by the owner or contractor, it is the author's perception that these services are either provided by professional engineers retained or employed by the contractor or by contractor employees who are not professional engineers. Having designers more involved in site safety issues could facilitate their involvement in engineering temporary construction structures, which would likely increase the factor of safety of these structures.

The U.K. CDM regulations do not address site inspections by designers or planning supervisors.

What Would Have to Change?

The previous section identified five tasks that designers routinely perform and suggested ways, by modifying how they perform the tasks, they could increase worker safety. Each of the suggestions in the entire previous section should have been prefaced with a prominent "theoretically" or "potentially" because there are substantial barriers to designers effectively executing what would be needed to increase worker safety. Several of these barriers were discussed briefly in Toole. This section of the paper discusses these barriers in detail and how they might be reduced.

Lack of Safety Expertise

If engineers are to effectively contribute to worker safety in any of the five tasks proposed in the previous section, it is essential that they possess at least a limited degree of expertise in construction safety. That is, they must be reasonably familiar with the OSHA standards, how they are enforced by OSHA, how companies manage safety on jobsites, and how workers are encouraged to—or choose to—take safety shortcuts. It is the perception of the author that the vast majority of design professionals have had limited or no academic exposure to safety management. This perception is supported by Gambatese, who found that out of 36 civil engineering departments who participated in a survey, none offered a course strictly on construction safety.

Without an understanding of safety standards and management, it would be difficult for designers to contribute to worker safety through any of the five tasks discussed earlier. For example, designers could not tailor their designs to reduce fall protection hazards if they do not know OSHA's fall protection standards or how contractors implement fall protection plans. The one safety-enhancing task that designers could potentially perform without knowledge of safety management is procuring for safety. While they would not be competent at reviewing bidders' safety plans and programs, the experience modification factors and OSHA 300 accident log are relatively objective criteria that could be included in the designers' recommendations for contract award.

Reducing the barrier posed by designers' lack of safety expertise could be accomplished through several actions that would vary considerably in the time needed to implement and the numbers of organizations needed to be involved. One potential solution would be to use outside safety experts during each of the five tasks. For example, experienced contractors and construction managers could review designs or accompany design engineers on site visits, helping to train designers while also ensuring appropriate safety expertise was present during the performance of the task. Participation in design-build projects could provide similar benefits to engineers and eliminate the need to hire an outside contractor.

A second potential solution would be to provide designers with formal training on the OSHA standards. Identifying a minimum number of hours of training needed would be difficult.

Requiring at least a 10-h OSHA class would be a good place to start. The training required for a trainee to receive a 10-h card issued by OSHA includes both technical standards for common topics—such as ladders, fall protection and electrical safety—as well as organizational components of safety management. Such a course would not only allow designers to better consider safety during their design, but also allow the managers of design firms to better manage the safety of their own employees when they visit construction sites.

When and how could designers receive such safety training?

The simplest solution might be to include it in the undergraduate engineering curriculum. The minimum content of undergraduate programs in engineering is established by the Accreditation Board for Engineering and Technology (ABET). ABET dictates, for example, that all engineering degree programs must demonstrate their graduates meet 11 specific outcomes, such as “an ability to apply knowledge of mathematics, science and engineering” as well as additional outcomes established by the discipline's lead professional society (ABET 2001). ASCE is the lead society for both civil engineering programs and for construction engineering programs. It is interesting to note that ASCE's required program criteria explicitly includes the term “safety” for construction engineering programs but not for civil engineering programs (Gambatese).

Lack of Understanding of the Construction Process

Being capable of contributing to worker safety through any of the five tasks proposed earlier would require more than knowledge of safety standards and the elements of a safety program. Designers would also require knowledge of how individual construction tasks are performed, the sequencing between the tasks, and how different trades and companies coordinate their work.

Reducing this barrier would be difficult because it apparently would require engineering students be actively engaged on a construction site for an extended period of time. Significant changes in the undergraduate curriculum would be required, such as requiring a summer or semester .

Cooperative experience or a substantial service learning project on a construction site.

Requiring practicing designers to acquire the needed deep understanding of construction processes seems so infeasible that it will not be discussed here.

It should be mentioned that designers' lack of safety expertise and process understanding could be ameliorated by design for safety tools proposed by several authors (Gambatese). Such tools, which include computer based databases, checklists, and graphics, could help them identify design decisions that have the highest potential for affecting workers safety, guide them toward decisions that result in an acceptable level of worker safety, and suggest details or other documents to include in the construction documents to maximize worker safety. Even if powerful design for safety software tools are developed, it is likely that designers would need to receive training on the philosophy and techniques for designing for safety, as well as detailed instruction on how to use any software tools developed.

Contract Terms and Scopes of Work

The two sets of needed changes discussed above relate to knowledge and tools that designers would need to increase their role in worker safety but currently typically lack. A third set of needed changes involves industry custom and practice. Even if designers were capable of assuming the safety-related actions discussed in the previous section of the paper, custom and practice would prevent most designers from assuming a larger role in safety. Contractual language typically used in the industry today is both an indication and a distinct component of custom and practice that would prevent designers from performing the five safety-related tasks proposed earlier.

The most common sources of such contractual language are promulgated by the EJCDC and the AIA. The key documents that indicate custom and practice are the model contracts between the owner and the designer—EJCDC E- 500 and AIA B 141 and between the owner and the contractor—EJCDC C- 700 and AIA A201. These documents refer to the activities that design professionals typically perform on a building project and establish limitations for liability. As discussed in the following and in Toole (2002a), portions of these documents are silent on safety responsibility while other paragraphs expressly disclaim designer safety responsibility.

In short, the current model project contracts in Afghanistan do not clearly and explicitly prohibit project designers of record from reviewing construction documents to ensure reasonable worker safety or from creating documents for worker safety as part of their design process. But because such behavior is

not part of the current custom and practice, text explicitly requiring designers to design for worker safety would clearly need to be inserted in the model contracts.

The situation regarding designers procuring for safety is similar to that discussed earlier. The model bid forms promulgated by the EJCDC (C-410, formerly 18-1910) do not explicitly state that contractors shall not be required to submit safety program and performance data. However, because custom and practice are such that contractor safety is typically not given major consideration by designers and owners in awarding contracts, the current model bid documents would need to be revised to require safety data be provided with bids.

It should be noted that performance specifications for concrete formwork and shoring, prefabricated exterior cladding systems, and other construction phases often shift the design responsibility to a professional engineer employed or retained by the contractor to design the system. Such specifications may facilitate designing for safety because the design professional designing for safety is not the design professional of record addressed in the model contract documents.

Liability and Professional Fees

The fear of undeserved liability for worker safety would likely be the chief concern voiced by designers in response to the five safety-related actions proposed earlier in this paper. It is suggested in the following that liability concerns are only one aspect of the fourth barrier preventing designers from contributing to worker safety: cost performing each of the safety-related actions will increase both direct and overhead costs for designers. Direct costs will increase because each task will require more time to accomplish—time that could otherwise be spent on other billable tasks or projects. The number of person-hours required for each task will increase in part because safety will be yet another design or analysis criterion that must be included in the task. Designing, analyzing, and reviewing would thus legitimately take longer to accomplish if safety is considered, even if there were designers with a strong design-for-safety background. What is more problematic is the increase in time resulting not from productive design and analysis, but from excessive review and re-checking by designers who are not familiar with designing for safety and concerned about liability.

Overhead cost-I.e. indirect costs—would increase in two ways. First, designers would have to receive safety training as part of their professional development. Time spent in this additional training would be time that could otherwise be billable. Some firms could elect to add to their payroll a staff employee or design manager with safety expertise whose (non-billable) Responsibilities would include reviewing or training for safety.

Another source of increased overhead costs would be insurance premiums. Courts to date have mostly absolved designers from responsibility for construction worker safety (Smith). But if designers begin explicitly attempting to contribute to worker safety, plaintiff lawyers will undoubtedly claim designers are at least partially responsible for preventing worker injuries, regardless of the circumstances. Insurance carriers providing designers with general liability and errors and omissions insurance will legitimately increase their premiums to cover increased costs associated with defending lawsuits against designers.

The magnitude of direct and indirect cost increases for designers cannot be predicted well at this point, but undoubtedly would vary between the five tasks and between firms. The cost of hiring an outside firm to provide a peer review of a completed design could be quite modest but the costs of making substantial design modifications to increase the inherent safety level of a design could be substantial. The costs of training all of a firm's designers to allow them to effectively design for safety, review submittals for safety, or inspect for safety would likely be significant. The costs for procuring for safety would likely be minor.

As a result of the increased direct and indirect costs associated with designers performing safety-related tasks, designers choosing to design for safety would likely need to substantially increase their professional fees. Such increased fees would clearly make the firms uncompetitive with design firms who continue performing the traditional design process. The future success of firms who choose to design for safety will likely require them to identify owners who are willing to pay a premium for safer designs or owners who award design contracts based on project life cycle costs rather than on merely low design fees.

Conclusions

This paper has suggested designers could increase construction site worker safety by modifying how they perform five tasks from current custom and practice: reviewing their designs for safety, creating safety-related design documents, assisting the owner in procuring safe construction, reviewing submittals for safety, and inspecting the work site for safety. It was stated that such changes from custom and practice represent options for engineers, not professional duties. It was also stated that such changes should supplement, not replace or reduce, the safety expertise and proactive safety management that OSHA requires of construction worker employers.

As an interesting point of comparison, the paper briefly mentioned safety requirements facing design engineers. That were relevant to the five tasks discussed in the paper.

The paper identified four sets of substantial barriers that would prevent designers from contributing to worker safety through the five safety-related tasks suggested in the paper. The barriers included designers' lack of safety expertise, designers' lack of understanding of construction processes, conflicts

with the existing model contract terms, and additional costs incurred by designers. Regarding the latter, it was suggested that firms choosing to design for safety will be noncompetitive on a cost basis unless owners adopt a life-cycle cost perspective or design-build is used.

For those espousing that designers increase their role in construction site safety, this paper has painted a somewhat bleak picture because the barriers to designers contributing to site safety are formidable. It is clear that increasing designers' role in construction safety would require long-term, intentional and focused effort by many different entities:

- Individual public and private owners,
- Individual designers and design firms,
- OSHA,
- Designers' professional organizations, such as ASCE and AIA,
- Universities and the engineering accreditation organization (ABET), and
- State licensing boards.

Designers' lack of safety expertise and lack of a deep understanding of construction processes are the least tangible but most significant of the four barriers because they would require the cooperation of the greatest number of organizations. Due to these two sets of barriers, it would be completely ineffective to enact legislation requiring designers to immediately start performing the five safety-related tasks suggested in this paper .

Although legislation forcing design engineers to explicitly design for construction worker safety would not be appropriate, it is entirely appropriate that the civil engineering and construction industry initiate a meaningful dialogue about designing for construction worker safety. Such dialogue is not only suggested by the ASCE Code of Ethics but likely critical to the long-term health of the civil engineering and construction professions.

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