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Designing for Construction Worker Safety—Recent Activities and Available Resources for Designers

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Introduction

The Design for Safety (DFS) methodology involves eliminating or mitigating hazards by engineering design. Addressing safety early in the design process has the most benefit (Hagan, 2001) as opposed to attempting to manage hazards in service. The benefits include significant reduction in injuries, increased productivity, reduced operating costs, and reduced retrofitting.

The DFS model starts with hazard identification and risk assessment followed by implementing appropriate action(s) to eliminate the hazard or reduce the risk to an acceptable level. The design options from highest to lowest priority include eliminating the hazard(s) by engineering design, incorporating safety device(s), applying warnings, operating procedures/training, and personal protective equipment. DFS applies to the design of facilities, hardware, equipment, tools, job tasks, machines, consumer products, and more.

The application of DFS to construction projects is a relatively new idea. It goes against the "traditional" approach to a construction project where safety is managed after the project is underway, long after the design professional has completed the plans and specifications. The Designing for Construction Safety (DfCS) model extends the designer's role to include construction site safety, constructability, and maintenance in the design phase. DfCS provides new opportunities for designers to apply their skills to positively impact construction safety.

There are a number of resources that available to design professionals. These include a website (www.designforconstructionsafety.org), a 2 to 4 hour course for design professionals, and the Construction Industry Council CDM Guidance for Designers.

Why DfCS is Necessary

The number of construction fatalities is disproportionate to the size of the workforce. Construction makes up only 5.5% of the workforce, but has 21.5% of the fatalities. There are

1226 fatalities each year and 200,000 serious injuries. That's about 100 workers killed every month. For every worker killed there are about 160 workers injured (BLS 2006).

Conventional Approach to Construction Versus DfCS

In general industry, design and fabrication takes place under one "roof". The design engineers, the machine shop, and the assembly workers are all employed by the same entity. The responsibilities are well defined. If the design engineer has a question on how his design will be implemented, he/she can walk downstairs or down the hall and ask the machine shop. Assembly is streamlined. Sequencing problems are worked out ahead of time.

Construction is different. The design professional and fabricator (contractor) are not under the same "roof". They are two separate entities bound by separate contracts. Under the conventional approach to a building project the owner separately contracts with an architect/engineer and with a general contractor, prime contractor, construction manager, program manager, or owner's agent. An owner may choose to contract with a design/build firm to perform both design and construction.

Design professionals prepare plans and specifications that comply with state and local building codes. The plans and specifications are legal documents that communicate the details on how the building should be built to the contractor. The codes contain minimum requirements to protect the public by addressing the safety and integrity of the finished product (the completed building). There are no legal requirements that require the design professional to address the safety of the construction workers. The only code provisions pertaining to construction safety are directed towards protecting pedestrians, adjoining property, and public rights-of-way (IBC, 2003).

Contractors have the task of implementing the design (construction) and maintaining job site safety at the same time. Frequently, this comes down to managing safety in a somewhat haphazard manner. A portion (or all) of the construction work may be subcontracted to specialty trade contractors. The safety responsibilities can become blurred. Some contractors may pass safety responsibilities onto others. Federal OSHA Regulations (29 CFR 1926) control the construction phase of a project with regard to worker safety.

Designers Understanding of the Construction Process

DfCS requires a knowledge of the construction process. This includes an understanding of the hazards involved, how each task is performed, the sequencing between the tasks, and how the work is coordinated. OSHA construction regulations (29 CFR 1926) provide an excellent resource in this regard. OSHA 1926 addresses the basic aspects of construction such as noise exposure, ventilation, fall protection, flammable and combustible liquids, material handling and storage, hand tools, power tools, welding and cutting, electricity, scaffolds, cranes, excavations, concrete and masonry, and steel erection.

For example, 1926.52 governs occupational noise control. Specifying equipment, a compressor for example, that has noise levels less than Table D-2 would be a better choice than that would require a hearing conservation program or personal protective equipment. Fall Protection is addressed in Subpart M. Knowing that guardrails should be at least 39 inches high, a designer might choose to design parapet walls or window sills that meet this height requirement so that fall

protection would not be required. Specifying permanent anchorage points would provide a tie off point. Specifying trenchless technology precludes protective systems that would be required for an open excavation (Subpart P).

Designers Knowledge of Safety

Designers also have to be knowledgeable about safety. In a 2002 survey of 75 U.S. design engineering firms, only 20% of the firms indicated that over 50% of their employees had received safety training. Nearly 70% stated that less then 25% of the employees had received safety training (Toole, 2005).

Engineering is a learned profession. One viewpoint of the engineering profession holds that all Professional Engineers (PE) must be knowledgeable in safety (Haight, et al, 2004). Otherwise, how does a Professional Engineer comply with one of the fundamental canons (NSPE) of the engineering profession? There are a number of professional organizations that provide safety training, information, and professional texts. These organizations include the American Society of Safety Engineers (ASSE), the National Safety Council (NSC), and the Board of Certified Safety Professionals (BCSP).

Design for Construction Safety (DfCS) 2 to 4 Hour Course

The OSHA Alliance has developed the Design for Construction Safety 2 to 4 Hour Course to assist in training design professionals in the DfCS process. The course is free and can be downloaded from the ASSE website (http://www.asse.org/professionalaffairs/docs/2to4hour.pdf). The course can be tailored to suit the needs of the particular organization. The course covers the following:

I.	Introduction	
	A.	Why is DfCS?
	B	Why is it necessary?
	C.	Construction Accident Statistics
	D.	Design does pay off
II.	Safety Engineering	
	A.	Identification and elimination of hazards
	B.	Recognized hazards
	C.	“Hidden” hazards
	D.	Design for Safety process
III.	Potential Area of Concern in Construction	
IV.	The Design for Safety Process	
V.	Case Studies	

Table 1. Design for Construction Safety 2 to 4 Hour Course Outline

The course can be used for “lunchtime” seminars, society meetings, company training, or as an Educational tool for design professionals. ASSE Chapter presidents, for example, could use the course at a monthly meeting.

Construction Industry Council CDM Guidance for Designers

The Construction Industry Council has a number guidelines for designers which can be found on the website www.safetyindesign.org. These guidelines include hazardous materials, asbestos, musculo-skeletal, noise, excavations, erection of structures, steelwork, refurbishment, temporary work equipment, work at height, roofs, spatial designs, suspended access equipment, blockwork, demolition, manual handling, lifting-cranes, interior finishes, demolition, excavations, steelwork, masonry, mechanical services, and electrical services.

Some of the design recommendations are listed in Tables 2 through 5. The reader is encouraged to refer to www.safetyindesign.org for more details and the complete list of design guidelines. For example T 20.008 pertains to work at height. The design guidelines recommend that work at height be avoided. Service runs should be designed so that they can be maintained from the floor above. Column splices should be designed so that they can be done from a finished floor. Anything that can be pre-assembled on the ground reduces or eliminates working at a height.

1. Design service runs so that they can be maintained from floor above
2. Pre-assembly and fitting of trusses
3. Position splices for steel columns so the splices can be done from a finished floor
4. Install stairways early to avoid the need for temporary access
5. Locate service equipment on ground if possible

Table 2. Guidance for Designers T 20.008 Work at Height

1. Check all steel members for erection loads
2. Ensure that all slender members can resists compression imposed by lifting slings
3. Maximize pre-fabrication
4. Ensure the spacing of purlins allows for the largest components to be lowered down through

Table 3. Guidance for Designers T 20.002 Erecting Steelwork

1. Provide anchor points for fall protection 2. Ensure roof structure can handle stacks of materials 3. Position gutters so that cleaning can be done from cherry pickers or from safe access routes 4. Consider parapets

Table 4. Guidance for Designers T 20.009 Roofs

1. Cast in crack inducers rather than saw cutting 2. Cast in anchors rather than site drilling 3. Avoid vibro-compaction of ground 4. Keep site grinding, cutting, etc. to a minimum

Table 5. Guidance for Designers H 20.002 Noise

Examples of DfCS Building Features

Case studies and examples of DfCS building features can be found in the DfCS generic presentation (www.designforconstructionsafety.org), the Design for Construction Safety 2 to 4 Hour Course, and the Design Best Practices (DBP) website, www.dbp.org.uk. The DBP website has over 100 case studies. Pre-fabrication can make a big difference. Anytime a building system can be pre-fabricated means there will be fewer activities performed above the ground, less chance of a fall injury. Exhibit 1 shows pre-fabricated steel stairs. Other pre-fabricated components include walls and bridge segments.

Exhibit 1.This photo shows pre-fabricated stairs. Pre-fabrication of building components reduces the number of work tasks that must be preformed above the ground. Pre-fabricated stairs with railings installed early in a project preclude the need for ladders and temporary guardrails.

Exhibit 2. This photo shows roof anchorage points. By designing fixed , structurally sound anchorage points workers will have convenient to tie off during construction and future maintenance.

Designing and specifying anchorage points make it easier for workers to use fall protection systems. Exhibit 2 shows anchorage points on the roof of a commercial building. Exhibit 3 shows tie offs installed on a residential building. Additional design features include beams above floor openings to support lanyards and lanyard connection points along beams.

Skylights are another example. Designers can design permanent guards around skylights (see Exhibit 4). Other design features for skylights include domed, rather than flat skylights, and, design skylights on a raised curb. These design features will protect construction and future maintenance workers .

Exhibit 3. This photo shows residential roof tie-offs. By designing and installing roof tie-offs roofers have a structurally sound anchor to tie off on when working on a residential roof.

Exhibit 4. Permanent guards over skylights provide protection when working on the roof.

Exhibit 5. This photo shows a pre-fabricated steel structure being lifted into place. By fabricating the structure on the ground less work has to be done at height.

Conclusion

The Design for Construction Safety (DfCS) approach to construction provides a new opportunity for design professionals. DfCS provides an opportunity for design professionals to improve job site safety and reduce construction injuries and fatalities. There are other benefits as well. Contractors will benefit from reduced worker's compensation claims and streamlined construction sequencing. Owners will benefit from reduced life cycle costs.

To be successful, the owner, design professional(s), and contractor(s) need to work together as a team. The owner controls the purse strings of the a project and therefore must budget design time for DfCS. Design professionals must consider worker safety when preparing plans and specifications. Contractors provide appropriate training for their employees and observe safety rules and regulations.

Revisions to the Building Codes to include worker safety are years down the road. Changes to engineering curricula requiring courses in safety may or may not occur, but are also years down the road. Professional liability is another potential barrier that has not been discussed in this article. In the meantime, design professionals can use their training and the knowledge that is available to produce designs that are safe to build.

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