

Prevention through Design (Safety in Design)

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Introduction

In looking at the built environment and the risks encountered by people using these facilities one identifies four (4) general groups. They are the people who work in these facilities, the people who visit these facilities, the people who build these facilities and the people who maintain them. Different codes and standards exist to ensure that people can enter, conduct business, work and exit these facilities safely even in emergency situations. Much of this is governed by the building codes and life safety standards. Design professionals are required to ensure that these standards are utilized in the design of structures, and the plans produced by these professionals are checked by building officials and fire marshals to ensure compliance. These same officials inspect the finished structure to ensure that it was built according to the approved plans.

The safety of workers working in these facilities is governed by the OSHA (1910) safety standards. These general industry standards govern safety in relationship to work hazards and it is the duty of the employers to ensure that the work environment and work practices are according to these standards. The expectation is that these standards will keep workers from harm while they perform their work. The safety of the construction worker is covered by another part of the OSHA (1926) safety standards. These standards are to protect the construction worker from harm while they go about building the facility.

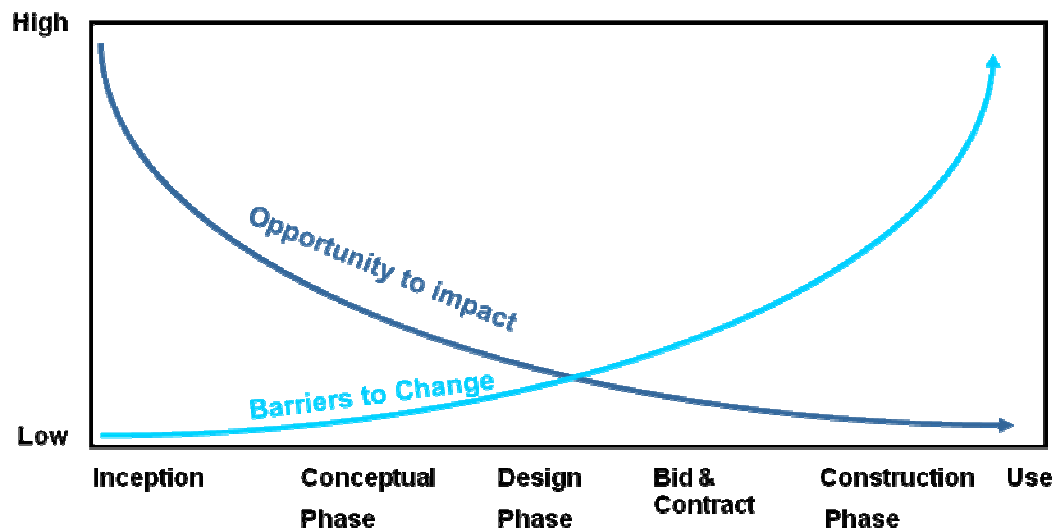
This paper will address the building process, and the risks faced by construction workers engaged in building these facilities. Traditionally the safety of the construction worker is viewed as the responsibility of the employer (the contractor). Research over the past couple of decades has shown that a substantial number of worksite accidents have their root in decisions made before any construction work starts. These studies have focused on the design decisions made during the design process that creates risks the contractors and construction workers have to deal with during the building process. Much of the solutions proposed by these researchers focused on what the design professional could or should do to mitigate these risks.

To properly address this we need to look at the process from inception (the decision by the owner that some sort of facility is needed) through the completion of the construction process. The key participants in this process are the facility owner (owner), the design team (architects and engineers - designers) and the constructor team (contractor, subcontractors and construction managers – where applicable). All the decisions made in this process end up affecting the risks that the construction worker, in some way or another, has to deal with in the building process.

A holistic view of this process (starting with a need for a facility through its final completion) involves decisions made by the owner, the designers and the constructors prior to any work in the field (Furst 2006). These decisions impose risks onto the system, and the greater the universe of risk, the greater the probability of injuries and losses occurring during construction. So it stands to reason, that to provide a “safe work environment” the potential risks to the construction worker have to be identified throughout the system and mitigated.

The owner has the greatest influence on the process because the owner starts it and has a great deal of control over it. So the decisions made at project inception should be carefully assessed for their potential influence on the design and construction process and the resultant risks created. The owner decides what is needed and establishes a budget and time line for it based on financial and business considerations. The owner selects and procures the site. The owner selects the key participants (designers & contractors) in the process. And to some extent the role the owner plays during the development for the design ultimately has an impact on the cumulative project risk faced by the employees of the constructor team.

Influencing Building Risk/Safety (Plan, Design, Build & Use)



The Owner

The project owner initial decisions can influence the quantity and quality of the risks faced by the construction workers. These decisions also quite possibly create barriers to elimination strategies that follow. The type of facility planned, its operational requirements, the site acquired, where it is located, etc. all have associated risks that flow down stream. Then there are the financial and business considerations that may dictate certain project duration and completion requirements that will necessitate accelerated schedules of operational plans by the contractor creating its own body of risks.

The owner also influences the risk picture through the selection of the designer and contractor teams, as well as a well qualified construction savvy safety professional. The services the owner requires from the designers and the contractors as well as all the contract terms impacts the risk picture. The owner's involvement in the process and the extent to which the owner oversees the development of the design and the construction process also has an impact of the end results. The quality of the owner's staff involved in the process plays a role as well. The designers, contractors and safety professionals could play a critical role at the inception of the project by providing the owner with input on the "safety" consequences of decisions and assist in the selection of alternative solutions that may result in lower "system" risks.

The Design Team

Prevention through design from the purely architectural sense is a methodology applied to the various phases of the design process for the identifying and mitigating the risks and hazards that will be encountered by construction workers during the building of the facility. This involves systematically incorporating hazard identification, analysis and mitigation steps during the design phases of construction or renovation of facilities.

The challenge at this juncture is to take a conceptual situation and determine what the physical hazards may be given the design. Here many of the researchers have suggested building parapet walls that are 42" high so as to eliminate the fall exposure for workers working on the roof of facilities. Assuming this does not have an adverse effect on other requirements then it is a good suggestion. But there are other situations where the solution is not as straight forward. Let's consider the building's structural frame. It can either be steel or concrete, each having its own unique hazards and risks. There are some fundamental reasons for selecting one over the other where the fall exposure may not be a deciding factor. Given that one or the other frame will be selected, then the challenge is to come up with a design and operational solution that will reduce the hazard to the workers engaged in the erection of that particular structural frame.

There are other considerations that will make the job safer for workers. The placement of equipment so that the worker may install it while standing on the "ground" rather than an elevated position. Allowance for enough space/room so that workers can make the installation in a safe manner. Creating a design that will lend itself to prefabrication, modularization or "make-ready" to minimize the exposure time. Creating design solutions that are inherently safe to install. Reviewing the constructability of details, all of which will reduce the risks faced by construction workers. Obviously making changes to the design is much less expensive than making them during construction.

The design team will require some education in construction means and methods (Behm 2006) as well as an appreciation for the risks faced by construction workers in the process of building the facility. They will have to gain an understanding of how to use the design tools they have to identify risks and hazards (BIM, etc.). Then with the assistance of contractors and safety consultants identify additional risks and hazards and come up with mitigating solutions that will meet the design requirements and intent as well as create a safer work environment for the construction worker. Designing for safety also encompasses communicating to the contractor the remaining risks & hazards that could not be eliminated during design so that the contractor may plan for appropriate controls or in the selection of means and methods so as to reduce their impact.

Architects, engineers and other consultants are reluctant to address construction worker safety as part of their standard practice (Gambatese 2005). The design professionals' codes of ethics, such as the code established by the American Institute of Architects (2004), as well as others set ethical priorities for ensuring final occupant safety and safety of the finished facility, but do not address the safety of the workers during construction. These professionals are also likely to avoid addressing worker safety out of fear that doing so will open them to legal action by injured construction workers. (Coble 1997). And there generally are no legal, contractual, or regulatory requirements to incorporate safety in design. Should a design professional want to engage in designing for safety they will find it difficult to find insurance coverage for such an activity. Risk transfer products are not readily available in the marketplace.

The Construction Team

There are two major elements to address here. The means and methods selected by the contractor to execute the construction operational plan, and the safety procedures employed to create a "safe" work environment at the project site. An initial operational plan is necessary in order to establish the project bid price. This is when some key decisions are made on how best to meet the contract terms and expectations. These decisions have associated risk and this process requires an assessment of the resultant risks that will later flow to the worksite and affect safety outcomes.

The means and methods selected, usually are based on past operational experience (familiar methods), equipment available or perceived efficient method (least cost/time). So to create an injury free work environment the contractor must use innovative construction management processes in order to minimize risk. Such tools as the last planner, for scheduling and a lean project delivery process all go far in minimizing worksite risks. The contractor's use of these tools will create fewer challenges for the designer in the elimination of risk during design.

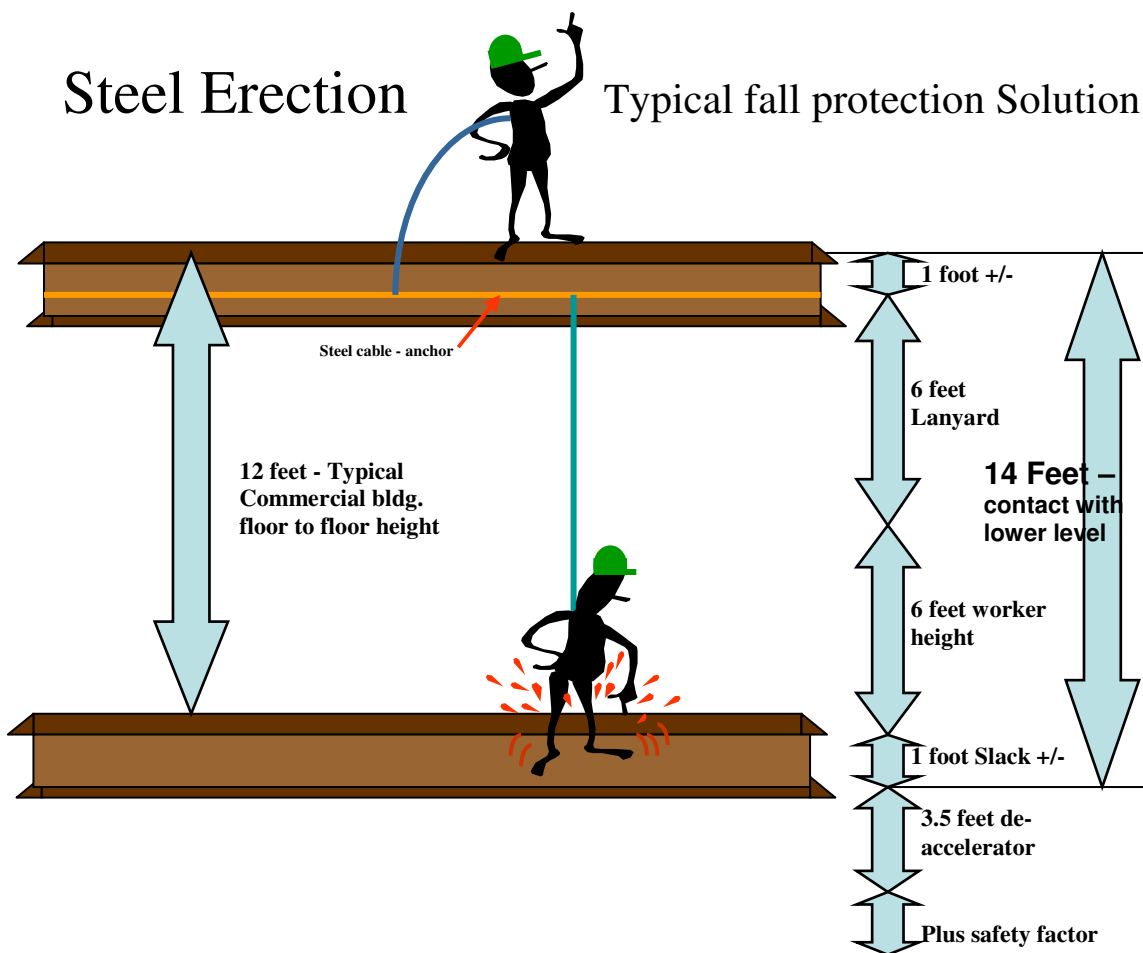
Usually in devising the project operational plan during preconstruction, not much thought is given to safety, except maybe some major exposures (falls during steel erection, excavation engulfment protection, scaffolding issues, etc. These considerations and protective methods usually are devised so as to meet minimum OSHA standards. An important issue here sometimes is in execution of the safety plan. If safety is not a perceived core value and production is at risk the field supervisors tend to "push: production at the expense of safety. The worker if faced with a perceived choice between working safely and being more productive given the work climate will invariably choose taking a risk. We also have to appreciate that taking risk does not always result in incidents and more rarely in injuries, so risk taking becomes more or less routine,

Let me site just one example. Fall from heights are treated differently in different parts of the standard. Fall exposure for most trades is limited to requiring protection if the fall distance is greater than 6 feet (Subpart M). Yet scaffold erectors do not require fall protection until they are exposed to falls greater than 10 feet (Subpart L). Then metal deck welders, and a number of other tasks do not require fall protection until they are exposed to falls greater than 15 feet (Subpart R, etc.). Yet steel connectors do not require fall protection until they are exposed to falls greater than 30 feet (Subpart R). So following these standards especially for steel erection will result in considerable risk to workers on a construction site. In order to provide an injury free work environment the contractor should go beyond these minimum standards.

Case in point: Assessing means & methods selected for fall protection that is implemented to protect workers from falls when disconnecting the sling (chocker) from the middle of the beam after it has been placed and connected. The usual method of providing an anchor point is to install a cable in the flange area of the beam to which the worker is directed to attach his lanyard.

Should a worker fall the total fall distance (from where his feet are before the fall to where his feet end up after) can be in the neighborhood of 14 -18 feet depending on some variables (Ellis 2001). Since many commercial buildings have a floor to floor height of around 12 feet this worker will impact the lower level and suffer an injury. So from this perspective the fall protection system selected by the “example” contractor to protect its employees is ineffective. So there is a “design” element in the contractor’s area of control that also needs to be addressed when selecting ways to protect the workforce from harm..

Depending on the height of the structure, in some cases the worker may be able to perform the task mentioned above from an aerial lift, thereby eliminating the need for fall protection. Another option available in case the steel member weight is within the capacity range of clamps, then the sling configuration is replaced with a safer option. There is also the possibility of using a different sling configuration that will eliminate the choker and can be done from the beam ends. All of these options must be explored during the contractor’s planning stage so that the cost of these options can be rolled into the bid price. This suggestion may potentially impact competitiveness in a bid situation. If the owner does not consider the safety aspects of the operational plan then the contractor must make a business decision, which in all likelihood will mean matching industry standards(the competitors will use) to remain competitive.



Next let us look at the safety procedures the contractor may employ to provide a safe workplace for its employees. The usual techniques are orientation, meetings, program rules, training, engineered controls and inspections. If any sort of planning is done during construction it may consist of completing JHAs for “high” risk tasks, and the use of a 2-3 week look-ahead window for coordination and resolution of any safety issues. These safety discussions are usually a small part of the production / coordination meetings. This is an ineffective application of the planning process, which is one of the powerful tools available to the contractor to create an injury free work site (Furst 2008).

Many construction firms are vertically organized. They have marketing, estimating, purchasing, cost & scheduling, and an operations department to name a few. So safety in these organizations nicely fits into a “silo”. This creates barriers in communication, coordination and integration. Most organization’s safety programs draw heavily on the OSHA standards and we have seen above these do not necessarily provide a safe work environment.

Safety Management & the Safety Professional

Safe performance is generally considered to be under the control of the worker. There are numerous studies of accident data over many decades that have shown, that virtually all accidents are caused by workers making choices which lead to incidents, injuries and ultimately losses (Heinrich, Byrd, et al). So over time safety programs, policies and procedures have generally focused their efforts on interventions that deal with controlling the physical environment and the behavior of the workforce. The underlying assumption being that by “fixing” the worker we resolve our safety problem. It is true that the worker does have control over their own behavior, and that they do make choices that sometimes lead to incidents, but in the workplace there is more at play than individual worker decisions and choices. Still the jobsite management can exercise considerable control over virtually everything that transpires at the workplace, including affecting the worker’s behavior, and decision making.

Let us consider a case where the owner requires an accelerated schedule as well as a very competitive bid structure. These certainly play role in the risks that flows to the worksite. Given the required accelerated production schedule, the contractor may not be able to eliminate the imposed risks. And the aggressive pricing may limit resources available for instituting any mitigating interventions so as to diminish the impact of the identified risks that the construction worker will have to deal with. The Contractor’s means and methods are another source of risk that may be impacted by the owner’s requirements.

Typically, safety performance improvement strategies start with a review of past losses. This analysis then establishes the interventions for the next time period. These interventions usually consist of more training, emphasis on certain program elements, or more rigorous inspections. In the short term some of these interventions do garner improved result in the safety outcome metrics. But in the long run the results never live up to expectations. Some of this is because the improvement strategy is based on historic data and the future is never exactly the same as the past. The data analyzed, may not give a true picture of all the contributing causes, and numerous other reasons. The focus generally is on the worker and not on the systems, processes and culture, etc. Since the worker is a part of the “system” that takes the design information and builds the physical structure, trying to “change” the worker’s behavior does not remove the underlying cause of the behavior. That remains to manifest itself in the actions of the next injured worker. And in industry this happens time and time again - somewhat like a self-fulfilling prophesy. Interventions focusing on workers have been used by organizations for decades generating some success, but the positive result generally tends to plateau.

There are a great number of areas in the management of the safety process that are out of alignment with innovative thinking. For example safety is generally end-of-the-line focused, and vertically managed; where it should have a cross departmental focus and a have functional horizontal value flow. Safety objectives are usually out of alignment with business goals. Safety management is not integrated into operational processes. Safety metrics have no relationship to measures used to manage the organization. There should be an organizational integrated strategy. With defined objectives, aligned metrics and achievable goals. Safety should report to senior management, etc. Safety should be an organizational core value – it should be instinctual!

Conclusion

Therefore a holistic approach to the creation of a safe work environment on a construction site requires a team effort in identifying, evaluating and managing the risks that flow to the worksite. All the participant, owners, designers, contractors, and safety professionals must cooperate and contribute in order to achieve this lofty goal. Paying close attention to the risks associated with the owner's requirements, the design of the facility, integrating safety processes into contractor operations, and utilizing innovative approaches to managing the safety process are key. The safety professional must be cognizant of innovative approaches to understanding human error (Dekker 2006) and the need to make the work environment and free of hazards and risk as possible. The owner plays a crucial role in orchestrating and managing the process, cooperation between the design team and the contractor team; supported by a construction process knowledgeable safety professional are critical.

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