

Safety Improvement Approaches in Construction Industry: A Review and Future Directions

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The construction industry ranks high in the rates of severe and fatal occupational injuries due to complexity and unpredictable nature of the tasks. Decades long efforts to combat occupational accidents by using various safety improvement approaches have reached a plateau. Figures published by Bureau of Labor Statistics show an improvement in the safety of the construction industry, yet a closer look reveals that it is lagging behind most other industries. In an attempt to identify the limitation of the prevailing safety approaches, this paper has reviewed the major approaches that have been implemented to improve occupational safety in construction industry. Evaluating nine major approaches in terms of techniques and effectiveness, it was found that all the approaches transfer the burden of responsibility on the contractors. While the role of contractors in ensuring the safety of workers is undeniable, researchers are of the opinion that ideal time to consider construction safety is during design phases. Considering the prolonged involvement from the phase of inception, architects and engineers can play important role in identifying and mitigating potential hazards to the construction workers. The new approach of preventing accidents and incidents through design has been recommended in this paper as the future direction of safety improvement in the construction industry.

Key Words: Construction safety, safety improvement approach, prevention through design, architects role in safety

Introduction

In the United States, more than 11 million men and women constitute the workforce for the dynamic and complex construction industry. Construction worksites are complex due to sequential work processes, levels of technology used, interaction between workers and equipment, and the varying degrees of safety awareness and training of the workers. The unpredictable and complex nature of the construction tasks has made safety a concern wherever construction activities take place. The number of occupational fatalities and injuries in the construction industry is exceedingly high. Apart from the societal cost of occupational accidents, the economic effect can have a sizeable impact on business performance. In 2002, the total (direct and indirect) cost of fatalities and non-fatal injuries was US $13 billion (CPWR 2008). These statistics highlight the importance of health and safety in the construction industry.

Improving safety in construction remains a priority in almost every country around the world, because the construction industry stands out among all other industries as the main contributor to severe and fatal accidents (Ahmed et al. 2000). The major approaches implemented in the construction industry to improve safety have been summarized in this paper along with their individual benefits and limitations. Upon review of the prevailing safety improvement approaches in terms of techniques and effectiveness, it was found that traditionally the burden of ensuring safety of construction work site has been placed solely on the contractor. While the contractor will always bear the responsibility for construction site safety, the novel concept of Prevention through Design (PtD) also allows architects and engineers to contribute in enhancing site safety. According to PtD which was initiated in 1985 by International Labor Office (ILO 1985), hazards should be 'designed out' such that they are eliminated or reduced before the workers are exposed to them. After reviewing the major approaches that have been taken to improve occupational safety in the construction industry, this paper concludes that PtD is a promising approach and can provide a positive impetus towards improving safety in the construction industry.

Safety Improvement Approaches

A systematic review of the literature from journal articles and conference proceedings identified nine major prevailing safety improvement approaches in the construction industry: (i) personnel selection, (ii) technological intervention, (iii) behavior modification, (iv) poster campaign, (v) quality circle, (vi) exercise and stress management, (vii) near-miss accident reporting, (viii) safety climate, and (ix) zero injury technique.

Personnel Selection

The concept of accident proneness gave rise to the personnel selection method of accident control. Risk analysts as early as 1920s noticed that a large percentage of any company's accident was caused by a relatively small percentage of employees. This led to the conclusion that some employees were more accident prone than others. Researchers identified variables that could be used in screening future employees namely personal maladjustment, social maladjustment, impulsivity, cognitive deficits, alcohol use and drug use (Guastello 1993). However, when these are put into effect for personnel selection, the selection technique emerged as the least effective method of improving occupational safety (Guastello 1993). Recent researches also show similar findings, which conclude that individual characteristics of construction workers do not play a major role in the occupational accidents (Chau et al. 2002).

Technological Intervention

Technological interventions can be mainly categorized into automation (Karwowski et al. 1988) and comprehensive facility redesign (Kjellen 1990). However, the effect of this intervention brings with it human errors that are typical with introduction of any new system (Guastello 1993). For instance, automation interventions have the potential to reduce accidents, but at the same time they give rise to new types of accidents (Chignell et al. 1986). To alleviate the situation, new control techniques emerged in the form of emergency switch operated by workers to stall the operation (Sjostrom 1990), a sensor that detects the presence of workers in the work envelope, or re-engineering the work station altogether eliminating the need of physical presence of workers (Malm and Souminem 1990). Technological intervention has been utilized in construction industry to improve the safety of specific construction operation (Bernold et al. 2001), such as the use of robotics in the pipe laying industry. The benefit can be seen in reduction of accidents and also reduction in cost by not having to adhere to stringent safety regulations (Li and Bernold 2005).

Behavior Modification

A typical behavior modification program of workers consists of basic training regarding safety information and safe behavior, followed by a period of observation and feedback. Feedback may be provided by the supervisors directly or by means of graphical updates displayed at the work place (Guastello 1993). Sulzer-Azaroff and Austin (2000), McAfee and Winn (1989) have reviewed behavior modification programs in great detail and have documented program variations, which incorporate goal setting, providing incentives, and use of mechanical aids for behavior monitoring. A behavioral approach becomes especially important in tackling safety issues since it focuses on the psychology of the workers at work. The National Safety Council reported that worker behavior was the cause of 94% of all injuries and illnesses (Loafman 1996). This justifies the importance of focusing on employee behavior as a critical element in achieving better safety performance.

Poster Campaign

Saarela et al. (1989) carried out a study on the effects of poster campaigns on safety at a ship yard, following the criteria of an effective campaign proposed by Hale and Glendon (1987). Interviewing randomly selected employees from the campaign ships, they concluded that the posters had limited effect on workers. However, there is evidence that safety campaigns can have positive effects on behavior and safety (Kaestner et al. 1967). The value of poster campaigns may not have a direct effect on accident prevention; the most valuable effect is increasing safety awareness among the workers (Saari 1998). To increase awareness, Occupational Safety and Health Administration (OSHA) has made it mandatory for the employers to display poster prepared by the Department of Labor informing employees of the protections of the Occupational Safety and Health Act, 1970 and its amendments.

Quality Circle

Quality circle is a committee of employees who perform similar types of work and meet voluntarily to solve issues related to product quality and productivity (Guastello 1993). In addition to these, quality circle techniques have been successful in preventing accidents also (Saarela 1990). In spite of the notion that temporary organizations such as construction projects are inappropriate for the participative approach of quality circles, the salient features of construction projects actually foster the utilization of quality circles (Rosenfeld et al. 1991). Some of the characteristics of construction projects which make them ideal for the utilization of quality circles are: short term or temporary employment of construction workers, unique and non-repetitive nature of the projects, and ad-hoc nature of the project organization. The task-oriented approach of construction projects greatly benefits from quality circle team approach. The quality circle is also appropriate for creative solutions to urgent problems. Thirdly, the shallow hierarchy of construction project organization and the wide authority of superintendents allow them to implement the suggestions of the quality circle. Based on survey and field experiments, Rosenfeld et al. (1991) concluded that quality circles in construction help in improving workers' safety along with short term monitory savings.

Exercise and Stress Management

Exercise programs have proven successful for reducing stress related injuries in physically demanding jobs (Gebhardt and Crump 1990). In a study on exercise programs, Cady et al. (1985) found that such programs had a positive effect in reducing work-related injuries and illnesses among fire fighters. Many of the leading construction companies in the US have developed routine exercise sessions that would benefit construction workers and warm up cold muscles before they start working. This initiative is a part of the companies' plan to reduce injuries and helps to reduce soft muscle tissues and back injuries among workers (Wolff 2009).

Stress management programs have been successful in reducing stress and improving job attitudes (Ivancevich et al. 1990). However Murphy (1984) pointed to the limitation of the stress management programs, which are not designed to eliminate the sources of stress but only educate workers to cope with the stress.

Reporting Near-miss Accident

The near-miss reporting program presumes that for every real accident, approximately ten near misses have also occurred. Thus reporting eleven times as many real accidents/incidents provides a greater opportunity to devise more preventive measures (Guastello 1993). A version of this technique, generated by Carter and Menckel (1985), showed an increase in the number of corrective suggestions generated, but without any reduction of the accident rate. In another study by the same researchers, the participants were given training to recognize and interpret critical incidents. The initiative resulted in a reduction of injury severity, but no reduction in the accident frequency rate was noted.

The technique of near-miss accident reporting was devised as a method to generate new accident control ideas and as a means of increasing closeness of safety supervision thus increasing the amount of feedback to workers regarding the safety of operations (Guastello 1993). In a study to explore the quality of accident data of large construction companies in Japan, Gyi et al. (1999) found that these investigations could give detailed information on the nature of unsafe acts associated with different tasks. However, measurement of near miss accidents is difficult due to higher level of occurrences. The construction industry is divided with regard to measurement and use of the term `near miss'. One section of the industry uses the term but admits that there is gross under-reporting involved with it, while the other section feels positive about the use of near miss auditing (Gyi et al. 1999).

Safety Climate

Safety climate is a "summary concept describing the safety ethic in an organization or workplace which is reflected in employees' beliefs about safety and is thought to predict the way employees behave with respect to safety in that workplace" (Williamson et al. 1997). The study conducted by Dedobbeleer and Beland (1991) on construction workers, suggested that the management commitment to safety and workers' involvement in safety were the two most important factors impacting the safety climate. A separate study on road workers found two separate set of principles for workers and for supervisors both of which included attitudes to safety in the organization, changes in

work demands and safety as part of productive work (Niskanen 1994). In order to determine and effectively translate these descriptive measures into an operational measure for safety management, several instruments have been developed. The majority of these instruments are in the form of self-reported questionnaires administered as large scale surveys in an attempt to determine the key factors affecting safety climate. Content analyses of the survey questionnaires used to measure safety climate in the construction industry by Ghosh et al. (2010) revealed that common themes of the questionnaires relate to implication of safety rules and attitude of the management towards worker safety.

Zero Injury Technique

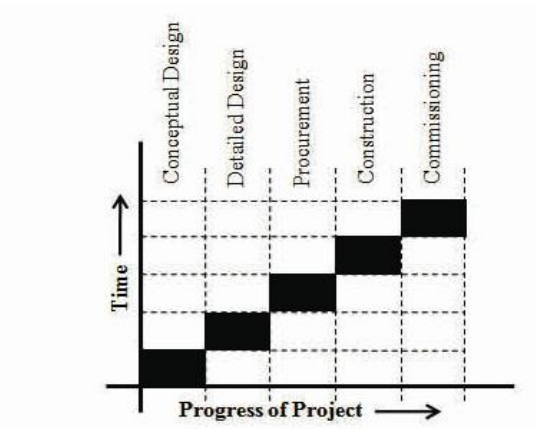
In (1993), the Construction Industry Institute (CII) initiated a research to demonstrate how to achieve zero accidents in construction projects and to convince owners, contractors and managers about the importance of an effective safety program (CII 1993). Based on interviews with owner/managers, construction managers, construction superintendents, and construction workers, the study generated five high impact techniques that are designed to help owners and contractors achieve zero accidents on their construction projects. The techniques include: pre-project planning for safety, safety orientation and training, written safety incentive programs, alcohol and substance abuse programs, and accident/incident investigations (CII 1993; Hinze and Wilson 2000). Following this study was another one in 1998 by Hinze and Wilson, which validated the importance of the five high impact techniques in safety performance. The five high-impact techniques identified by the CII in 1993 were revisited in another study in 2003, which addressed the importance of using several safety techniques in construction projects (CII 2003). These techniques were categorized into nine groups: management commitment, staffing for safety, planning (pre-project and pre-task), safety education (orientation and specialized training), worker involvement, evaluation and recognition/reward, subcontract management, accident/incident investigations, and drug and alcohol testing.

Limitations of the Prevailing Approaches

The various safety improvement approaches discussed above have yielded positive results and reduced accidents in the construction industry. Rates for work related fatalities in construction industry have decreased by 22% in the period from 1992 to 2005 and occupational injuries and illnesses with days away from work dropped by 55% in the same period (CPWR 2008). However a closer look at the numbers reveal that in the same period (1992 – 2005) construction industry has accounted for the lives of 16,068 workers, an average of about 1,147 workers per year (BLS 2009a). Considering that it is the responsibility of the companies to make sure that their employees return home safe and unharmed at the end of the day, the huge number of injuries, illnesses, and fatalities in the construction industry is totally unacceptable. Many industry leaders and researchers have tried to raise the safety bar quite high by calling for ‘zero accidents’ in construction (CII 2003). In spite of all the initiatives, in reality the construction industry continues to lag behind most other industries. Based on 2005 statistics, only agriculture, mining and transportation industries had a higher fatality rate and transportation industry had a higher rate of occupational injuries and illnesses with days away from work than that of construction (CPWR 2008). Moreover, researchers are of the opinion that the efforts to improve occupational safety and reduce accidents by implementing prevailing safety improvement approaches have stalled and progress have reached a plateau (Abdelhamid 2003).

The current situation reflects a fundamental problem of the prevailing safety improvement approaches, which fail to recognize that safety of any operation is determined long before the people, procedures, and equipment come together at the work site. Construction operations are not different in this respect from any other operation. Until recently, most of the efforts expended to improve safety performance have been targeted towards implementing rules, regulations, and devising advanced equipment – in brief transferring the burden on the contractors. Construction contracts and regulatory requirements from OSHA place the burden for worker safety solely on the contractor. The owners also play a major role in placing the burden on the contractors by utilizing pre-qualification practices of selecting only those contractors with good safety performance, lower insurance rates, and written safety programs. On the other hand, the role of the architects and engineers to impact safety in construction projects has not been fully utilized. A major reason behind this can be found in the lack of motivating forces (i.e. legal, contractual, economic, or regulatory) in the United States that will encourage a designer to consider potential health hazard and risks of the workers during the design phase (Behm 2005). The legal agreement in the traditional method of engineering-procurement-construction and design-bid-build precludes a designer from considering construction site safety during the design process.

From a strategic point of view, the architects and designers are the entities who have the most prolonged involvement in any construction project, other than the owners. As a natural corollary they have the opportunity to influence the outcome of the project from the phase of inception. Breaking down a typical construction project into five broad phases, Figure 1 lists the different stakeholders involved in each one of them. It is clearly evident that the architects and designers can play effective role in identifying and mitigating potential hazards to the workers more effectively than the contractors who are brought on board at a later stage of the project. Recently, the National Institute for Occupational Safety and Health (NIOSH) has started a national initiative in the United States called Prevention through Design (PtD), to utilize the role of designers in safety improvement. PtD addresses occupational safety and health needs in the design process to prevent or minimize the hazards down the stream (Howard 2008).



Architect	X	X		X	X
Owner	X	X	X	X	X
Engineer		X		X	X
Contractor			X	X	X

Figure 1: Involvement of stakeholders in different phases of a construction project

The Concept of Prevention through Design

Schulte et al. (2008) defined the concept of PtD as "the practice of anticipating and 'designing out' potential occupational safety and health hazards and risks associated with new processes, structures, equipment, or tools, and organizing work, such that it takes into consideration the construction, maintenance, decommissioning, and disposal/recycling of waste material, and recognizing the business and social benefits of doing so". Historically PtD was first conceptualized in 1985 by the International Labor Office (ILO). It recognized that the architects and engineers could actually play a significant role in the safety of construction projects. ILO emphasized that architects and engineers should consider the safety of the construction workers, during the design phase. Recommendations of ILO was supported by The European Foundation for the Improvement of Living and Working Conditions, which concluded that nearly 60% of all fatal accidents in the construction industry was caused due to decisions made prior to actual construction. Their claim that design and design decisions are linked to construction accidents was supported by the work of Jeffrey and Douglas (1994). Upon review of safety performance of the United Kingdom's construction industry, Jeffrey and Douglas (1994) concluded that there is a causal relation between design decisions and safety performance of construction projects. Safety considerations should be incorporated in the design process from the very beginning to increase the efficacy. According to Szymberski (1997), the ideal time to consider construction safety is during conceptual and preliminary design phases to be more effective. In contrary to the prevailing safety approaches, which are implemented during the actual construction phase, PtD is more effective as it is introduced earlier in the design phase (shown in Figure 2).

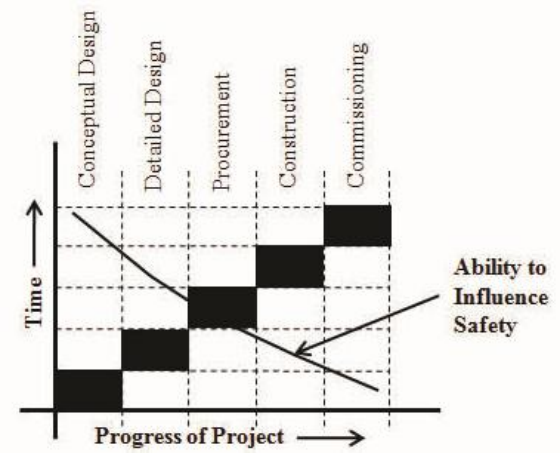


Figure 2: Time vs. safety influence graph (adopted from Szymberski (1997))

Based on the investigation of more than two hundred construction fatalities, Behm (2005) has summarized existing design suggestions to reduce fatalities as also new design suggestions. While detailed discussion of the design suggestions is beyond the scope of this paper, examples of design suggestions to prevent fatal accidents are: consideration of permanent anchorage points, lifeline attachments, and perimeter holes for guardrail attachments during designing roofs; inclusion of permanent guardrail systems in the design and scheduling them early in the construction process when design features cause floor opening to occur; specifying scaffolding tie-off points into exterior walls of buildings for construction and maintenance purposes, etc. Though the designers play a major role in the PtD initiative, the role of the contractors cannot be undermined in ensuring the safety of the workers during the construction phase. In order for the construction safety concept specified in the design to improve worker safety, the contractors must adhere to the design specifications (Behm 2005).

For the PtD initiative to be successful, it is not enough that architect and engineers only consider occupational safety and health. There is a need for business decision makers, including those who purchase products and services, to insist on specifications that prevent and minimize occupational safety and health risks (Schulte et al. 2008). A growing number of industry leaders in the US and other countries have started recognizing PtD as a cost-effective means to enhance occupational safety and health. The United Kingdom has made it mandatory for construction companies, project owners, and architects to address safety and health during the design phase of projects in 1994, and companies there have responded with positive changes in management practices to embrace the move. Australia developed their National OHS Strategy 2002–2012, which set "eliminating hazards at the design stages" as one of the priorities (Howard 2008). In addition, France passed regulations, which mandate a holistic view of construction safety including the design and other European countries have since followed with similar regulations (Behm 2005)

Conclusion

The prevailing safety improvement approaches in the construction industry have put the burden of responsibility for the workers' safety on the contractors. While the role of the contractors in the occupational safety and health risks of the workers is undeniable, yet the lack of improvement in the safety performance of construction industry in comparison to others have urged the practitioners and researchers to look for novel concepts. PtD is such a concept, which if embraced by the construction industry and utilized properly can minimize occupational safety and health risks. Utilization of this concept calls for architects and engineers to participate in enhancing construction site safety. PtD concept utilizes the fact that architects and engineers are in a position to make decisions about construction safety and reduce or eliminate certain identifiable risks before those risks reach the construction site.

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