DESIGNING FOR CONSTRUCTION WORKERS' SAFETY

Zahra Jabbarani Torghabeh, Seyyed Shahab Hosseinian
Department of Structure and Materials, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), Johor Bahru, Johor, Malaysia

ABSTRACT

Protection of safety and health of construction workers seems challenging as a result of diversity and dynamic features of construction industry. Despite remarkable evolvement in construction industry, safety and health problems still exist in construction sites. Traditional approach towards accidents in construction site is reform after incident which causes expenses and disability of identifying the root causes of accidents. Identifying the root causes of construction accidents and fatalities has revealed the fact that not only contractors but designers, architectures and structural engineers are capable of influencing the safety and health of construction workers. Considering workers' safety in the initial stages of project design encounters imitations such as legal and liability issues and lack of designers' safety knowledge, which primarily originate from gap between designers and constructors in terms of commitment to and knowledge of jobsite safety. Addressing construction workers' safety in the design phase is expected to eliminate or reduce the hazards in the construction phase therefore the constructors' safety performance and management could be improved. This paper provides useful perception of the history of 'Designing for construction workers' safety' concept and aims at introducing potential contribution, which could be made by designers and architectures on workers' safety.

KEYWORDS: *Construction industry, Safety, Hazards, Design phase, Design for construction safety*

I. INTRODUCTION

In improvement of countries' economy, the role of construction industry is irrefutable; however there are many evidences in representing construction industry as a hazardous industry. Despite remarkable evolvement in construction industry, safety and health problems still exist in construction sites due to the fact that time, cost and quality are three factors which are mostly considered ahead of construction safety [1]. Protection of safety and health of construction workers seems challenging as a result of diversity, changeability, complexity, extensive scope of the works and dynamic features of building and construction industry [2]. Site safety has always been an area of concern for employers of construction workers; moreover safety responsibility of general contractor encompasses subcontractors' workers. Safety concerns have been intensified because of increasing costs of premium compensation of workers, increase in the number of liability lawsuits, the intensification that has been made to safety regulations and obligations enacted by owners to address workers injuries and accidents [3].

According to statistics provided by safety and health organizations and formal evidences, construction industry includes a broad range of accidents and fatalities. Labor forces at construction sites are exposed to a variety of hazards that can cause permanent or temporary disability or fatality [4]. This matter has placed the construction industry among the industries with high rates of fatal accidents; only mining, transportation and agriculture have higher rates than construction [5]. According to US Bureau of Labor Statistics (BLS) on industrial injuries, in year 2003 construction workers constituted only 7% of all workforce but 1,166 fatal injuries occurred in this industry which accounted for 21% of

the total industrial fatal injuries; at the same year 155,400 injuries and accident, which required day away from work, happened in construction industry (7.9% of all). Construction accidents may lead to serious financial and humanitarian impacts such as delay in the process of project progress, increase in expenses, decreased productivity, incurring a loss to contactors reputation and reliability and negative psychological effects on workers [6]. On the contrary, unessential and excessive safety measures for enhancing construction safety may also lead to schedule delays as well as costs overruns [7].

As a wrong belief construction industry is inherently unsafe and design of the project does not have any influence on safety and health of construction workers. Physical condition of work is not necessarily providing hazardous situation but sometimes the design characteristics create a hazardous situation which cannot be attributed to constructors. Traditionally construction workers' safety is ignored until the initial stage of construction phase [3]. Institute for Safety Through Design (ISTD) states that considering workers' safety in the initial stages of project design produce considerable advantageous such as productivity improvement, decrease in operating costs, no need of expensive reassessment of safety deficiencies, considerable reduction in number of injuries, illnesses, disabilities and also environmental harm and decrease in attendant costs [8]. Traditional approach towards accidents in construction site is "reform after incident" which causes expenses as well as disability of identifying the root causes of accident. Recent development in safety and health programs has lead to the appearance of the idea that construction accidents should be recognized and prevented [9]. Identifying the root causes of construction site accidents and fatalities has revealed the fact that not only contractors but designers, architectures and structural engineers are capable of influencing the safety and health of construction workers [9, 10, 11, 12, 13]. It is believed that the safety of any activity can be determined much time before the persons and equipments gather at the construction workplace [14]. Sometimes professionals of safety and health declare that safety and health hazards are designed into the construction projects [8]. For safety of construction workers to be addressed by designers and architectures on a regular basis or as an integral design function on all projects, a dramatic change must occur in the mindset of the design profession [10].

This paper provides useful perception of the history of the 'Designing for construction workers' safety' concept. The paper also provides practical insight into the opportunities, implementation and barriers facing the designers and architectures, who are willing to contribute to the matter of construction workers' safety. The paper first provides a summary of the history of designing for construction workers' safety, the contributions that have been made by researchers and different concepts. The paper then discusses the barriers by which designers and architectures are faced in considering workers' safety in design process and the effect of considering workers' safety in the design process on construction accident as well. Finally the current tools of designing for construction worker safety are discussed. This paper tries to provide an overview of the current scenario of the concept of designing for construction worker safety, designers' role, barriers and tools. The paper is aimed at introducing potential contribution, which could be made by designers and architectures on workers' safety, through reviewing recent research and findings in the area of designing for construction workers' safety.

II. 'DESIGN FOR CONSTRUCTION SAFETY' CONCEPT

The history of linking workers safety and health to design goes back to 1800s which include safer designing and implementation of guards for machinery; followed by ergonomics design of workplaces [15]. In year 1985, International labor organization (ILO) proposed the idea that design engineers should regard the workers' safety during the design stage; since then designers are enforced to consider safety issues during their designing [14, 9]. According to a research done by Hinze and Wiegand in 1992 the majority of designers were unwilling to address workers safety in their design based on the advice given by legal counsel to avoid any liability assumption. Designers who consider workers safety in their design prefer to work in design-build companies; in such firms the benefits of the safe design will be achieved by the same firms. In another studies done in 1993 and 1994 by Hinze and Wiegand the owners were asked about the role of designers in workers safety; the results of these two studies were very similar as they show that the majority of designers did not address safety in their design. It was surprisingly remarkable that only 17% of designers considered themselves as

responsible for considering workers safety in their design [3]. Table1 shows a comprehensive review of the history of design for construction safety concept.

Table 1: The history of "Designing for construction safety" concept [3, 9, 14, 15, 16]

The history of "Designing for construction safety" concept	
1800s	Design and implementation of guards for machinery: Linking workers safety to design
1955	National Safety Council's accident prevention manual: PtD was proposed and application of PtD in US began when the construction industry institute sponsored Prof. J. Hinze and J. Gambatese in 1990s
1985	International Labor Organization (ILO): Designers were forced to consider safety issues during their designing
1996	PhD thesis on safety through design by john Gambatese: Drew the attention to concept of safety through design later in his papers (Gambatese 1998, 2000)
1992	Temporary And Mobile Construction Sites Directive: Designers held responsible for the construction site safety (Europe)
1995	Law: Construction (design and management) (CDM) regulations is enforced in U.K.
1997	Fred Manuele (1997): "Designing for construction safety as an intervention is supported by the hierarchy of controls common to the safety and health professions which identifies designing to eliminate or avoid hazards as the preferable means for reducing risk".
2003	Symposium at university of Oregon, USA: PtD attracted more interest
2005	Michael Behm (2005): Remarkable percentages of fatalities are linked to design without any relation to the nature and type of the construction project but they are related to design elements.
2008	Framework of PtD initiative are: Research, Practice, Education and Policy

III. 'DESIGN FOR CONSTRUCTION SAFETY' CONCEPTS

Design and Planning for Construction Safety (DPfS), Designing for Construction Safety (DfCS), Design for Safety (DfS), Safety through Design, Prevention through Design (PtD), Design for Construction Safety, and Construction Hazard Prevention through Design (CHPtD) are all various phrases developed by researchers in order to define the core concept of design for construction workers' safety [17].

3.1. Design and Planning for Construction Safety (DPfS)

DPfS includes the collaboration between the designers and constructors for geometrical design and construction planning as well. Unlike "Safety through design" which take care of construction product and "Safety through construction planning" which take care of safety in construction phase, the DPfS will observe the interaction between process and the product [17].

3.2. Design for Construction Safety (DfCS)

(DfCS) is a procedure and routine in which the safety and health of construction workers are clearly taken into account by engineers and architects during the design process. DfCS can be thought as designing for constructability because it can be regarded as a way of safe construction while meeting the cost, schedule and quality goals. There are three main reasons that distinguish the advantages of DfCS [17]:

i. Since construction is among the most dangerous industries therefore it is not false to expect owners, contractors and designers to be capable of performing tasks in a way which reduce the safety risks.

ii. Approximately the majority of injuries occur from forces, stresses, dynamic motions and electricity, so high education professionals in these areas can reduce the safety risks by considering safety during design.
iii. Safety as well as cost, quality and schedule can be strongly affected by decisions that are made at early stages of construction life cycle and especially by designers.

The primary implication of diffusion of DfCS is that engineering licensure should be modified in a way which contains more construction safety courses. The other DfCS development is that design civil engineers must be better information collectors and communicators on project information which are ignored now (Information may include site utilities and also availability of prefabricated components) [17].

3.3. Design for Safety (DfS)

Manuele (1997) expressed that "Designing for construction safety as an intervention is supported by the hierarchy of controls common to the safety and health professions which identifies designing to eliminate or avoid hazards as the preferable means for reducing risk" [16]; he proposed the safety approaches in terms of hierarchy of priority and efficiency (Hierarchy of Control). The first step of Hierarchy of priority is 'Designing to eliminate or avoid the hazard' following by the next steps of 'Designing to reduce the hazard', 'Incorporating safety devices after the fact', 'Providing warning devices' and finally ends up with 'Institute training and operating procedures'. Similar to Manuele list of safety approaches, Andres (2002) introduced a "Safety hierarchy" which initiates with 'Eliminating the hazard' and following by 'Providing engineering controls', 'Warnings', 'Trainings' and finally ends up with 'Providing Personal Protective Equipment (PPE)' [8].

3.4. Prevention through Design (PtD) initiative

Prevention through Design (PtD) can be defined 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**.** There are four functional areas that build the framework for PtD initiative including [18]:

i. Research is associated with wide range of questions on efficiency of design, relationship between design and accidents, design evaluation tools, information propagation and economic matters.
ii. Practice area is associated with affecting the practices of designers and their safe product demanders. Designers are led by their profession science as well as the market demand; when demanders seek for safer designed products the designers try to consider safety principles into their design.
iii. Education area is associated with the training programs; education focuses are increasing the curriculum courses and stimulation of professional accreditation programs. These accreditation programs treasure the value of PtD aspects and will be used in proficiency evaluation.
iv. Policy area is associated with policies which advocate the improvement of research and practice. This area is consisting of guidelines, rules, advices, instructions and standards in order to integrate safety and health issues in design phase.

The final intention of the PtD initiative is to mitigate or avoid occupational injuries, illnesses and deaths by incorporation of design suggestions in design stage which influence the workers safety and health. NIOSH has developed a framework in order to acquire information on PtD issues from stakeholder called NORA (National Occupational Research Agenda). The strategic PtD plan is divided into 3 phases [18]:

i. First phase lasts for three years and includes the development and implementation of PtD strategic plan; this phase includes design and performing tasks as well as identification of performance indicators of tasks.

ii. Second phase include a conference on achievements and implementation of the PtD strategic plan which will be held in the fourth year to identify the extra efforts needed to be done on strategic plan and its implementation.

iii. Third phase, which is three years following the conference, the extra efforts for eliminating deficiencies will be performed.

3.5. CHPtD

Construction hazards prevention through design (CHPtD) is defined as a process in which the architectures and engineers take into account the safety of workers in construction sites during the design phase. CHPtD offers three persuasive advantages [18]:

i. CHPtD tries to consider safety as well as cost, quality and schedule.
ii. Since site hazards are related to forces, stresses, dynamic motion and electricity, well qualified designers with extensive safety knowledge can identify the risk associated with these factors and would be able to mitigate these risks through the design stage.
iii. Statistics show that the construction industry is among industries with high rate of hazards and accidents, therefore it is reasonable to think that all parties involved in this industry should be responsible namely owners, contractors and designers.

The trajectories, suggested to be followed by CHPtD are 'Prefabrication of components more than before', 'Larger usage of less hazardous materials and systems', 'Further application of construction engineering' and 'More spatial investigation and consideration'. (18). Lack of knowledge on construction site safety as well as construction processes essential to execute CHPtD, are the most significant factors impeding the improvement of safe design trajectories. The current gap in communication and knowledge that impede diffusion of CHPtD may be less critical among those designers who are involved in design-build contracts. Negotiations on safety issues between designers and builders in a design-build contract must honestly consider the hazards and risks related to design, therefore the development of CHPtD concept is seemed to be accelerated through design-build approach [9, 18, 19].

IV. IMPLEMENTATION BARRIERS OF 'DESIGN FOR CONSTRUCTION SAFETY' CONCEPT

There are barriers through dissemination of the design for safety concept which primarily originates from gap between designers and constructors in terms of commitment to and knowledge of jobsite safety; consequently the site safety information is provided by constructors' site personnel and forwarded to designers. Designers attribute their ignorance of safety issues in their design to 'Lack of safety training and knowledge', 'Lack of knowledge on construction processes', 'Lack of safety database in order to assist designers in identifying hazards and modifying design so as to mitigate the hazards' and 'Liability exposure which make designers to deliberately ignore workers safety in design' [3]. Implementation of the 'Design for construction safety' concept faces barriers such as:

- Legal and liability issues that are supported by case law: designers are advised by legal counsel not to regard safety issues in their design because of liability and insurance matters [3, 9, 10, 14]
- Regulatory actions: due to the resistance by a large part of construction industry regulations has not come dominant [14].
- The nature of construction contracts: The nature of design-bid-Build (DBB) contracts which separate different phases of a project is another barrier in safe design concept while in design-build contracts designers and constructors are working cooperatively [20].
- Lack of safety knowledge: Many designers currently lack skills in designing to avoid or reduce health and safety risks and they feel uncomfortable and threatened by the Regulations [18, 20].

V. 'DESIGN FOR CONSTRUCTION SAFETY' IMPLEMENTATION

The viability of the 'Designing for construction workers' safety' concept depends on the feasibility of implementation and efficiency in producing expected results; e.g. designers are willing to implement concepts that are relatively easy to implement, do not need extra resources and contribute to other project goals. The key to successful implementation of 'Design for construction safety' concept is a

considerable change which requires time and effort; crucial factors required for acceptance of the concept are listed below [8]:

- **A change in designer mindset:** Designers should realize the fact that their effort can enhance the workers safety [10].
- **Motivated designers:** Many design professionals require better motivations than benefits to safety of workers; design contract, information on cost savings potential, professional ethical codes, construction codes, regular design practices and legal actions are examples of motive [8, 15]
- **Knowledgeable designers:** Designers should be trained on safety-related issues during their university education; design suggestions database should be provided for them so they can implement design alternatives to enhance safety of workers in sites [3, 5]
- **Constructor involvement:** Communication between constructors, construction workers and designers can help designers to identify site hazards; therefore designers are capable of modifying design features endangering the workers safety [3, 8]
- **Mitigation of liability exposure:** As far as liabilities are existed, designers are not willing to address workers safety in their designs; legal and insurance professionals should be employed by construction industry to protect designers against additional lawsuits for integrating safety issues into their designs [5, 8, 13, 14].

VI. CONSTRUCTION ACCIDENTS AND DESIGN DECISIONS

European Foundation for the Improvement of Living and Working Conditions (1991) stated that 60% of all deaths in construction industry are due to decisions that have been made before commencement of construction stage. A study on U.K. construction industry revealed that there is a certain relationship between safety of construction and decisions made in design process regarding the accident causation [14]. In 1997 Szymberski introduced a diagram which shows that the most suitable time for consideration of construction safety is in the initial stages of conceptual, feasibility and preliminary design stage. According to time/safety influence curve of Szymberski the ability of influence on construction safety will be declined gradually from concept through start-up phases of a construction project lifecycle (See Figure 1) [14, 21].

Based on an extensive study which was performed in U.K. in 2003 it was indicated that design professionals (architectures and design engineers) had the ability to reduce the associated risks in construction accidents [22]. Studies on Iranian construction industry also revealed the fact that 33% of accidents are associated with decisions made in the design phase on project [9].

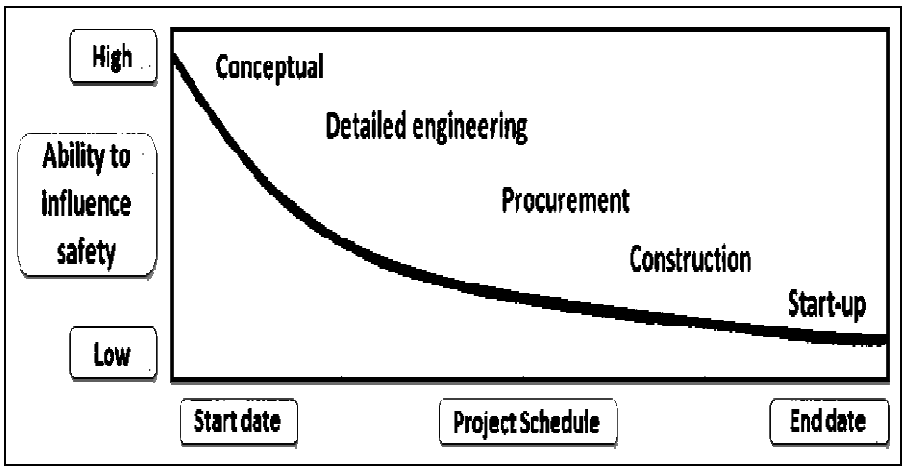

Figure 1: Time/safety influence curve (Szymberski, 1997)

More studies are required to determine the casual link that exists between design and construction safety. According to Haslam et. al. (2003) a noteworthy proportion of construction fatalities are linked to the design for construction safety concept; Construction fatalities that are linked to the design for construction safety concept are not related to the nature of the construction project (i.e. new construction, upgrade, and demolition); Construction fatalities that are linked to the design for

construction safety concept are not related to the type of construction project (i.e. residential, commercial, engineering, and industrial construction); Construction fatalities that are linked to the design for construction safety concept are related to the design element constructed at the time of the accident (design element is categorized as one of the 16 Divisions as specified by the Construction Specifications Institute); Construction fatalities that are linked to the design for construction safety concept are not related to the injured contractor's Standard Industrial Classification (SIC) code; and construction fatalities that are linked to the design for construction safety concept are related to the designer's discipline (e.g. architectural, structural, civil, mechanical, and electrical) involved in that aspect of the project that caused the fatality the following results [22].

Architects have the most important effect on construction safety compared to civil engineers, electrical, and mechanical engineers in designing for construction safety concept. Construction safety and health can be affected by design engineers directly and indirectly. Determining the system of procurement, preparing documents of contract, putting the stages of construction in order and decisions based on duration of the contract are the areas that can be affected directly by design professionals, while the type of structure, materials and design are issues that can be indirectly affected [14].

VII. CURRENT TOOLS OF 'DESIGN FOR CONSTRUCTION SAFETY'

Integration of construction process knowledge into the design process is the initial requirements of designing for safety concept. Designers lack the required knowledge therefore they have to perform a comprehensive risk assessment for every design element [8]. Tools of 'Design for construction safety' (See Table 2) incorporate two methods of reminding the safety analysts about the hazards:

i. Hazard identification through checklist: It is the direct talk/ask the analyst about specified hazards in a project. Hazards of previous projects are gathered into checklists but the limitation of this database in terms of identified hazards, which have been identified before, is the weak point of this method. Therefore this method cannot help the safety analyst to identify new and unique types of hazards in projects [3, 5, 17]
ii. Hazard identification through prompt words: Reminding the safety analyst of hazards through driving the mind of analyst by prompts words; CHAIR uses this method; "Height/Depth", "position/location", and "movement/direction" are some prompt words in CHAIR [17]

The study on checklists and prompt words method depicts that checklists-based methods are too specific and prompt words-based tools are too generic which in both methods the detail level are the same during the process. While the level of precision differs during the process of hazard identification from generic to specific; these methods remain unchanged [23].

7.1. 'Design for construction safety toolbox'

Providing design engineers with a design suggestions database in order to familiarize them with the aspects of design for workers safety was the chief objective of the design tool; therefore design engineers would be aware of actions which they could do in their design in order to contribute to workers safety [3]. The final revision of the computerized design tool named 'Design for construction safety toolbox'. A common cause that the safety and health consideration through design is not practiced widely is that designers are mostly unfamiliar with the methods and approaches of applying safety into the design. Many researches and solutions have been carried out for applying safety into the design; these design suggestions, which are directly implemented afterwards, impede the creativity of designers and also interrupt the design process [3, 5]. 'Design for construction safety toolbox' provides a user with design suggestions and its main concentrate is on project's 'Components of design', 'Hazards at construction sites' and 'Project systems'. The user have to decide the area accessing to the database, then the program ask the user some questions in order to identify the safety concerns; the program then proposes set of design suggestions and safety related concerns based on the answers given by the user [8].

7.2. CDM (Construction Design and Management) Regulations

CDM regulations were enforced in U.K since 1995 and place a responsibility on designers to ensure that any completed design does not interfere with the workers safety. CDM regulations 13 clearly

defines the responsibility of designers and states that if the designers do not comply with the regulations they will be fined [8]. Despite the CDM regulations design profession has not sufficiently improved in meeting CDM requirements. Lack of knowledge on what they are going to achieve and how to fulfill the requirements of CDM regulations are the main reasons of slow improvement in designing or safety [23]. CDM regulations are met provided that designers and constructors work together such as in design-build and construction management firms. Involvement and success of designers who follow the CDM regulations are highly influenced by the following factors [8]:

- The majority of design professionals ignore the CDM regulations which place a responsibility on designers to ensure the safety of any completed design.
- Design professionals mostly do not have safety and health knowledge.
- Design professionals mostly lack knowledge about materials, construction processes and methods.
- Designers usually apply standard materials without knowing the use of them; this may cause safety hazards.
- HSE (Health and Safety Executive, the establisher of CDM regulations) must come up with more innovative approaches to encourage efficient communication between designers and constructors

The four categories of 'Design for construction safety' tools as it is illustrated in Table 2 can be classified into two main bundles. The categories one and two, checklists and risk assessment forms, are a series of checklists which are to be traced by safety and health analysts. Documentation and structured review processes, third category, are mainly some prompts for motivating safety and health analysts mind in order to think safety and health hazards of design. Category four, visualizing 3d and 4d tools, fall in the mentioned group as well. They show construction processes or products in a way which stimulate the thinking of hazards associated with them. However the model checkers are also can be included in the first group such as checklists [16]. Safety design manuals and checklists provide information on hazards during the start-up, operation and maintenance of a project, therefore the close relationship between construction and start-up phases and between construction and maintenance make the design tool beneficial for construction phase as well as start-up and maintenance phases [3]. Although it may seem reasonable to provide a list of design solutions for improvement of safety in design phase, it can interfere with the creativity of the designers. In others words, designers' major concerns in using 'Design for construction safety' tools are that their freedom in design and design process should not be interfered [19].

Table 2: Current tools for "Designing for construction safety" [17]

Tool category	**Category example**	**description**
Checklists	ToolBox	Based on sets of checklist followed by safety analyst
Risk assessment forms	ToolSHeD	
Documentation and structured review processes	CHAIR	Prompts which stimulate the safety analyst mind for thinking about hazards
Visualizing 3D & 4D	DPfS tool	

A range of digital tools have been developed by researchers to be used in construction phase to help constructors achieve safety in their projects which use various digital technologies such as Virtual Reality (VR), Online databases, Geographic Information Systems (GIS), 4D CAD, Building Information Modeling (BIM), Sensing and Warning technologies etc., extensively for safety and health hazard prevention and safe delivery of project. The ToolSHed system uses regional health and safety regulations for guiding risk analysis. Although ToolSHeD uses the web platform and it is suitable for multi-party collaboration across the internet, geometric information related to the building components is not incorporated into the system [24].

VIII. CONCLUSION

High rates of accidents and fatalities in construction industry have made this industry inconsistent and risky. Construction accidents may lead to serious financial and humanitarian impacts such as delay project progress, increase in expenses, decreased productivity and negative psychological effects on

workers, on the contrary, unessential and excessive safety measures for enhancing construction safety may also lead to schedule delays as well as costs overruns.

Identifying the root causes of construction site accidents and fatalities has revealed the fact that not only contractors but designers, architectures and structural engineers are capable of influencing the safety and health of construction workers. The choices which designers select as well as the materials they use are the main factors that determine the safety and health level of the building practices. This paper provided a perceptual revision of the history of 'Designing for construction safety' concept which goes back to 1800s including safer designing and implementation of guards for machinery followed by enforcing designers to consider workers' safety in design by ILO in 1985 and introduction of PtD initiative framework in 2008 as research, practice, education and policy. The barriers through dissemination and implementation of designing for construction workers' safety concept were discussed as legal and liability issues that are supported by case law, the nature of construction contracts which separate different phases of a project and lack of designers' safety knowledge. The key to successful implementation of 'Designing for construction workers' safety' concept is a considerable change which requires time, effort and crucial factors for acceptance of the concept such as a change in designer mindset, motivated designers, knowledgeable designers, constructor involvement in design process and mitigation of liability exposure. Tools of designing for construction workers' safety incorporate two methods of reminding the safety analysts about the hazards hazard identification through checklist and through prompt words. Checklists-based methods are too specific and prompt words-based tools are too generic which in both methods the detail level are the same during the process of hazard identification.

Training designers on construction safety and processes, incorporation of professional constructors into the initial stages of design, prioritizing workers' safety over time, cost and quality, improving safety commitment through training, modification of construction regulations and laws to motivate design professionals for safe design, establishing proper communication among parties involved in construction industry, establishing organization empowered to evaluate the safety level of designs can be considered as potential and applicable contributions that could be performed. Addressing construction workers' safety in the design phase may eliminate or reduce the hazards in the construction phase therefore the constructors' safety performance and management could be improved. However, considering workers' safety in the design phase has not become a part of design professional's responsibility. Further research and contributions are required to disseminate the advantages of designing for safety concept.

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AUTHORS

Zahra Jabbarani Torghabeh received B.Sc. degree in Civil Engineering from Ferdowsi University of Mashhad (FUM), Mashhad, Iran in 2005 and M.Sc. in Construction management from Universiti Teknologi Malaysia (UTM), Malaysia in 2012.

Seyyed Shahab Hosseinian received B.Sc. degree in Civil Engineering from Islamic Azad University (IAU), Mashhad branch (Mashhad, Iran) in 2002 and M.Sc. in Construction management from Universiti Teknologi Malaysia (UTM), Malaysia in 2012.