ASSIMILATING CONSTRUCTION WORKER SAFETY INTO DESIGN – A REVIEW

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ABSTRACT : Construction industry is an essential element in Malaysian economy. However, with the highest fatality rate compared to other industries in the country, construction industry faces a great challenge. In order to address this challenge, researches have demonstrated that decisions made throughout construction upstream activity i.e. the design stage can stimulate construction safety. In Malaysia, safety topics are often not highlighted until the start of construction stage. Assimilating construction worker safety in the design consideration presents designs that are safe to be built and maintain. During design process, designers can provide best safety practices such as modification to permanent features, preparation of plans and specifications with construction safety is considered. Besides, communication of risk regarding design and utilization of specific safe design can also be integrated to eliminate or reduce hazards during construction and occupational stage. Assimilating construction worker safety into design is consistent with safety hierarchy of control which calls for eliminating or minimizing hazard before relying on management or temporary controls to protect workers. This paper aims to review the concept of assimilating construction worker safety into design published by various literatures.

Keywords : construction worker, design, safety, accidents.

1. INTRODUCTION

The construction industry has strong influence in Malaysia's economy. Although it only accounts for less than 5% of Gross Domestic Product (GDP), the industry enables the growth of other industries through its role as a fundamental building block of the nation's socio-economic development through expanding economic infrastructure and social infrastructure (CIDB, 2007). The industry has extensive linkages with construction related manufacturing industries with value added accounted for 27% (RM32.9 billion) in 2003 and financial services nearly 44% (almost RM200 billion) in 2005 (DoS, 2006). Construction industry also plays an important role in term of employment generation to the country. It contributes about 9% of total employment to the country in the year 2005 (DoS, 2006).

Regardless of its important role to the nation economy, the stakeholder of construction has low priority on the occupational safety and health of the worker. Although it seems to be a welcome declining in the number of reported fatalities in recent years but construction accidents continue to happen at an unacceptable rate. In the year 2003, out of the total 73,858 industrial accidents reported, 4,654 cases were recorded by construction industry, 566 cases resulted in permanent disabilities

while 95 cases resulted in death (SOCSO, 2003). The fatality rate per 100,000 workers for construction industry is 26 which is the highest compared to agriculture, forestry & fisheries industry and manufacturing industry which is 16 and 13 respectively in the year 2003 (SOCSO, 2003).

2. COST OF ACCIDENTS

The accidents statistics represent not only human tragedies but also significant to economic cost. Accidents have high direct and indirect cost (Levitt & Samelson (1987), Goetsch (2002) Bahari (2006)). The direct costs are insured which include medical costs, workers' compensation insurance claims, liability and property-damage insurance (Levitt & Samelson, 1987). The cost of these insurance rates varies since it is controlled by legislature and law as well as each company's own accident experience. Goetsch (2002) defined indirect costs as costs that are not directly identified with workplace accidents. According to Levitt & Samelson (1987), indirect or noninsured or hidden costs are the other and much larger economic burden imposed by construction accidents. They are rarely recorded and very hard to quantify.

Reduced productivity, job schedule delays, added administrative time, damage to equipment and facilities and costs of administering and handling workers' compensation insurance are hidden costs associated with accidents (Levitt & Samelson, 1987). Davies & Tomasin (1996) list out other effects of accidents in construction which are damage to plant & equipment, damage to work already completed, loss of productive work time while debris is cleared and damaged work rebuilt, reduce work rate until normal site working rhythm and morale are restored, disruption while investigations are carried out by the company safety department, the insurers, inspectors from authorities and representatives from trade unions, legal costs, fines, increased insurances premiums and loss of confidence.

Drawing icebergs demonstrate the relation between the direct and indirect costs of accidents (Levitt & Samelson (1987), Bahari (2006)). As illustrated in Figure 1, the top of the pyramid or iceberg represents the cost insurance premiums or direct cost. Down below which is the larger part represents another group of costs presumed the indirect costs. This describe that accidents are heavy financial burden to construction firms. Since accidents are controllable, savings can be made by reducing accidents. The very first step in controlling accidents is through safety. Effective safety input by

construction stakeholders pay off in financial as well as humanitarian terms (Levitt & Samelson,1987).

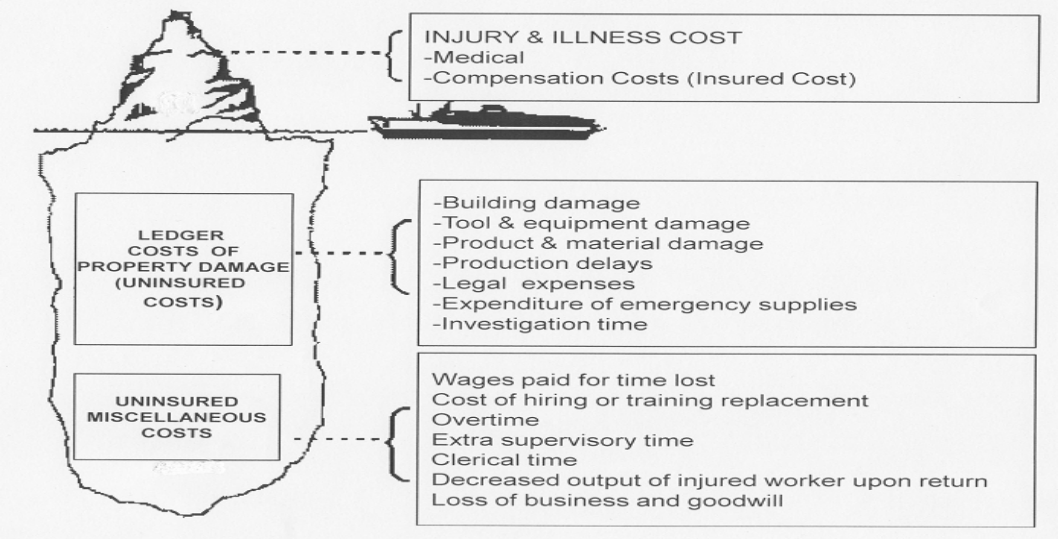

Figure 1. Accident cost iceberg (Bahari, 2006)

3. INFLUENCE OF DESIGN IN CONSTRUCTION SAFETY

According to Szymberski (1997) in Behm (2005), the greatest influence to safety of construction workers is in the early stage of a project i.e. conceptual and design phases. This time/safety influence curve, shown in Figure 2, illustrates that the ability to influence construction safety diminishes as the schedule moves from concept to start-up. Disappointingly, in Malaysia safety is usually is not address until construction begins. Therefore, the ability to effectively design for the elimination and reduction of hazards is not fully utilized.

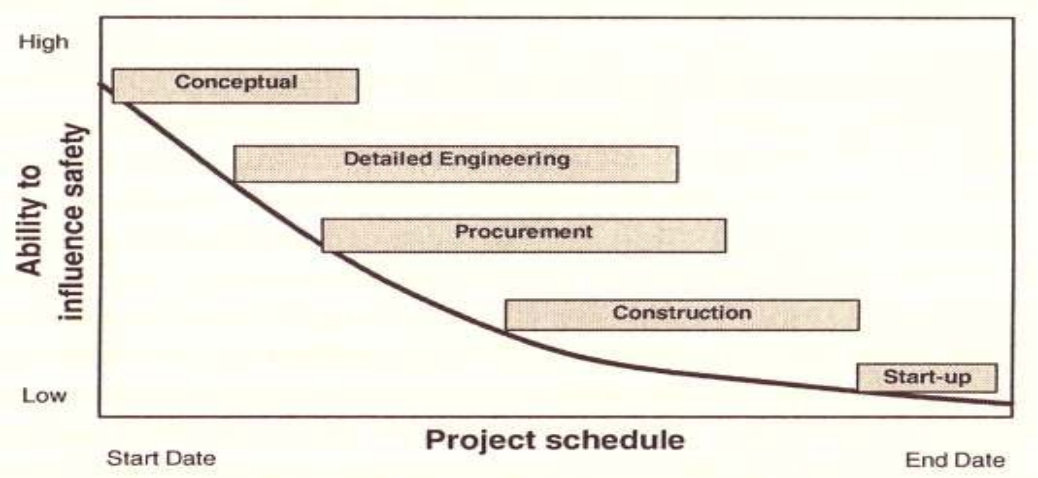

Figure 2 : Time/safety influence curve (Szymberski,1997)

Some studies have shown that a fairly large percentage of hazard that contribute to construction accidents could have been eliminate, reduced or avoided by making a better choices in design. Although survey by Kobe et al. (1988) failed to show details relationships between features of building design and accidents; research presented later by Behm (2004) found that the design was linked to the accident in approximately 22% of 226 injury incidents. In 2005, Behm discovered 42% of 224 fatality accidents in United States was linked to design. Afterward, Behm (2006) suggested that design have a strong influence on construction safety when he found out one third or 151 cases of the 450 incidents were determined to be linked to the design. To further explore the relationship between design and construction worker safety, Gambatese et al. (2007) utilized the knowledge and experience of an expert panel of construction industry professionals and academics. The expert panels were in agreement of the link between design and safety for 71% of the cases reviewed.

These findings supported Weinstein et al (2005) research who analyzed a large-scale safety in design initiative during the design and construction of a semiconductor manufacturing facility. The analysis provides important insights into how accident prevention efforts in construction industry can be done in preconstruction stage via design changes. Toole (2005) studied on designer's role on safety proposed that the designer could contribute through reviewing their design and creating design document for construction worker safety. Haslam et al. (2005) identified permanent works design as one of the originating influences or root causes of contributing factors in construction accidents. Although the effects of design are subtle and difficult to trace, their research demonstrated that nearly half of every 100 cases of construction accidents can be prevented through revising designs.

4. THE CONCEPT OF ASSIMILATING CONSTRUCTION WORKER SAFETY INTO DESIGN

THE CONCEPT

Earlier the concept is labeled as designing for safety, which is the formal process that incorporates hazard analysis at the beginning of a design (Mroszczyk, 2006). The hierarchy of design measures starts with eliminating the hazards by engineering design, then safety devices, warnings, instruction and training as the last resort. This process has been applied to the design of products, equipment, machines, facilities, buildings and job tasks (Mroszczyk, 2006). Designing for construction safety is an

extension of designing for safety to construction projects. The concept of designing for construction safety is viewed as a viable intervention to improve worker safety (Gambatese et. al., 2005). To be precise and comprehensible in Malaysian context, the term recommended is the concept of assimilating construction worker safety into design.

The concept of assimilating construction worker safety into design is an adaptation from designing for construction safety concept by Behm (2005) and Workcover (2001). The concept of assimilating construction worker safety into design is described as the deliberate consideration of construction worker safety during new construction, demolition, renovation, repair and maintenance works in the design of a project. This includes the modification of design to the permanent building features in such a way construction worker safety is considered; attention to construction worker safety during preparation and revision of design plans specifications and documents; communication of hazards and risk regarding the design in relation to the workplace and work to be performed; and utilizing of specific design available in design for safety suggestions. This concept call for concerns from multiple stakeholders such as clients, architects, engineers, surveyors, safety professionals, authorities, builders, end-users and maintenance or service representatives.

This concept is consistent with the hierarchy accident prevention approach used by safety professionals. This initiative calls for eliminating hazard, tackling risk at source and adapting work area to methods of work which could be done at the earliest stage in project lifecycle i.e. conceptual and design stage; before relying on technology, personal protective equipment, training or safety management at site (Holt, 2001). It is significant to note that this concept applies only to the aspects of design that make a project safer to build and maintain (Toole et. al., 2006). This approach does not focus on how to make different methods of construction engineering safer. For instance, this concept does not address how to erect safe scaffolding, but it does relate to design decisions that influence the location and type of scaffolding needed to safely accomplish the work (Toole et. al., 2006). Similarly, it does not focus on how to use fall protection, but it does include design decisions to eliminate or reduce hazards when using fall protection equipments.

The following is a sample of the design for safety suggestions by Gambatese & Hinze (1999), Mroszczyk, (2006) & Behm (2005):

1. Suggestion: Design components to facilitate pre-fabrication in the shop or on the ground so that they may be erected in place as complete assemblies. Purpose: Reduce worker exposure to falls from elevation and being struck by falling objects.
2. Suggestion: Allow adequate clearance between the structure and overhead power lines. Bury, disconnect, or re-route existing power lines around the project before construction begins. Purpose: Overhead power lines which are in service during construction are hazardous when operating cranes and other tall equipments.
3. Suggestion: Design permanent anchorage points at beams, columns and roof. Purpose: Provide fall protection anchorage during construction and maintenance.
4. Suggestion: Design and schedule a permanent stairway to be constructed at the beginning, or as close as possible to the start of construction. Purpose: Timely erection of permanent stairways can help eliminate fall and other hazards associated with temporary stairs and scaffolding.

IMPLEMENTATION – BARRIERS AND BENEFITS

In a survey participated by the designers, construction worker safety has been ranked as the lowest work priority when designing (Gambatese et al., 2005; Christionson, 2005). The quality of work was the highest priority ranked criteria among the designer, followed by final occupant safety and then project cost. Many designers perceive that designing for safety can lead to increased of project costs. Others mentioned that the concept would extend the project schedule and diminished design creativity (Gambatese et al., 2005). In contrast, Sinnott, (1985) believed that the designer must not allow the pursuit of artistic value or other objectives to obscure the need for safety. He also stress that design that does not accommodate safety is not a responsible design.

Concerns about legal liability of designing for construction worker safety also pose as limitation to the designers (Gambatese et al., 2005; Gambatese & Hinze, 1999). However, based on past legal cases, practice standard and professional duty, failure to employ safety knowledge may lead to increase liability exposure (Gambatese, 1998). For instance, if reasonable care with regards to address hazards or reasonable steps to prevent harm is not provided, the designer may be considered negligent in the performance of professional duties and perhaps liable for resulting

worker injuries. Designing a building is a target for litigation; implementation of safety measures is the key to protect against any action (Coble & Blatter, 1999)

Gambatese et al., (2005) discovered the factors that impact the implementation of design for safety concept and the impacts resulting from the implementation of the concept. Figure 3 illustrates the relationship to design for safety concept. Two critical factors to implement design for safety concept are the designer's knowledge and acceptance of the concept (Gambatese et al., 2005). Safety knowledge will not occur without conscious effort (Coble & Blatter, 1999). This effort starts with desire of the designers to study on safety fundamentals that is required by workers during construction and maintenance works. Safety input and experience from the constructors, owners and other safety professional will enhance designers understanding to assimilate safety into design. Safety will not be address if the designer is not alert of the concept; or does not allow the concept as part in the design practice; or does not know how to put the concept into practice (Gambatese et al., 2005).

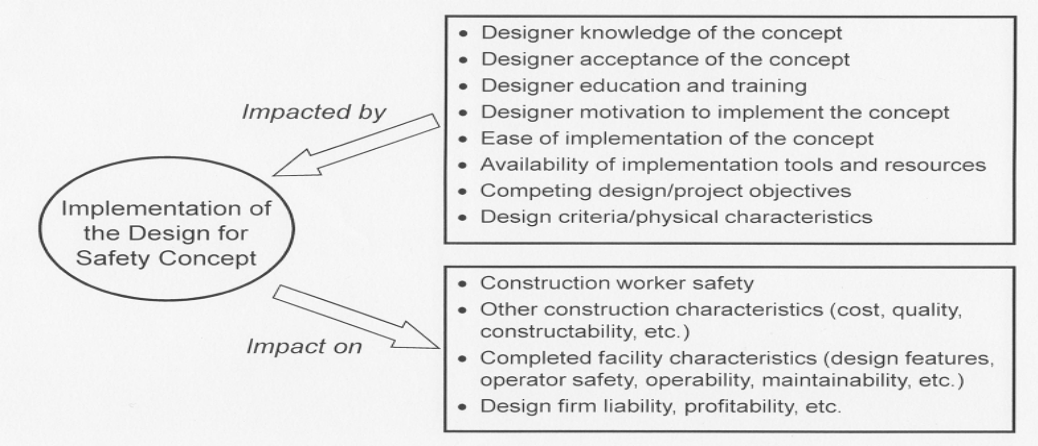

Figure 3: Factors affecting implementation of design for safety concept (Gambatese et al., 2005)

The concept of assimilating worker safety into design will benefit the entire construction industry. According to Gambatese & Hinze (1999) and Behm (2004) the consideration of construction worker safety during design stage can eliminate common safety hazards and reduce worker accidents. These will prevent injuries and fatalities; thus reduce associated accident cost during construction stage (Gambatese, 1998). If accidents happened, the cost associates with worker injuries and fatalities are passed to the constructors or owners and therefore increase the

overall project cost. Furthermore, through prevention of workers injuries and fatalities, the chances of the designers, constructors and owners will be involved in third party lawsuits might as well decrease (Gambatese, 1998). Other than construction stage, addressing safety in design will also lead to improved safety while performing maintenance during occupational stage (Gambatese, 1998; Behm, 2005).

Gambatese et al., (2005) recommended the concept of designing for construction worker safety to be incorporated in to building codes and standards; sustainability models; and construction occupational safety and health act. Coble & Blatter (1999) suggested the usage of contract to avoid conflict in defining safety responsibility for the reason that a contract is a tool to communicate the understanding of parties who documented their 'meeting of the minds'. Professional designers, owners and constructors are also urged to educate themselves on the principles and applications of design for safety (Workcover, 2001). They also need to communicate among each other to share knowledge and resolve problems relating to design, construction and maintenance as a team oriented approach of designer, owner and constructor is viable for this concept to be meaningful (Behm, 2005).

5. APPROCHES IN ASSIMILATING CONSTRUCTION WORKER SAFETY INTO DESIGN

DESIGN FOR CONSTRUCTION SAFETY TOOLBOX

A study has been conducted by Construction Industry Institute, United States on creating a database of safety ideas and a design tool that allows designers to address construction worker safety in designs. These design suggestions were developed as computer-based safety tool entitle Design for Construction Safety Toolbox (Gambatese et al., 1997). The design tool provides safety hazard identification; suggestion the best means to eliminate or reduce hazard occurrence; effective documentation and generation of report result; and the ability for other design suggestions to be included, saved and used in the future. This user friendly design tool is useful to increase designer involvement not only in construction phase, but also during startup, maintenance and decommissioning phases of a project

CONSTRUCTION HAZARD ASSESSMENT IMPLICATION REVIEW (CHAIR)

CHAIR (Construction Hazard Assessment Implication Review) is a tool that has been developed in Australia to assist construction stake holders in reducing construction, maintenance, repair and demolition risk associated with design. The aim of CHAIR is

to identify and eliminate or minimize risks in a design in the construction project lifecycle. CHAIR consist of three phases (Workcover, 2001) as illustrated Figure 4:
CHAIR 1 is performed at the conceptual stage of a design which is the best opportunity to make fundamental change, even though much of the design is still to be determined.
CHAIR 2 focuses on construction and demolition issues and is performed just prior to construction, when the full detail design is known.
CHAIR 3 focuses on maintenance and repair issues and is performed at the same time as the CHAIR 2 study.

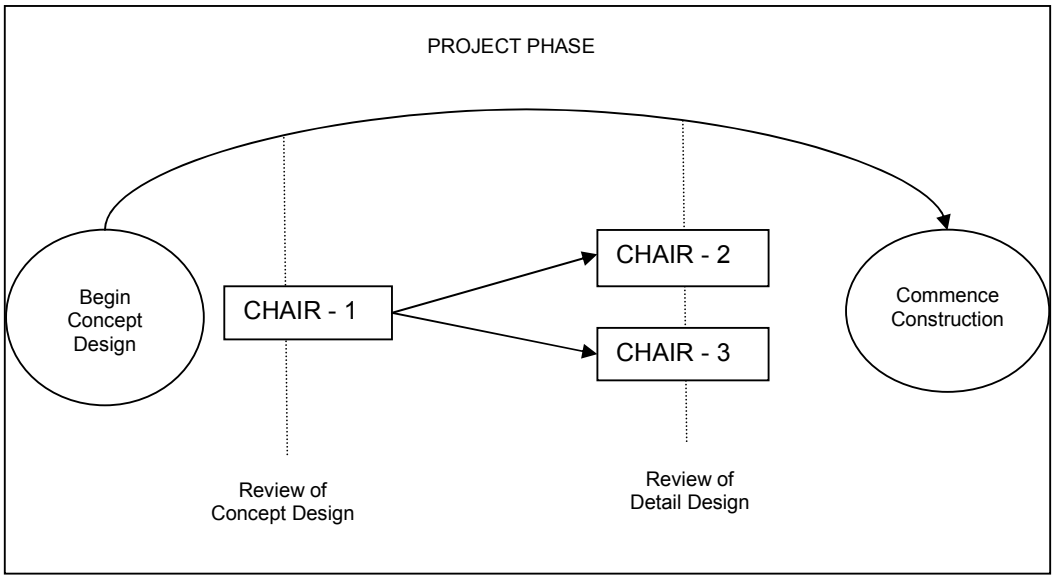

Figure 4 : CHAIR framework (Workcover, 2001)

CHAIR workshop intended to form a final design by means of key consideration of operability, aesthetics, economics, with the elements of safety in constructability and maintainability (Workcover, 2001). A facilitator is required to encourage participants to constructively challenge the design and explore whether issues have been overlooked or sufficiently thought through.

CONSTRUCTION (DESIGN & MANAGEMENT) REGULATIONS 2007 (CDM 2007)

Construction (Design and Management) Regulations 2007 (CDM 2007) are the revised form of Construction (Design and Management) Regulations 1994 (CDM 1994). CDM 2007 were laid before Parliament as Statutory Instrument 2007 No320, and enacted on 6 April 2007. These regulations apply to all construction work in Great Britain and its territorial waters. CDM 2007 which are accompanied by an

Approved Code of Practice (ACoP), are the combination of update CDM 1994 and the remnants of Construction (Health, Safety and Welfare) Regulations 1996 (HSE, 2007; Summerhayes,2008). The following Figure 5 points out the content of CDM 2007:

Part 1	Regulations 1 to 3	Introduction	Contains the application of the Regulations and definitions
Part 2	Regulations 4 to 13	General management duties: all construction projects	Contains general duties that apply to all construction projects
Part 3	Regulations 14 to 24	Additional duties where project is notifiable	Contains additional duties that only apply to notifiable construction projects
Part 4	Regulations 25 to 44	Duties relating to health and safety on construction sites	Contains practical requirements that apply to all construction sites
Part 5	Regulations 45 to 48	General	Contains the transitional arrangements and revocations

Figure 5 : Content of CDM 2007 (HSE, 2007; Summerhayes,2008):

CDM 2007 requires all those who work in construction industry have their parts on safety and health; and improving the industry's record (HSE, 2007). During design process, emphasis should be on hazard identification and risk management strategy. On all projects, designers are required to eliminate hazards and risks during design stage and provide information about remaining risk. As addition, on notifiable projects (projects involve 30 days or 500 person days of construction works), designers ought to provide information needed for health and safety file. Clients of notifiable projects are required to appoint a CDM coordinator. The CDM coordinator is required to coordinate health and safety aspects of design works and cooperate with other duty holders.

5. CONCLUSION

The advantages of considering construction worker safety are to lessen the human misery through diminishing injuries and fatalities at work; as well as to reduce the accident cost whether the direct or indirect cost. As for the government, the decreasing number of accidents will boost the image of the country's construction

industry in delivering the economic and social benefits to the public (CIMP, 2006). Besides, safety implementation is vital to build a sustainable local construction industry in competing with the global practices and players.

One of the means to reduce or eliminate accidents is through assimilating construction worker safety in design consideration. This concept is viable and significant to improve safety as indicated in previous studies by Gambatese et al. (2005) and Behm (2005). The approaches that have been developed in other countries could assist not only designers, but also other construction key holders in providing best practices to shrink and remove of hazards during design stage and deliberately enhance construction worker safety. Putting this concept into practice in Malaysian construction industry requires substantial changes which required time, effort, regulatory, knowledge and mindset transformation among construction players.

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