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Identification of the Activity-based Hazards/risks Involved in the IBS Construction Process: Case Study of Project That Uses Prefabricated Steel Framing System and Prefabricated Timber Framing System

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Abstract. Construction industry is known for its hazardous physical working environments and high accident risks. In reducing risk at the workplace, Occupational Safety and Health (OSH) is an important aspect. It is a standard which are set in legislation with the purpose to eliminate and reduce hazards at workplace. The objectives of this paper are to identify the major activities of the construction process in IBS residential and the OSH risks associated throughout the construction. This study involved a field observation to two different methods and two factory that use IBS as construction method which are 'prefabricated timber framing system', and 'prefabricated steel framing system'. This involved interview to the executive staff, operatives and supervisors, and observing and documenting operations. In achieving this, four case study were descriptively analysed and availing a revelation exposure to UV and mobile plant risks as the major risk in IBS construction site. This paper intends to contribute in providing a way for designers to integrate construction process knowledge into design to eliminate or reduce hazards during construction. It will effectively address the designer's role in making decisions in their designs and further illuminate the level of OSH risk their designs pose.

1. Introduction

The construction industry is known for its hazardous physical working conditions and high accident risks. It is one of the most hazardous industry compared to other industries due to the nature of activities at the worksites [1-2]. The construction industry is one of the four major contributing industries in the workplace. Despite, the average five years of death for this industry in Malaysia is 99 employees per year from 2011 to 2015. The death rate for 100,000 construction workers in 2015 was 10.94, higher than the average mortality rate for five years 2011-2015 of 8.17. The trend of fatal injuries to construction workers has risen since 2012, and 140 construction workers have died in 2015, the highest since 2001 and the highest in the 21st century.

As shown in Figure 1, the number of fatal injuries to workers in all industries, overall showed a decline, but the number of fatal injuries of workers in the construction industry showed an increase. The five-year average from 1999 to 2003, number of fatal injured workers in all industries was 898,



while the average five years from 2011 to 2015 was 639. The five-year average for the deaths of all industry workers showed a 28.8% decline. Besides, the five-year average from 1999 to 2003, the number of fatal injured workers in the construction industry was 115, while the average five years from 2011 to 2015 was 99. Five-year average for the fatal injuries of all industry workers showed a decrease, but at lower rates at 13.9%.

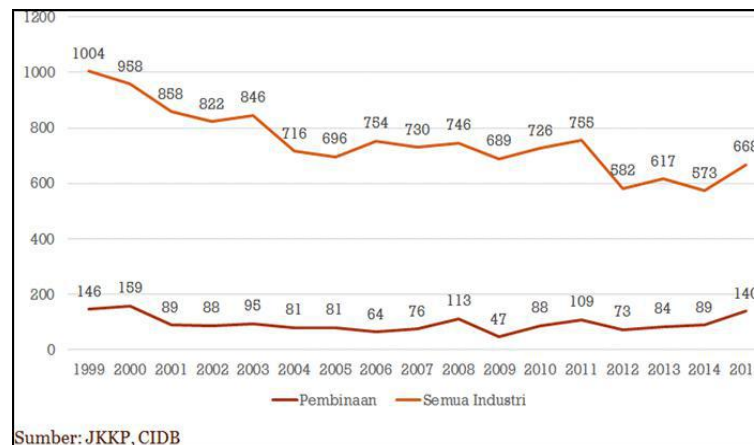


Figure 1. Accident statistics for construction and overall industry from 1999-2015 [3].

Accidents do regularly occur on construction site, though some of the accident causation or prevention models have failed to mention the types of accident on building site, whereas it is domineering to expose the various types of accident occurring on building sites[4]. Building site accidents range from fall-related accidents [5], fire outbreak [6], explosion [7], electrocution/electrical incidents [8], vehicle accidents [9], roof construction falls [10], fall of heavy objects during lifting, and contact with electric current [11]. Additionally, different types of accident on construction sites among many others to be: falls from roof, scaffold, stairs, ladder, ramp, and elevator shaft; crane accident; struck by moving vehicle, struck by an operating machine or defective machines (boilers, bulldozers, backhoes), run over by operating equipment; equipment/tools-related accident; slips and trips; electrocutions/electricity; and explosions [12].

Due to frequent accidents, IBS construction has been suggested as a replacement to traditional construction methods of the many initiatives that could be implemented to improve OSH performance [13-14]. The Malaysian government is actively promoting the adoption of IBS and encouraging a paradigm shift in the construction process, from a traditional to an industrialized approach [15]. This is demonstrated by the promulgation of the Construction Industry Master Plan (CIMP) 2006-2015 [13], which specifically mentions IBS and its implementation through IBS Roadmaps.

IBS is contrary from that traditional processes in term of the nature of activities that consist of four stages which manufacturing, delivery, component installation and in situ works [2]. IBS is an industrialized process in which components of a building are conceived, planned, and fabricated, and then transported to and erected on site [15][16]. Compared to the traditional method, IBS or more specifically offsite construction are claims can reduce site accidents [17-20][15].

This paper presents the findings of the risk involved in a construction process that use IBS as the construction method. This finding of the study is presented by showing the list of the hazards involve in the construction building wall for several IBS method which pre-fabricated steel framing and pre-fabricated timber framing.

2. Methodology

This study involved a field observation on two different IBS system construction sites and two factory of IBS component. Two sites have been visited, which represent IBS types which are 'prefabricated

timber framing system' and 'prefabricated steel framing system'. This involved talking to the managerial staff, operatives and supervisors, and observing and documenting operations.

This study focused on the major activities of the construction process in IBS residential construction that only cover for structure and building envelope. Data has been collected on on-going construction projects, which used the selected construction approaches to observe the process involved and to identify the associated OSH risks.

3. Result

This study was completed through a combination of field observation, interviews and document analysis. These served to identify the construction process in terms of activities and the risks associated with the process. This section summarizes the data from field observation and the interviews.

3.1. Prefabricated steel framing system

This type of IBS classification is commonly used with pre-cast concrete slabs, steel columns and beams. Steel framing systems have always been the popular choice, used extensively in the fast-track construction of skyscrapers. Recent development in this type of IBS includes the increased usage of light steel trusses consisting of cost-effective profiled cold-formed channels and steel portal frame systems as alternatives to the heavier traditional hot-rolled sections [21].

The project was a government project with the contract worth about RM 430,000.00. The system used for the construction of the building uses pre-fabricated steel framing system, by integrating assembling components of a structure in a factory or other manufacturing site and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located. The connection system used for this project is a combination of bolt and screw and welding joint.

The main risks were associated with the lifting component of materials to the required position, for example site conditions and the stability of materials. In addition, radiation and thermal also highlighted during installation of H-column and I-beam. The risks were then categorized into damaging energies for evaluation. Table 1 provides a clearer view of the risks involved in each activity.

Table 1. Activities and risks on prefabricated steel framing system [15].

Process	Activities	Risk/Hazard and description
Manufacturing	Material preparation	MSDs
	Forcing pliable metal through large rollers;	MSDs Exposure to UV Electrical shock Dermatitis
	Heat hot-rolled beam above the recrystallization point	Heat from the burning point MSD, RSI Mechanical handling Inappropriate material handling method
	Cutting of metal	MSD Excessive noise
	Assemble of component	Mechanical handling
	Transferring the components to stockyard	Inappropriate stacking method
Delivery	Load component onto truck	Mobile plant risks (vehicle injury) Musculoskeletal Disorder (MSD), Repetitive Strain Injury (RSI)

		Mobile plant risks
	Transport and deliver materials	Road traffic risks Instability of materials
	Off-load materials on-site	Mobile plant risks (vehicle injury) MSD, RSI Mobile plant risks
	Stacking component	Collapse of elements/materials
Pre-in situ	Installation of BRC for slab	MSD, RSI Exposure to UV
	Casting and Vibrating	MSD, RSI Dermatitis Hand-arm vibration (HAVs) Exposure to UV
Installation	Lifting component	Excessive noise from mobile plant Exposure to UV Craneage risk
	Installation of H-column	Craneage risk, working at height, Due to inappropriate installation Vehicle injury MSD, Hand injury Excessive noise from mobile plant Exposure to UV Exposure to welding heat
	Installation of I- Beam	Craneage risk, working at height, Due to inappropriate installation Vehicle injury MSD, Hand injury Excessive noise from mobile plant Exposure to UV Exposure to welding heat
	Adjusting component to required position	Craneage risk Vehicle injury MSD, hand injury Exposure to UV
	Installation of bracing or propping	HAVs Electrical shock From machine Due to inappropriate propping Exposure to UV
In-situ	Prepare for bricklaying	
	Transfer brick	MSD, RSI Mobile plant risk Lifting equipment risk Exposure to UV
	Moving brick to workface	MSD
	Mix mortar	Dermatitis MSD, RSI Exposure to UV
	Cut brick	Electrical shock

		Exposure to excessive noise from cutting machine Struck by cut brick from saw
	Laying mortar	Dermatitis MSD, RSI Working at height Exposure to UV
	Laying of each course of brick	Working at height MSD, RSI Dermatitis Exposure to UV
	Fix wall ties;	MSD, RSI Working at height
	Plastering and finishing	Exposure to chemical compound Working at height RSI Exposure to UV

3.2. Timber framing system

Prefabricated timber framing systems consist of timber building frames and timber roof trusses. While the latter are more popular, timber building frame systems also have niche markets; offering interesting designs from simple dwelling units to buildings requiring high aesthetic values such as chalets for resorts [21].

The project was a private project with the cost about RM 150,000.00. The system used for the construction of the building uses timber framing system, by integrating assembling components of a structure in a factory or other manufacturing site and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located. The connection system used for this project is a combination of bolt and screw.

The OSH risks highlighted were mainly associated with the ergonomic-related risks, and exposure to UV. The cutting timber involved RSI due to repetitive works. The use of chemicals was identified in the activities planning works. In mortise and tenon cutting, the main OSH risks highlighted were MSD and manual handling. Mobile plant risks were identified in moving and storing the panels. The risks associated with the activities are depicted in Table 2.

Table 2. Activities and risks on timber framing system method [15].

Process	Activities	Risk/Hazard and description
Manufacturing	Material preparation	-
	Wooden log split	Cuts Excessive noise from cutting machine Electrical shock RSI
	Timber cutting	Cuts Excessive noise from cutting machine Electrical shock RSI
	Planing the timber	Cuts Excessive noise from cutting machine

		Electrical shock RSI Dermatitis
	Transfer to mortise place	Road traffic risk Stability of material
	Mortise and tenon cutting	Cuts Excessive noise from cutting machine Electrical shock RSI
	Drilling hole for connection	Cuts Excessive noise from cutting machine Electrical shock RSI
Delivery	Load component onto truck	Mobile plant risks (vehicle injury) Musculoskeletal Disorder (MSD), Repetitive Strain Injury (RSI) Mobile plant risks
	Transport and deliver materials	Road traffic risks Instability of materials
	Off-load materials on-site	Mobile plant risks (vehicle injury) MSD, RSI Mobile plant risks
	Stacking component	Collapse of elements/materials
Pre-in situ	Installation of BRC for slab	MSD, RSI Exposure to UV
	Casting and Vibrating	MSD, RSI Dermatitis Hand-arm vibration (HAVs) Exposure to UV
Installation	Lifting component	Excessive noise from mobile plant Exposure to UV MSD
	Installation of timber column	Working at height, MSD, Hand injury Excessive noise Exposure to UV
	Adjust the position of the column	MSD, hand injury Exposure to UV
	Installation of timber beam	Working at height, MSD, Hand injury Excessive noise Exposure to UV
	Adjusting component to required position	MSD, hand injury Exposure to UV

	Installation of bracing or propping	HAVs Electrical shock From machine Due to inappropriate propping Exposure to UV
	Bolt and screw the connection between beam and column	MSD
	Installation of timber plank	MSD
	Nails the end of the plank	Excessive noise from hammer Exposure to UV Working at height
	Finishing	Exposure to chemical compound Working at height

4. Results and Discussions

From the table above, the delivery stage provides likenesses in the process for most construction approaches; pre-fabricated steel framing system; and pre-fabricated timber framing system. This likeness provides general of the processes. However, there are differences in element nature between the approaches, whether it is timber component or steel framing. The difference is designed by the way the process is done and the physical feature of the element which will eventually give a different risk. Besides, manufacturing stage, pre-fabricated steel framing shown that MSD is the major risk due to were manual handling activities. Pre-fabricated timber framing shown RSI is the major risk due to repetitive work on manufacturing stages. For installation of component, exposure to UV were the major risk for both constructions approaches due to exposed to sun during the installation activities. For instance, ‘lifting component’ activities for both construction approaches shown that exposure to UV and excessive noise from the mobile plant were the risk which provides likenesses in the process. The in-situ stages provide similarities in the activities which will eventually give a same risk for both construction approaches.

5. Conclusion

This paper had identified and discussed the activities and risk associated in IBS construction in Malaysian construction industry. The level of safety in IBS industry in the construction industry was still low even though the government had seriously promoted and encouraged the use of IBS to have a better practice in the construction industry. The risk on IBS construction site faced by the workers had been discussed and mainly revolves around UV exposure, MSD, working at height, excessive noise and mobile plant risk. Despite the negative perspective concerning IBS method, this does not mean the future for adoption of IBS method by the prospects would be low. Future research is sought for more investigation to be done for the qualitative stakeholders’ perspectives on the factors that impede the IBS adoption in the construction industry.

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