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The Effect of Prefabricated Steel Framing System Towards Construction Occupational Safety and Health (OSH)

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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 and to compare the impact of IBS construction with conventional method. This study involved field observation to one (1) construction sites that use IBS construction which are 'prefabricated steel framing system'. Observations were also conducted at the manufacturing facilities of the prefabricated steel framing system. This also involved interview to the executive staff, operatives and supervisors and documenting analysis. The analysis is done by comparing the effect of IBS method with conventional method. In achieving this, one (1) case study was descriptively analyzed and availing a revelation exposure to UV and mobile plant risks as the main risk in IBS construction site. This paper intends to contribute in providing a way to integrate construction process knowledge to eliminate or reduce hazards during construction.

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%.

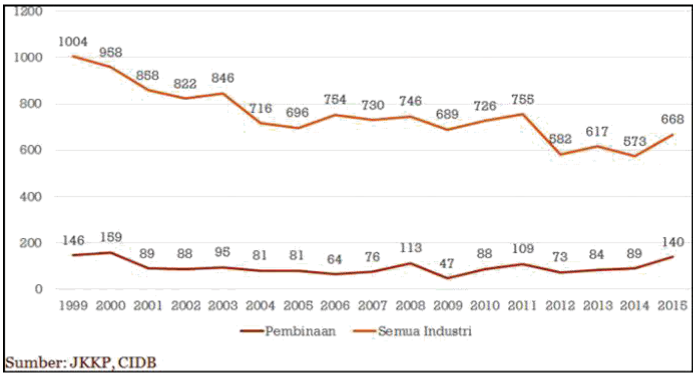

Figure 1. Accident statistics for the construction and others industry from 1999-2015 [3]

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].

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 [5-6]. 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 [7]. This is demonstrated by the promulgation of the Construction Industry Master Plan (CIMP) 2006-2015 [5], which specifically mentions IBS and its implementation through IBS Roadmaps To date, the importance of IBS in improving construction industry is highlighted under Construction Industry Transformation Programme (CITP) 2016-2020. IBS offers better productivity, quality and safety, and can further help towards a better construction industry, as well as enhance the global competitiveness of Malaysia construction industry [2].

The implementation of IBS changes the nature of activities, which are different from traditional processes. In IBS, the process is industrialized by which components of a building are conceived, planned, fabricated, transported to and then erected on site [8]. Even though there are several studies indicating IBS can significantly reduce OHS risks in traditional construction [9], [10] extent of IBS impact upon safety and health in construction is still unclear as there is no current system to assess OHS risk in the construction process. UK government reports including identified offsite as a strategy for health and safety performance improvement, however, there is an ongoing need to address the lack of knowledge regarding offsite and its affects. Knowledge relating to the identification of the occupational safety and health risks in the offsite factory is required. This study aims to investigate the effect of IBS methods towards construction OSH risk.

The findings are presented by showing the comparison of the hazards/risks associated with the activities of the construction process in IBS and conventional building construction. Due to the limitation of time, this study only covers three IBS methods, which are: pre-fabricated steel framing, pre-fabricated timber framing and formwork system.

2. Literature Review

2.1. Overview of construction industry

The new interest in Industrialized Building Systems (IBS) to replace the traditional in-situ construction method has been fostered as the huge demand for construction projects especially in building construction. The importance of IBS implementation is highlighted in the *Construction Industry Master Plan* (CIMP 2006-2015), under the *Strategic Thrust 5* [6]. The Government of Malaysia has emphasized the full utilization of IBS for government projects by the inclusion of not less than a 70% IBS component [5]. Further, the IBS Roadmap 2011-2015 aims to raise the existing IBS score from 70% to 80% by 2015 for government projects above RM10 million.

The Construction Industry Transformation Programme (CITP) 2016-2020 was initiated to streamline the construction industry, with the vision to create an advanced, highly productive construction industry that will be a major contributor towards Malaysia's ambition of becoming a high-income nation by 2020. The CITP, which sets important strategic goals and milestones to bring Malaysia's construction industry to the next level, aims to transform the construction industry, encompassing four strategic thrusts: 1. Raising the overall productivity level of the industry, 2. Environmental sustainability being incorporated in the design, construction, and subsequent maintenance of buildings and infrastructure, 3. Focusing on improving competitiveness in the capability and capacity of industry players to foray internationally, and 4. Improving the overall quality, safety and professionalism of the industry [11].

2.2. Types of IBS
In Malaysian context, there are six (6) types of construction methods classified under IBS categories [23], which are: i) precast concrete framing, panel and box system; ii) prefabricated steel framing; iii) prefabricated timber framing; iv) formwork system; v) blockwork system; vi) innovative system. In this study, only one (1) types of IBS are covered which is prefabricated steel framing system. The details of selected type of IBS method are described below:

2.2.1. Pre-fabricated 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 [11].

2.3. The phases of IBS construction compare to conventional method
There are differences between construction process between IBS and conventional methods. Commonly, conventional construction only involved delivery of construction materials and components to site, before massive in-situ construction activities begin. The process is different from IBS, in which IBS requires the manufacturing of the building components either in factory or onsite, before transporting to- and installation of the components at the site. The different stages between IBS and conventional is shown in Figure 2. In each stage, there are several activities involved in which these activities create hazards and risk to the workers involved.

The different situation for IBS (off-site) and traditional (in-situ) construction is depicted in Figure 2. For traditional construction, the activities require materials and components (fixtures and fittings) to construct building on site. In contrast, IBS involves materials and components to assemble building elements in a factory, which are delivered and installed on site. Within these phases, there are several activities involved within them.

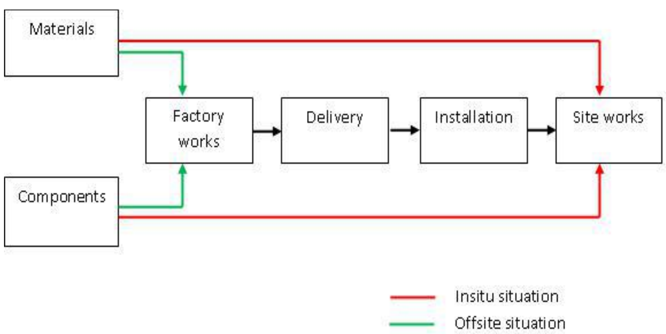

Figure 2. Conventional and IBS processes [7][10]

3. Methodology

This study involved a field observation on one IBS system construction site and one factory of IBS component of prefabricated steel framing system. One site has been visited, which represent IBS types which is 'prefabricated steel framing system'. This involved interview to the managerial staff, operatives and supervisors, and site observing and documenting operations.

Observation can complement interviews as a valuable source of additional data. During the site observation, a significant amount of time has been spent directly observing the activities and process operations of each case.

For the purpose of this research, semi-structured interviews have been used which offer open responses from participants to specific questions. Several artefacts and documentary sources have been collected during the empirical data gathering activities. These included case study organizations' corporate publications, and case study organizations' public website and presentation material. This documentary evidence acts as a method to cross-validate information gathered from interviews and observations and provide guidelines in assisting the author with the inquiry during interview. Documents and records pertaining to the construction process observed are analyses. The corroboration of multiple qualitative techniques for these case studies enhances the validity and reliability of findings. This method also used to support the knowledge obtained from field observation and interview methods.

In addition, this study used the data gathered by Abas [7] when obtaining the information about activities and associated hazards/risks involved in the construction process of conventional method. Next, the data is analyzed by comparing the risk changes for IBS method with conventional in each construction stage. The comparison is made by the authors based on referred guidelines, legislations, journals, and other published materials.

4. Result and Discussion

4.1. 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.

4.1.1. Prefabricated steel framing system

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.

4.2. Comparison of IBS method and conventional method

4.2.1. Comparison between conventional and pre-fabricated steel framing system

The summary of comparison is shown in Table 1 (Appendix 1). The risks change is described:

Risks removed by IBS

There are several risks that eliminated with the usage of IBS as compared to conventional method. One of the risks that being emphasized with the use of pre-fabricated steel framing system is the risk of manual handling within the activity of installation of column and beam formwork. Besides, the risk that also can be eliminated is the exposure to chemical compound during curing process. The system eliminated the usage of human energy during installation of component, a major benefit in eliminating this serious risk type using offsite.

Risk changes – amelioration of risks

Furthermore, three risks were analyzed to be more controllable and of a less serious nature in the transition from in-situ to IBS, this helps to explain the changes in risk which the take up of offsite has had on the manufacture of products/units. The installation of column and beam were less likely to incur exposure to chemical compound, repetitive tasks and excessive vibration.

Activities with similar risks

From the Table 2, the specific activities; the delivery of materials; load component, delivery of element, off-loading the element and stacking of element was analyzed to be the same for both in-situ construction and IBS. The suggestion is that there are certain activities where the risk remains unchanged regardless of the construction technique or technology used.

Additional risks

Several risks that were apparent as same extent between the IBS techniques and in-situ activities. Welding of the component during component installation were expose to the UV where it led to the exposure to radiation and eye irritating which have a more serious consequence.

4.3. Discussion

From the table above, the delivery stage provides likenesses in the process for most construction approaches; conventional method and pre-fabricated steel framing system This likeness provides general of the processes. However, there are differences in element nature between the approaches, whether it is timber component, formwork system 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.

The main risk associated with the conventional method were to be associated with the transport of material, road traffic, site access, inappropriate method of handling and mobile-plant risk. The main risk associated with in situ site work were associated with dermatitis, repetitive task, manual handling and MSD.

For IBS method, the main risk associated with the pre-fabricated steel framing system at Table 1 were MSD, mobile plant risks, manual handling and exposure. For installation of component, exposure to UV were the major risk for all 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 all construction approaches.

The results also revealed that, for prefabricated steel framing construction method, risks keep on in several activities. For example, the risk in laying mortar during in situ works is similar to that involved in the in-situ concrete and masonry method. Moreover, it consists of several activities during in situ works that are like those of the traditional method, e.g. bricklaying. This is in agreement with [15] that suggest that designers cannot assume that IBS will remove all occupational health and safety risks. Rather, the risk profiles showed that for certain damaging energies, they may be absent or relatively low in one phase but exist in other phases.

5. Conclusion

This paper had identified and discussed the activities and risk associated in IBS construction in Malaysian 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. 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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APPENDIX 1

Table 1. Comparison between in situ and masonry method and pre-fabricated steel framing system

In Situ and masonry method				Pre-fabricated steel framing system			
Main Delivery Activities				Main Delivery Activities			
cf IBS	**Main Risks**	**Main Hazards**	**Main Off-Site Activities**	**Main Off-Site Activities**	**Main Hazards**	**Main risks**	**cf insitu**
S	Vehicle (mobile-plant) risk Musculoskeletal Disorder (MSDs) Repetitive Strain Injury (RSI)	Mobile plant Manual handling	Load onto transport	Transfer to stockyard	Mobile-plant Caught in between object Repetitive work, manual handling Exposure to UV	Mobile plant risk (death) MSD Skin cancer, cornea	S
S	Road traffic risks, Musculoskeletal Disorder (MSDs) Repetitive Strain Injury (RSI)	Mobile plant Inappropriate method of bracing the element	Delivery of element (transportation)	Load onto transport	Manual handling Mobile Plants	MSD, RSI Mobile plant risks (death)	S
S	Mobile plant risks, vehicle (mobile plant) risks	Manual handling,	Off-loading the element at site	Delivery of element (transportation)	Road traffic Inappropriate method	Mobile plant MSD, RSI	S
S	Musculoskeletal Disorder (MSDs) Repetitive Strain Injury (RSI)	Inappropriate method of bracing the element	Stacking of element	Off-loading the element at site	Crane Manual handling Mobile plant risks	Creneage risk RSI, MSD Mobile plant	S
				Stacking of element	Inappropriate method of stacking element	MSD, RSI	S
Main in-situ work activities				Main Component Installation Activities			
cf IBS	**Main Risks**	**Main Hazards**	**Main On-Site Activities**	**Main On-Site Activities**	**Main Hazards**	**Main Risks**	**cf insitu**
S	Chemical burn from wet concrete, Respiratory tract irritation RSI, MSD Skin cancer, cornea	Exposure to chemical compound Manual Handling Exposure to UV	Mix concrete	Install the BRC for slab	Manual handling Exposure to UV Inappropriate method	MSD, RSI Skin cancer, cornea	LL
S	RSI, MSD Chemical burn from wet concrete, Respiratory tract irritation Hand-arm vibration (HAVs)	Manual handling, repetitive tasks Exposure to chemical compound Excessive vibration Exposure to UV	Concreting and vibrating	Casting slab and vibration	Excessive vibration Electricity	HAVs Electric shock	S

IOP Conf. Series: Materials Science and Engineering **601** (2019) 012035 doi:10.1088/1757-899X/601/1/012035

	Skin cancer, cornea						
ML	RSI, MSD Skin cancer, cornea	Manual handling, repetitive tasks Exposure to UV	Fix rebar/steel bar for column	Column stump construction	Manual handling Exposure to sun, heat	MSD, RSI Heat fatigue	LL
LL	RSI, MSD	Manual handling	Install column formwork, propping	Drill the stump	Repetitious drilling Electricity Manual handling Exposure to spark Exposure to noise Excessive vibration	RSI. HAVs Electric shock MSD, RSI Skin burns Excessive noise, loss of hearing HAVs	A
A	Chemical burn from wet concrete, Respiratory tract irritation Hand-arm vibration (HAVs) Skin cancer, cornea	Exposure to chemical compound Excessive Vibration Exposure to UV	Pour concrete into formwork & vibrating	Anchor bolt setting	Repetitive works Exposure to UV	RSI Skin cancer, cornea	LL
LL	Chemical burn from wet concrete, Respiratory tract irritation	Exposure to Chemical compound	Curing compound	Preparation of column and beam installation	Exposure to UV Repetitive works Muscle injury Manual handling working at height	Skin cancer, cornea RSI MSD MSD, RSI Falling from height	A
A	RSI, MSD	Manual handling	Formwork removal	Install the H-column and I-beam	Manual handling, Excessive noise, Exposure to UV Inappropriate methodworking at height	MSD, RSI Loss of hearing Skin cancer, cornea MSD	A
S	Vehicle (mobile plant) risks Lifting risks, RSI, MSD Skin cancer, cornea	Mobile plant Manual handling, repetitive tasks Exposure to UV	Transport bricks (from storage to working areas)	Welding the H-column and I-beam	Exposure to chemical compound Exposure to UV Electricity	Chemical burn from wet concrete, Respiratory tract irritation Skin cancer, cornea Electric shock	A
				Main In-situ Work Activities			
S	RSI, MSD	Manual handling	Carriage/moving bricks to workface	Transport brick	Manual handling, repetitive tasks Vehicle (mobile plant) Exposure to UV	MSD, RSI Vehicle (mobile plant) risks Skin cancer, cornea	S
A	RSI, MSD Falling from height	Manual handling, overhead work Working at height	Erecting work platforms	Carriage of brick to workplace	Manual handling	MSD, RSI	S
S	Chemical burn from wet concrete, Respiratory tract irritation Skin cancer, cornea	Exposure to chemical compound exposure to UV	Mix mortar	Mix mortar	Exposure to chemical compound exposure to UV	Chemical burn from wet concrete, Respiratory tract irritation Skin cancer, cornea	S
S	Loss of hearing MSD, hand injury	Excessive noise from cutting machine Struck by the saw	Cut bricks	Cut brick	Excessive noise from cutting machine	Loss of hearing Hand injury, MSD	S

IOP Conf. Series: Materials Science and Engineering **601** (2019) 012035 doi:10.1088/1757-899X/601/1/012035

					Struck by the saw		
S	Chemical burn from wet concrete, Respiratory tract irritation MSD, RSI Skin cancer, cornea Falling from height	Exposure to chemical compound Manual Handling Exposure to UV Working at height	Laying mortar	Laying mortar	Exposure to chemical compound Manual Handling Exposure to UV Working at height	Chemical burn from wet concrete, Respiratory tract irritation MSD, RSI Skin cancer, cornea Falling from height	S
S	Falling from height, RSI, MSD Chemical burn from wet concrete, Respiratory tract irritation Skin cancer, cornea	Working at height Manual handling, repetitive tasks Exposure to chemical compound Exposure to UV	Laying of each course of bricks	Laying of each course of brick	Working at height Manual handling, repetitive tasks Exposure to chemical compound Exposure to UV	Falling from height MSD, RSI Chemical burn from wet concrete, Respiratory tract irritation Skin cancer, cornea	S
S	RSI, MSD	Manual handling, repetitive tasks	Fix wall ties; fix mesh reinforcement; place lintels and DPC	Fix wall tiles	Manual handling, repetitive tasks	MSD, RSI	S
S	Exposure to toxic chemical Falling from height MSD, RSI Skin cancer, cornea	Exposure to chemical compound Working at height Repetitive task, exposure to UV	Plastering/finishing	Painting and finishing	Exposure to chemical compound Working at height Repetitive task, exposure to UV	Exposure to toxic chemical Falling from height MSD, RSI Skin cancer, cornea	S

Risk change code: **S= Same (no change), A = Additional (new risk), LL = Less likely, ML = More Likely, LC = Less serious consequence, MC = more serious consequence, C = more controllable**