

A Study of Tower Crane Accidents and its Mitigation Measures

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Abstract: The construction of high-rise towers, large apartment blocks or urban buildings requires the use of tower cranes in urban areas. Loss of life, injuries and property damage are the effects that can arise if the crane handling criteria and procedures are not performed correctly. Therefore, the objectives of this study are to identify the causes of tower crane accident at site and to suggest possible mitigation measures with related to tower crane operator welfare to reduce the tower crane accident. This study uses the quantitative method by sending structured questionnaires to safety professionals and tower crane operator as targeted respondents. The questionnaire is created using Google Form, an online survey tool, and stored in Google Drive Data Storage. Expert review has been conducted in order to ensure the questions are constructed ideally. The review was done by the experts from Universiti Tun Hussein Onn Malaysia. Therefore, to achieve the objectives of this study descriptive analysis will be used to analyze the data. Based on the survey answered by the respondents, main causes of tower crane can be seen in this survey is due to the condition of foundation of the tower crane and not wearing full set of personal protection equipment where there were 86% respondents strongly agreed about the statements. There were 89.3% of respondents agreed that tower crane should be maintained and meet all safety standards as it is one of the possible mitigation measures that related to tower crane operator welfare.

Keywords: Tower Crane, Accidents, Mitigation Measures

1. Introduction

Construction site is known as a workplace that have various difficulty and dangerous activities that are managed simultaneously. In fact, the construction industry is recognized as one of the most dangerous sectors that threatens the lives of site workers [1]. The reliance of the industry on cranes as the most significant form of material transport at construction site has been related to the increasing industrialization of construction processes and modular components of off-site manufacturing [2]. Since

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year 2000, 872 cases and 668 fatality loss due to tower crane accident were recorded. Besides, in year 2009 recorded 116 tower crane accidents and 44 losses of life. Zaini *et al.*, (2020) has stated the major causes that lead to crane failure and accidents in a construction site are due to operational and technical causes followed by safety management, human and the environment [3]. There are around 500 crane operator which are from year 2018-2019 in Malaysia are unregistered and does not have qualified license which are required by Department of Occupational Safety and Health [4]. Moreover, due to less work supervision and weak communication between the crane operator and site foreman it has cause human error which can cause the accidents. The operator could have delivered incorrect control commands that have been applied differently from the intended control commands [5]. On the other hand, environment problem also led to crane accident due to hazardous and bad weather condition. This can cause low visibility to crane operator which leads to difficult for lifting operation [6].

Therefore, this study is focused on tower crane accidents and its mitigation measures with related to tower crane operator welfare to reduce the tower crane accidents. Two objectives have been set for this study which are to identify the causes of tower crane accident at site and to suggest possible mitigation measures with related to tower crane welfare to reduce the tower crane accident. The data was collected from safety professionals and tower crane operator in construction site and area of study is all states in Malaysia.

2. Overview on tower crane accidents

Tower crane is used for high-rise building construction of electrical equipment, it is important to speed the progress of construction and shorten the construction time and it also helps to minimize project costs. However, the uses of tower crane usually exposed to accidents which can lead to fatality and damage to the property. Based on the research that was conduct by Milazzo *et al.*, (2016), there were 22% of accidents that was involving tower crane which include 8% in EU, 8% in North America and 6% in the rest of the world [7]. This is based on an analysis of 937 crane safety incidents happening across the globe from 2011 to 2015. Shin (2015) mentioned that between 2001 and 2011 there are 68.4% of fatal accidents involving tower crane occurring in Korea that was occurred during installing/dismantling and during normal operation of crane there are 18.5% of accidents happen [8].

According to Zhou *et al.*, (2018), in China there are some factors providing to tower crane safety accidents [9]:

- The workers involved in crane assembly or lifting activities, including the attitudes, abilities and behavior of employees.
- The equipment used, including the option of type of crane, structural stability and safety equipment.
- The construction site environment, including the site supervision, layout and job scheduling.
- The condition of environment which include wind conditions and visibility.
- The regulatory environment, including WHS preventive regulations and certificate of the requirements for crane use.

2.1 Prevention of tower crane accidents

In order to prevent the tower crane accidents, there will be some previous studies regarding the crane safety risk factors have been explored in this report.

Traditional safety training approaches are less efficient in resolving the risks involved in certain tower crane-related activities and it is not effectively engaged either instructors or labors [10]. Therefore, to improve the safety training for individual that involve with tower crane some researchers have proposed some system which can increase their awareness of the safety during handling with tower crane. Based on research that was done by Li *et al.*, (2012) to educate individuals that take part in tower crane disassembly, a game-engine rendered in 3D environment have been used as an on-the-job safety training platform [11]. This helps the workers experience a close-to-reality which can allow them for practicing their work responsibilities in a safe and simulated environment. In order to assist trainers and trainees to identify safety issues, the data from construction training environment and real-time location tracking can be fused and presented in a virtual visualization environment [10]. By demonstrating its

effects on the safer conduct of iron workers served by the crane, they tested the efficacy of their proposed data fusion.

Crane operator's acquaintance with the system and their individual experience, skill and characteristics can lead to successful operating of a new system or technology [10]. For improving the lift performance of the operator from a cognitive viewpoint, Fang & Cho (2016) have explored for assessing effectiveness of a real-time safety assistance system [15]. The Best Practice on Occupational Safety and Health in Construction Industry (2019) as shown in Table 2 is used to provide safe and healthy workplace environment [14]. All the preventive methods are related with Malaysian OSH Acts and Standards.

Table 2: The Best Practice on Occupational Safety and Health [14]

Authority approval	<p>Before new tower crane mobilize to site, DOSH Putrajaya need to approve for the obtain material and design.</p> <p>Approval letter is required from DOSH State office to obtain installation or dismantling.</p> <p>Foundation of the tower crane must be tested and authorized by DOSH Officer before casting concrete.</p>
Operation	<p>A qualified person that holds valid competency certificate issued by DOSH Malaysia can operate the tower crane.</p> <p>Trained lifting supervisor need to supervise lifting operation.</p> <p>Tower crane shall carry out a regulation pre-operation safety inspection checklist if any discretion concerning safe operation has been identified and the crane operation shall cease.</p>
Maintenance	<p>Maintenance inspection and service needs to carry out monthly, and the report need to keep for record keeping at site office.</p> <p>To access the egress to tower crane safe access platform on the tie-back beam will be installed.</p> <p>Install a board at the base of tower crane to show information pertaining to PMA certificates, operator's certificate, the names of lifting supervisor, rigger and signalman.</p>

3. Research Methodology

This study uses the quantitative approach by randomly sending structured questionnaires to construction industry professionals tower crane operator as targeted respondents. According to Department of Occupational Safety and Health (DOSH), the population for safety professionals and crane operator in Malaysia is about 11, 135 workers. The estimated respondents for this study will be about 100 workers. The location is set in construction site in Malaysia and the questionnaire will be distributed to the tower crane operator and safety professional in construction area.

The questionnaire is constructed using Google Form, an open online survey tool, and the results are stored in Google Drive Data Storage. The questionnaires are divided into 4 parts which are correspond to the objectives of this study. Section A will cover the background of the respondents, Section B is to identify the causes of tower crane accidents, Section C is to cover the working benefits of a tower crane operator and Section D is possible mitigation measures with related to tower crane operator welfare to reduce the tower crane accidents. Besides, the respondents need to give score from range 1 to 5 where the range is from strongly disagree to strongly agree. In another word: 1- strongly disagree, 2- disagree, 3- neutral, 4- agree, 5- strongly agree [15].

Expert review is used by researchers to group of experts to review their questionnaires. These methods are used to identify the viability questions, the breakdown and other possible measurement error in the survey [16]. Although there are many different types of expert reviews, the two main

purposes are to identify problems with a survey instrument so that they can be fixed before being distributed and to divide items into groups that are more or less likely to display measurement errors [17]. Therefore, for this study the review was done by the experts where they are all academicians from Universiti Tun Hussein Onn Malaysia. The experts are from different backgrounds but they have some experience in construction. Data analysis is the method of using logical and statistical methods to analyze the data obtained in the process. Descriptive analysis is the method of summarizing and analyzing all the raw information obtained to interpret the tables and charts that can be analyzed. The mean score analysis would be used for comparison in data analysis. Data collected from respondents were evaluated according to the ranking order derived from the average index, using the Likert scaling. Table 3 shows the Likert scaling data analysis.

Table 3: Scale index [18]

Scale	Level of agreement	Index
1	Strongly disagree	$1.0 \leq \text{Mean index} \leq 1.5$
2	Disagree	$1.5 \leq \text{Mean index} \leq 2.5$
3	Moderate	$2.5 \leq \text{Mean index} \leq 3.5$
4	Agree	$3.5 \leq \text{Mean index} \leq 4.5$
5	Strongly agree	$4.5 \leq \text{Mean index} \leq 5.0$

4. Findings and conclusion

There are 4 questions to discover the background of the respondents participated in the survey. The questions that have been asked to the respondents are regarding their range of age, working experience and their job position.

4.1 Analysis of identification of the causes of tower crane accidents

Based on this sub-section, there were 10 statements for respondents to select based on their opinion towards their awareness on the identification of the causes of tower crane accidents. This section was using likelihood range from strongly disagree to strongly agree. Table 4 below shows the analysis of the likert scale for this section.

Table 4: Ranking of strongly agree for identification of the causes of tower crane accidents.

No	Element	Percentage (%)
1.	I understand the need and importance of wearing Personal Protective Equipment when working near a tower crane.	86.0
2.	I know that the condition of foundation needs to be investigated before install tower crane.	86.0
3.	I know how to perform job in a safe manner.	82.6
4.	I know that tower crane needs to undergo maintenance regularly to ensure the safety of tower crane.	81.8
5.	I acknowledge that the safety uses of tower crane is important during operating the tower crane.	80.2
6.	If any accidents happen, I know to whom I need to report to.	80.2
7.	I am aware that the foundation of tower crane is important for the installment of tower crane.	79.3
8.	I am aware that if any bad weather occurred, the tower crane cannot be used for any construction works.	75.2
9.	I have been exposed with safety of tower crane before beginning with construction activities.	68.6
10.	Tower crane accidents happened due to operational and technical factors.	61.2

Based on the survey, there were 86% of the respondents agreed that it is important to wear personal protection equipment when working near tower crane and they also agreed that the condition of foundation needs to be investigated before install tower crane. This indicate that the respondents are aware that personal protection is important for their own safety's sake and the condition of foundation is important. But from the findings, only 61.2% of respondents agreed that tower crane accidents happened due to operational and technical factors. This should be a worry because based on data from DOSH it shows that most of accidents happened due to operational and technical factors [19]. Besides, only 68.6% of respondents agreed that they have been exposed with safety tower crane before beginning with construction activities. This should be taken more seriously because it shown that some of the respondents might not aware with the danger when working near tower crane and it would cause accidents and fatal towards the workers.

4.2 Analysis of the respondents based on the working benefits and protection for tower crane operator.

Based on this sub-section, it consists of 9 statements and questions for respondents to answer. Each of the questions is to assess the working benefits for tower crane operator. Based on Table 5, it shows the rank of strongly agreed statements by respondents.

Table 5: Ranking of strongly agree for the working benefits and protection for tower crane operator

No	Element	Percentage (%)
1.	The employers should provide Employees Provident Fund (EPF) and Social Security Organization (SOCSO) to tower crane operator.	92.6
2.	Tower crane operator should be registered and insured by their employers.	92.6
3.	If any accidents happened at site to the tower crane operator, it should be covered by the insurance.	90.1
4.	It is the employer's responsibility to provide all compensation to the employees if any accidents happened at site.	87.6
5.	A safe and healthy work atmosphere can reduce tower crane accidents at site.	85.1
6.	Rest day need to be given to tower crane operator once a week.	82.6
7.	It is important for a tower crane operator to be working in shift work if they are required to work more than 8 hours per day.	82.6
8.	The maximum working hours for a tower crane operator should be 8 hours per day.	76.0
9.	It is not necessary for an employer to pay extra towards the tower crane operator if they are required to make an overtime job.	10.7

For working benefits of tower crane operator which is according to Best Practice on Occupational Safety and Health in Construction Industry 2019 it stated that the company need to provide Social Security Organization (SOCSO) and Employment Provident Fund (EPF) towards their employees [14]. This can be supported that 92.6% of the respondent strongly agreed that the employers need to provide EPF and SOCSO towards the crane operator as their working benefits. Based on Section 16 of Employment Insurance System Act 2017 it mentioned that it is compulsory for an employer registered and insured their employees [20]. These have been supported that most of respondents strongly agreed (92.6%) that tower crane operator should be registered and insured by their employers. However, most of the respondent strongly disagree (10.7%) that it is not necessary to pay extra towards the operator if they are required to make an overtime job. This is because they are concerned that the employers should paid their overtime work. Section 60A (3) of Employment Act 1995, it stated that employees should be

paid at rate of not less than 1 ½ time of the employee hourly rate of pay if they are required to make an overtime job [21].

4.3 Analysis of the possible mitigation measures with related to tower crane operator welfare to reduce the tower crane accidents

In this sub-section, it contains of 8 statements to ask the respondents on the mitigation measures with related tower crane operator welfare to reduce the tower crane accidents so that the third objective can be achieved through this survey. Table 6 shows the rank of strongly agreed by respondents for this section.

Table 6: Ranking of strongly agreed for possible mitigation measures with related to tower crane operator welfare to reduce the tower crane accidents

No	Element	Percentage (%)
1.	Tower crane should be maintained and meet all safety standards to ensure it is in a good condition and operator can use it without any failure.	89.3
2.	It is necessary for a tower crane operator to hold a valid competency certificate issued by Department of Occupational Safety and Health (DOSH).	87.6
3.	Alternate work should be done if the operator is required to work at long hours.	84.3
4.	The cabin for operator needs to be comfortable because they have to work at long hours.	84.3
5.	By joining any safety training, the crane operator can prevent accident during handling tower crane.	82.6
6.	If any crane operator or workers work near the tower crane using personal protective equipment, it can reduce the injury and fatal at site.	82.6
7.	If the operator needs to work at extra hours without any rest, it can cause carelessness during handling tower crane.	82.6
8.	Tower crane operator that are not exposed with new system or technology can easily cause failure during handling the tower crane.	80.0

For possible mitigation measures with related to tower crane operator welfare to reduce the tower crane accident, 89.3% of the respondents strongly agreed that tower crane should be maintained and meet all safety standards to ensure that it is in a good condition. Based on Table 2 it also mentioned that tower crane should undergo maintenance inspection and service monthly. This can avoid any technical and operational problem happened when operating tower crane. Besides that, Best Practice on Occupational Safety and Health in Construction Industry 2019 had stated that it is necessary for tower crane operator to hold valid competency certificate issued by DOSH [14]. These have been supported by the respondents where 87.6% of them strongly agreed that the operator needs to hold valid competency certificate to operate the tower crane. This is because person that hold a valid competency certificate has been trained with safety of tower crane. In addition, tower crane operator needs to exposed with new system and technology even though this statement has the lowest ranking of strongly agreed (80%) but it is important to expose them with new system and technology where this might help to improve the quality of work when using tower crane.

5. Conclusion

Tower crane is one of an important machinery for high rise buildings construction. However, if any failure occurred when handling and operating the tower crane it can caused accidents at site which can lead to fatality. Based on this study, using full personal protection equipment is important when working near tower crane. Therefore, sufficient supervision at work site needs to be done by safety professionals to ensure all the workers including the operator to wear a full set of personal protection equipment. Besides that, safety management needs to expose with tower crane safety not only to tower crane operator but to all workers at site. This is because some of the workers might not aware with the hazard that might happened at site due to tower crane.

Some mitigation measures that related to crane operator welfare needs to be taken in order to reduce the accidents of tower crane. Through this analysis, it shown that alternate work should be done if the operator needs to work at long hours and the cabin for the operator needs to be comfortable. This is due to the operator needs to sit up there all day long with hot and sweaty condition. This can avoid ergonomic hazards towards the operator. From this survey also it can be seen that it is important for the operator to join any safety training before they work at actual workplace. This is to give some safety awareness of the tower crane and which can prevent any misuse of the crane when handling it. It is important for the operator to have rest if they are required to work at extra hours to avoid any carelessness happened. If the operator does not have rest, it might cause them feel tired since they sit all day long and exposed with uncomfortable condition.

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