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Analysis of the Application of Occupational Safety and Health on Tower Cranes to the Risk of Work Accidents

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A B S T R A C T

This study aims to assess workers' compliance with Occupational Safety and Health (OSH) implementation and risk control using Hazard Identification Risk Assessment and Risk Control (HIRARC) and Job Safety Analysis (JSA) methods on tower cranes to reduce workplace accident risks. Using a quantitative descriptive method through questionnaires, interviews, and field observations, the study found that workers' compliance is generally high but still not optimal, requiring further actions such as regular monitoring, safety patrols, and preventive measures. Risk identification using HIRARC identified 21 high-risk variables and 1 medium-risk variable. Risk control was implemented through the Hierarchy of Control and JSA methods, helping reduce potential hazards and improve safety performance on tower crane operations in the workplace.

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INTRODUCTION

Tower cranes are vital heavy equipment in high-rise building construction projects due to their ability to lift heavy materials to heights and hard-to-reach areas, thus speeding up the construction process. However, despite its efficiency, the use of tower cranes also carries a high risk, especially if not accompanied by adequate technical understanding and implementation of work safety. Work accidents on construction projects are generally caused by unsafe conditions and unsafe behavior, which are rooted in low awareness of the importance of OSH (Soekiswara, 2020).

According to Tempo Magazine (2018) states that the number of work accidents to tower cranes in Indonesia is still high, such as in the double-double track railway project in Jatinegara, where a tower crane collapsed which caused 4 workers to die, or in the case of an accident on the Palembang Light Trail Transit (LRT) construction project where the LRT support pole fell which caused 2 workers to die. For this reason, the application of Occupational Safety and health (OSH) is very important in minimizing risks. Occupational safety has been regulated in the national regulation Law Number 1 of 1970 which emphasizes the need for a protection system for workers. This research aims to identify potential risks of work accidents on tower cranes and develop control measures with occupational safety and health (OSH) principles to improve safety and encourage the development of risk management in the construction sector.

LITERATURE REVIEW

Occupational Safety and Health (OSH)

Occupational Safety and Health (OSH) is an effort to protect workers to ensure safety both physically, mentally, and socially in carrying out work. Based on Law No. 1 of 1970 and Minister of Manpower Regulation No. 5 of 2018, OSH aims to prevent work accidents and occupational diseases, and increase national productivity. Occupational Hafety and health (OSH) is very important to be applied to construction work that is full of risks, because it can avoid or prevent losses caused by work accidents. One of the heavy equipment that requires special attention in the application of OSH is a tower crane, which is a heavy lifting machine used to transport materials in the construction of high-rise buildings.

Tower Crane

Tower cranes are load-lifting machines used to facilitate the construction process, especially in high-rise buildings. The characteristic of a tower crane is its size that can reach up to 100 meters above the ground. Because of this size, tower cranes are the type that is often used when building apartments, tall buildings, corporate offices, and others (Ismail, 2022). Tower cranes are one type of heavy equipment that is often used to build high-rise buildings or bridges. The function of this tower crane is to transport materials or materials or building construction from below to the part above (Putri & Lestari, 2025) .

Hazard Identification, Risk Assessment and Risk Control (HIRARC) and Job Safety Analysis (JSA)

Hazard Identification, Risk Assessment and Risk Control (HIRARC) is a method used to identify potential hazards in the workplace, assess the level of risk, and determine appropriate control measures (Mastam et al., 2024). This method is very commonly used in construction projects as it provides a systematic approach to risk management, especially in high-risk jobs such as the use of tower cranes. Based on the Risk Matrix, risk assessment in HIRARC is carried out based on two main parameters, namely severity and likelihood, which are then classified into risk levels: extreme, high, medium, and low, usually marked with green to red colors.

Meanwhile, Job Safety Analysis (JSA) is a complementary method that focuses on analyzing work steps in detail to identify hazards at each stage of work activities (Yusriyyah et al., 2024). JSA is useful for anticipating specific potential hazards in each work process, as well as establishing safe work procedures that must be followed by workers. In tower crane operations, the application of JSA is very relevant because the process involves many stages and technical risks. The combination of HIRARC and JSA can strengthen the effectiveness of risk management, assist in designing appropriate controls, and increase workers' awareness of the importance of work safety.

METHODOLOGY

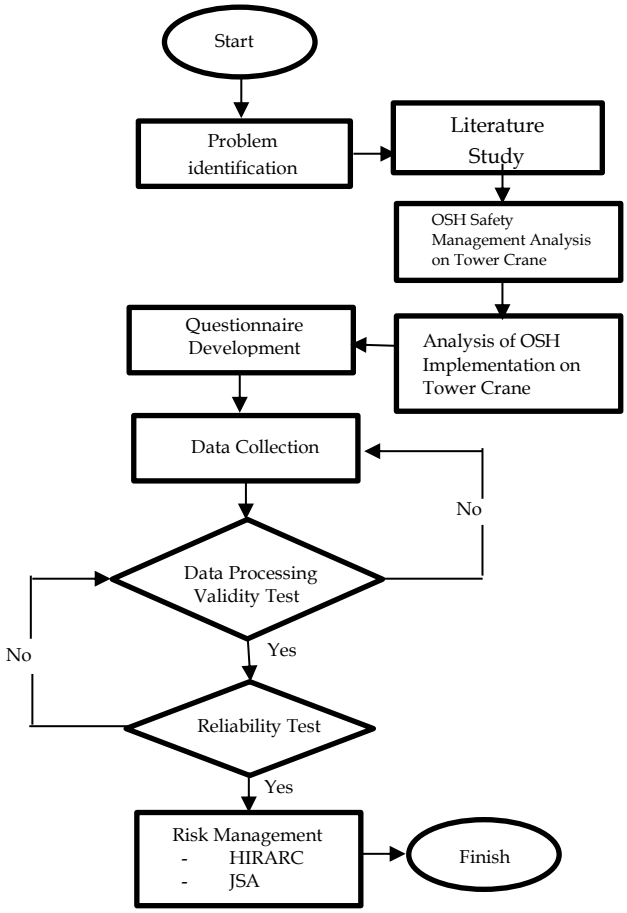


Figure 1. Research Flow

This study uses a descriptive quantitative approach that aims to describe the application of occupational safety and health (OSH) and identify the risk of work accidents in the use of tower cranes. Data collection was carried out through distributing questionnaires and interviews to 51 respondents of PT. B on the Hospital A construction project in Majalengka consisting of the head of the HSE division, tower crane operators, quality control, implementers, mechanics, demolition technicians, foremen, and field workers. The sampling technique used is typical case sampling, while the data source consists of primary data (questionnaires, interviews, and direct observation in the field) and secondary data in the form of company documents such as SOPs, inspection documents, and tower crane technical drawings.

The questionnaires distributed were divided into two types, namely, the application of OSH to tower cranes in the field using a dichotomous scale, and potential risks to tower cranes using a Likert scale of 1 to 5. Data processing was then carried out using IBM SPSS version 22 software to test the validity and reliability of the instrument. The validity test states that the instrument is valid if the value of r count> r table, while the reliability test uses the Cronbach's Alpha method with an alpha value> 0.60 declared sufficient and> 0.80 declared very strong and consistent. For risk management analysis, the Hazard Identification, Risk Assessment and Risk Control (HIRARC) and Job Safety Analysis (JSA) methods were used to map potential hazards and formulate appropriate control measures.

RESEARCH RESULTS

The results of the validity test of the questionnaires that have been distributed using IBM SPSS 22, show that the r value obtained is> r table value (0.232) with a total sample of 51 respondents. And the reliability test results resulted in a Cronbach's Alpha value of 0.928 for variables X1 and X2 and 0.960 for variable X3, both of which exceeded the 0.8 threshold. These results indicate that the data obtained is valine and consistent so that it can be used in the further analysis process.

Table 1. Cronbach's Alpha Assessment

Cronbach's Alpha Value (r)	Reliability Level
0,00-0,20	*Very Low*
0,21-0,40	*Low*
0,41-0,60	*Medium*
0,61-0,80	*High*
0,81-1,00	*Extreme*

Source: Jannah, 2021

The assessment of variables related to workers' compliance with occupational safety regulations refers to Government Regulation No. 50 of 2012 concerning the Occupational Safety and Health Management System. This assessment uses the percentage of "yes" and "no" responses to categorize the

level of compliance. The results are then interpreted to indicate the risk category, where a higher percentage of "yes" answers reflects better compliance and a lower risk level, while a higher percentage of "no" answers suggest lower compliance and a potentially higher risk category.

$$\textbf{Compliance Level Percentage} = \frac{\textbf{Number of "Yes" Responses}}{\textbf{Total Responses}} \times 100$$

$$\textbf{Compliance Level Percentage } X1.1 = \frac{47}{51} \times 100$$

$$\textbf{Compliance Level Percentage } X1.1 = 92,16\%$$

The compliance level percentage for variable X1.1, based on the "yes" responses, was 92.16%, indicating that the OSH system has been implemented comprehensively and consistently. Meanwhile, the "no" responses reflect the presence of risks within the assessed category.

Table 2. Compliance Categories

Compliance Percentage	Compliance Category
85-100%	High (Satisfactory)
60-84%	Medium (Good)
<60%	Low (Deficient)

Source: Government Regulation No. 50 of 2012

Table 3. Level of Worker Compliance with OSH Procedures in the Field

Variable	Compliance Level (%)	Compliance Category	Variable	Compliance Level (%)	Compliance Category	Risk Category Based on Compliance
X1.1	92,16	High	X2.1	88,24	High	Low
X1.2	88,24	High	X2.2	90,2	High	Low
X1.3	88,24	High	X2.3	92,16	High	Low
X1.4	88,24	High	X2.4	92,16	High	Low
X1.5	88,24	High	X2.5	88,24	High	Low
X1.6	88,24	High	X2.6	90,2	High	Low
X1.7	92,16	High	X2.7	90,2	High	Low
X1.8	92,16	High	X2.8	90,2	High	Low
X1.9	88,24	High	X2.9	86,27	High	Low
X1.10	88,24	High	X2.10	92,16	High	Low
X1.11	88,24	High	X2.11	88,24	High	Low
X1.12	88,24	High	X2.12	92,16	High	Low
X1.13	88,24	High	X2.13	88,24	High	Low
X1.14	90,2	High	X2.14	90,2	High	Low

X1.15	92,16	High	X2.15	88,24	High	Low
X1.16	92,16	High	X2.16	92,16	High	Low
X1.17	88,24	High	X2.17	88,24	High	Low
X1.18	90,2	High	X2.18	82,35	Good	Low
X1.19	88,24	High	X2.19	92,16	High	Low
X1.20	88,24	High	X2.20	92,16	High	Low
X1.21	88,24	High	X2.21	88,24	High	Low
X1.22	88,24	High	X2.22	88,24	High	Low
X1.23	86,27	High	X2.23	92,16	High	Low
X1.24	92,16	High	X2.24	90,2	High	Low

The results, referring to Government Regulation No. 50 of 2012 concerning the Occupational Safety and Health Management System, show that the level of worker compliance with the implementation of OSH in human behavior indicators across all variable elements is categorized as high. For environmental and equipment indicators, compliance is also high across all variables, except for variable X2.18, which falls into the good category. This high level of compliance not only reflects workers' awareness of the importance of occupational safety but also indicates that the OSH management system has been implemented effectively and consistently within the project environment.

Risk assessment on tower cranes using the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) method is conducted through a risk assessment matrix. This involves multiplying the severity and likelihood values to determine the level of risk. The results are then categorized into four risk levels: extreme, high, medium, and low. The risk level is calculated using the following formula:

$$\boldsymbol{Risk = Severity\ x\ Likehood}$$

Where :

- Severity refers to the potential impact or consequence of a hazard.
- Likelihood refers to the probability of the hazard occurring

Table 4. Risk Categories

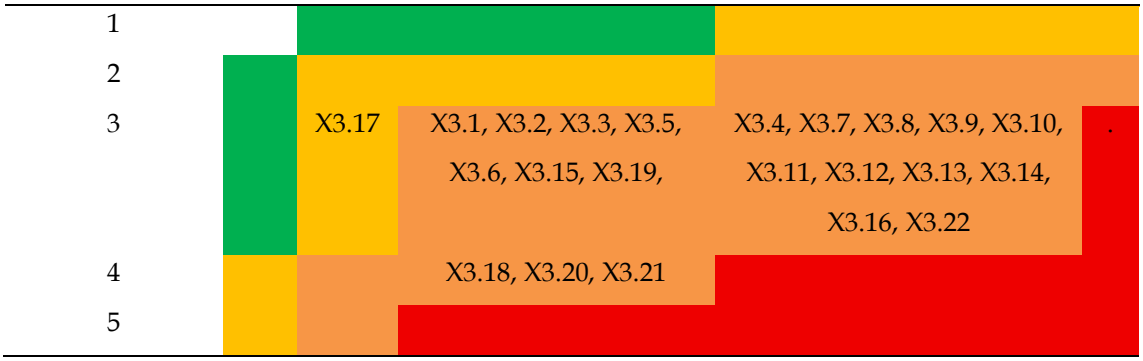
Extreme	More than 12
High	7 to 12
Medium	3 to 6
Low	1 to 2

Source: (Putri & Trifiananto, 2019)

The results of the risk assessment using the risk matrix for 22 variables produced risk indices classified into two risk categories: high and medium, both of which require further control measures to minimize these risks effectively.

Table 5. Risk Index (X3)

Risk Table	Severity or Impact				
Likelihood	1	2	3	4	5



DISCUSSION

Analysis of OSH Implementation of Tower Cranes

Based on the results of interviews, field observations, and related statutory sources, the variable elements of the application of occupational safety and health (OSH) to tower cranes are obtained as follows:

Table 6. OSH Implementation Variables on Tower Cranes

OSH Variables on Tower Crane Human Behavior Indicators	Reference	OSH Variables on Environment and Equipment Indicators on Tower Cranes	Reference
Use of Personal Protective Equipment (PPE) while in the field	Minister of Manpower Regulation No. 8 of 2020	Complete document requirements prior to work execution including; SIA, SIO, Rigger who has the ability, SILO	Minister of Manpower Regulation No. 8 of 2020
Workers realize the importance of using Personal Protective Equipment (PPE) while working in the field	Minister of Manpower Regulation No. 5 of 2018	Personal Protective Equipment (PPE) that meets safety standards is provided to workers.	Minister of Manpower Regulation No. 8 of 2020
Workers understand the risk of hazards that can occur on tower cranes	Minister of Manpower Regulation No. 5 of 2018	Installation of tools (during tower crane installation) is done correctly	Minister of Public Works and Public Housing Regulation No. 10/2022
The load capacity lifted by the *tower crane* does not exceed the maximum permissible load.	Minister of Manpower Regulation No. 8 of 2020	The tower crane has a name plate that contains the following data; manufacturer's name, year of manufacture, model, serial number, and load capacity.	Minister of Manpower Regulation No. 8 of 2020

OSH Variables on Tower Crane Human Behavior Indicators	Reference	OSH Variables on Environment and Equipment Indicators on Tower Cranes	Reference
Tower *cranes* do not make sudden movements that can cause shock loads.	Minister of Manpower Regulation No. 8 of 2020	There is a description of the maximum permissible load capacity	Minister of Manpower Regulation No. 8 of 2020
Tower *cranes* carry or transport passengers in excess of the number of seats available	Minister of Manpower Regulation No. 8 of 2020	Tower crane has an emergency stop button	Minister of Manpower Regulation No. 8 of 2020
No workers are under the tower crane when it is in operation.	Minister of Manpower Regulation No. 8 of 2020	Tower cranes have safety equipment and protective equipment as required.	Minister of Manpower Regulation No. 8 of 2020
Stop tower crane operation if the wind speed exceeds 38 km/h.	Minister of Manpower Regulation No. 8 of 2020	There is an effective operation warning sign while the tower crane is operating.	Minister of Manpower Regulation No. 8 of 2020
Communication between operator and rigger is good while the tower crane is operating or about to operate.	Minister of Public Works and Public Housing Regulation No. 10/2022	Tower cranes are equipped with effective lighting	Minister of Manpower Regulation No. 8 of 2020
It is prohibited to hang cargo on the tower crane when repairs are being carried out.	Minister of Manpower Regulation No. 8 of 2020	Operator's cabin and control room that meet the specified requirements	Minister of Manpower Regulation No. 8 of 2020
The rigger must attach the sling to the hook firmly while moving.	Minister of Manpower Regulation No. 8 of 2020	The operating track of a loaded tower crane must be given at least 90 cm of free space from left and right along the track.	Minister of Manpower Regulation No. 8 of 2020
The operator must raise the hook sufficiently so that it does not touch people and objects in the vicinity.	Minister of Manpower Regulation No. 8 of 2020	The boom has a collision prevention device that functions automatically.	Minister of Manpower Regulation No. 8 of 2020

OSH Variables on Tower Crane Human Behavior Indicators	Reference	OSH Variables on Environment and Equipment Indicators on Tower Cranes	Reference
Security and safety guarantees for workers	Minister of Manpower Regulation No. 8 of 2020	Use of slings that are suitable for the type and capacity	Minister of Manpower Regulation No. 8 of 2020
All workers receive training related to the implementation of OSH and emergency procedures while in the field	Minister of Public Works and Public Housing Regulation No. 10/2022	The air temperature in the cabin is properly regulated to support work activities	Minister of Manpower Regulation No. 5 of 2018
All workers receive training related to occupational hazards, especially in tower crane work.	Minister of Public Works and Public Housing Regulation No. 10/2022	Engine noise is heard when the tower crane is operating	Minister of Manpower Regulation No. 5 of 2018
Routine inspection of the tower crane is carried out before or during operation.	Minister of Public Works and Public Housing Regulation No. 10/2022	Organized material placement location	Minister of Manpower Regulation No. 5 of 2018
A load lifting test has been carried out on the tower crane before the work is carried out.	Minister of Manpower Regulation No. 8 of 2020	Good level of work environment cleanliness	Minister of Manpower Regulation No. 5 of 2018
Tower cranes have undergone a thorough inspection prior to work	Minister of Public Works and Public Housing Regulation No. 10/2022	Safety equipment is available for operators	Minister of Public Works and Public Housing Regulation No. 10/2022

OSH Variables on Tower Crane Human Behavior Indicators	Reference	OSH Variables on Environment and Equipment Indicators on Tower Cranes	Reference
Operator's physical condition is qualified	Minister of Public Works and Public Housing Regulation No. 10/2022	Changeable weather conditions that affect tower crane operation	Minister of Public Works and Public Housing Regulation No. 10/2022
Routine *safety patrols* are carried out in the field	Minister of Public Works and Public Housing Regulation No. 10/2022	There are safety signs installed in the work area	Minister of Manpower Regulation No. 8 of 2020
Workers are aware of accident emergency response	Minister of Public Works and Public Housing Regulation No. 10/2022	Electrical installations are in accordance with standards	Minister of Manpower Regulation No. 5 of 2018
Tower crane operators receive adequate training	Minister of Manpower Regulation No. 5 of 2018	Safe work location, such as avoiding hazardous chemicals, not slippery	Minister of Manpower Regulation No. 8 of 2020
Periodic risk assessment to identify hazards that may arise during operation	Minister of Manpower Regulation No. 5 of 2018	Lightning rod installed around the site area	Minister of Public Works and Public Housing Regulation No. 10/2022
Clear and easily accessible emergency procedures in the event of a tower crane accident	Minister of Manpower Regulation No. 5 of 2018	The location of the tower crane placement is not adjacent to electric poles or other buildings	Minister of Public Works and Public Housing Regulation No. 10/2022

According to the Indonesian Minister of Manpower Regulation No. 05 of 1996 concerning the Occupational Safety and Health Management System, the causes of work accidents are categorized into two, namely, *unsafe* behavior (*unsafe human acts*) and *unsafe* work environment (*unsafe conditions*). Based on the results of a questionnaire that has been conducted with reference to PP No. 50 of 2012 concerning the Occupational Safety and Health Management System, the level of compliance with human behavior indicators is in the high category in all elements of the variable, with an average value of 89.30%. While the level of compliance with environmental and equipment indicators is in the high category in all elements of the variable except for variable X2.18, namely available safety equipment for operators which has a percentage of 82.35% in the good category. The average value obtained is 89.71% and the compliance level category is high.

A high category of compliance with OSH rules indicates a low level of risk (Anasari & Trisnawati, 2024). The high compliance level category reflects good implementation, but not yet fully optimized. Therefore, to achieve the maximum level of compliance, further controls are needed, such as increased supervision, continuous training, and enforcement of work discipline. As for the results of the control carried out using the hierarchy of control method, further controls that can be carried out on the application of human, environmental and equipment indicators are regular monitoring, routine HSE safety partol, safety morning talk related to the application of OSH, installation of safety signs, daily inspection of tower cranes, and a prohibition zone under the tower crane area.

Risk Control with Hazard Identification, Risk Assessment and Risk Control (HIRARC) Method

Hazard identification is the initial stage in the Hazard Identification, Risk Assessment and Risk Control (HIRARC) analysis as an effort to minimize the potential for accidents and create a safe work environment. Risk identification is carried out by examining the entire work area to identify potential hazards in a job (Tetelepta et al., 2025) . Based on field observations, interviews, and literature review, the results of risk identification are divided into 22 variables. (Table 8)

The next stage after risk identification is risk assessment to determine the level of risk from potential hazards that have been identified (Hasibuan et al., 2024) . Risk assessment is carried out using a risk assessment matrix, namely by multiplying the value of impact (severity) and likelihood (likelihood) . There are four categories of risk levels (AZ/NZS Standard, 2004): extreme, high, medium, and low. As for the results of the questionnaire on 22 risks on tower cranes that have been identified, the risks are divided into two categories, namely: high and medium.

Table 7. Risk Index Assessment

Variable	Impact Value	Likelihood Value	Risk Index	Risk Category
X3.1	3	3	9	HIGH
X3.2	3	3	9	HIGH

X3.3	3	3	9	HIGH
X3.4	4	3	12	HIGH
X3.5	3	3	9	HIGH
X3.6	3	3	9	HIGH
X3.7	4	3	12	HIGH
X3.8	4	3	12	HIGH
X3.9	4	3	12	HIGH
X3.10	4	3	12	HIGH
X3.11	4	3	12	HIGH
X3.12	4	3	12	HIGH
X3.13	4	3	12	HIGH
X3.14	4	3	12	HIGH
X3.15	3	3	9	HIGH
X3.16	4	3	12	HIGH
X3.17	2	3	6	MEDIUM
X3.18	3	4	12	HIGH
X3.19	3	3	9	HIGH
X3.20	3	4	12	HIGH
X3.21	3	4	12	HIGH
X3.22	4	3	12	HIGH

Risk control is the final stage in the Hazard Identification, Risk Assessment and Risk Control (HIRARC) analysis which is carried out using the Hierarchy of Control approach. Hierarchy of Control is a sequence in controlling risks that may arise from several levels in sequence. Risk control is carried out to reduce or minimize the potential risks that occur in a job.

Table 8. Risk Control

Potential Risk	Related Legislation	Risk Level			Risk Level	Risk Control
		S	L	R		
Electrical accidents due to electrical installations not meeting standards	Minister of Manpower Regulation No. 8 of 2020	3	3	9	HIGH	Install grounding with standard resistance and lightning rod around the tower crane area.
Mechanical accidents due to poorly installed equipment components	Minister of Manpower Regulation No. 8 of 2020	3	3	9	HIGH	Daily checklists and periodic audits of heavy equipment and maintenance records
Workers are exposed to hazardous chemicals around the job site.	Minister of Manpower Regulation No. 8 of 2020	3	3	9	HIGH	Chemical safety data labels (MSDS) are available and the operation area is cleared of unnecessary materials.

The load was dropped during the installation process due to an error in the arrangement and handling of the load	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	Created SOP for tower crane installation and lifting plan
Unsafe working environment conditions that can cause work accidents due to the work environment	Minister of Manpower Regulation No. 8 of 2020	3	3	9	HIGH	Daily inspection by HSE
Overloading that can result in worker injury and equipment damage	Minister of Manpower Regulation No. 8 of 2020	3	3	9	HIGH	SOP for tower crane operation was created and daily inspections were conducted by the operator and HSE
Falling load due to sudden movement of equipment during operation	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	SOP for tower crane operation and daily inspection by operator and HSE created
Operating error due to lack of visibility ability of the operator	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	Operators must have an operator license and stop operations if the weather turns bad.
Loads fall over due to improperly secured loads	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	Riger has a certificate of expertise and an operating SOP including how to tie materials correctly is made.
Accidental fall of tool components during dismantling due to worker inattention.	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	SOP for tower crane dismantling and guardrails for workers to pass through were created
Worker fell from a height during demolition due to not using PPE	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	HSE conducts safety patrol during tower crane dismantling
Tower crane sling rope accident broke	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	Daily checklist including the sling ropes used.
Tower Crane collapsed due to incomplete installation of tools	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	Erection checklist load test before tower crane is used

The lifted load hit other materials	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	Communication between operator and signalman and clearing unnecessary materials around the area
Accidental fall of material due to TC sling breaking or material being lifted not fastened properly	Minister of Manpower Regulation No. 8 of 2020	3	3	9	HIGH	Daily checklist including sling ropes and TBMs for potential operating hazards
Noise caused by the sound of the engine when it is in operation	(Makomulamin and Qori, 2017)	4	3	12	HIGH	Routine maintenance of the tower crane and a special path to prevent workers from passing under the operating area.
Tower crane arms hitting other objects can be caused by the tower crane being located too close to electric poles, or other buildings.	Minister of Manpower Regulation No. 8 of 2020	2	3	6	MEDIUM	The location of tower cranes is prohibited from being close to electric poles or tall buildings without calculating the working radius and making emergency procedures in the event of a collision.
Fatigue due to working beyond the maximum working hours	Minister of Manpower Regulation No. 5 Year 2018	3	4	12	HIGH	A shift system is in place for tower crane operators.
Operator or worker exposed to lightning	Minister of Manpower Regulation No. 8 of 2020	3	3	9	HIGH	Discourage the operation of tower cranes during extreme weather such as lightning rain and create emergency response procedures when the weather turns extreme.
Work accidents caused by workers' negligence of safety rules	Regulation of the Minister of Manpower and Transmigration of the Republic of Indonesia Number 9/2010	3	4	12	HIGH	TBM is related to the importance of implementing OSH in the field and routine safety patrols are carried out by HSE.
Work accidents are caused by workers' ignorance of safety rules while in the field.	Minister of Manpower Regulation No. 8 of 2020	3	4	12	HIGH	TBM related to the implementation of OSH in the field as well as training workers related to mandatory OSH in the field
Counterweight fall hazard	Minister of Manpower Regulation No. 8 of 2020	4	3	12	HIGH	SOP for counterweight installation and no-go zone under the crane area.

The results of risk assessment and control obtained high and medium risk categories. Based on risk ratting, the high category means a Medical Treatment Case (MTC) or work accident case that requires wound treatment from medical professionals. For example, in variable X3.12, the tower crane sling rope accident broke, risk control was obtained with a daily checklist including the sling rope used.

For the medium risk category based on risk ratting, there are accidents that need action to reduce the risk of work accidents. Controls that can be carried out on variable X3.17, namely the tower crane arm hitting other objects can be caused by the location of the tower crane which is too close to an electric pole, or other buildings, by placing the tower crane location is prohibited close to electric poles or tall buildings without calculating the working radius and making emergency procedures in the event of a collision.

Risk Control with Job Safety Analysis (JSA)

Job Safety Analysis (JSA) data processing is conducted to provide additional management measures for work activities that are categorized as having extreme or high levels of hazard. This process aims to analyze each step of the job in detail, identify potential hazards, and establish specific safety procedures to minimize risks and ensure safer work practices in high-risk operations.

Table 9. Job Safety Analysis

Job Hazard Analysis: Tower Crane					
Stages of Work	Potential Hazards				Hazard Control
	Human	Equipment	Materials	Environment	
Tower crane installation/erection process		Mechanical accidents caused by poorly installed equipment components		Electrical accidents caused by electrical installations that do not meet standards	1. Create work area boundaries with barricades and safety cones so that not everyone can cross the tower crane installation area. 2. Check the tower crane regularly 3. Check the cable before installation 4. Make sure those who do the electrical installation are competent 5. Perform a merger test on the cable before the cable is used.

Material Lifting		Accidents caused by broken tower crane slings	1. Ensure that the material lifted does not exceed the maximum load on the far jib 2. Use of experienced and certified riggers in terms of materials 3. Operators and mechanics routinely make daily reports on tower crane operations. 4. Ensure the sling used is in good condition, the sling is tied to the material lifted with the correct clamp, the sling is firmly attached to the hook and the safety lock is locked. 5. Signal man standby to dispel workers who want to pass through the track area during the lifting process.
Tower Crane Demolition	Workers fell from a height during tower crane dismantling due to not using personal protective equipment.	Accidents due to falling tools or components during the dismantling of tower cranes caused by workers' inattentiveness	1. Make work area boundaries with barricades and safety cones so that not everyone can pass in the tower crane dismantling area. 2. Pay attention to the direction of the swing of the meterial at the time of lifting. 3. Using riggers who are experienced in dismantling section/jib material. 4. Checking the portable crane and slings before use.

	Make sure the sling used is in good condition, the sling is tied to the material being lifted with a properly installed clamp, the sling is firmly attached to the hook and the safety lock is locked.

CONCLUSION AND RECOMMENDATION

The level of compliance with the application of occupational safety and health (OSH) in construction projects, especially those using tower cranes, can reflect workers' understanding of the importance of work safety, and shows that the OSH management system implemented has been running effectively and consistently in the project environment. Based on 51 respondents tested, the results of the level of worker compliance for 24 variables of OSH application of work behavior indicators with high compliance category, which means that the OSH system for tower cranes has been implemented thoroughly and consistently in the field.

Meanwhile, in the implementation of OSH indicators for the environment and equipment, 24 variables have a high compliance category and 1 variable has a good compliance category level, namely variable X2.18. The good category means that OSH implementation is quite good but still requires improvement in several aspects. Overall, the implementation of OSH has been carried out thoroughly and consistently, but it is not optimal so it still requires further control. The further controls that can be carried out are periodic monitoring, routine HSE safety partol, safety morning talk related to the application of OSH, installation of safety signs, daily inspection of tower cranes, and a prohibition zone under the tower crane area. (Alwie et al., 2020).20)

In addition to the implementation of OSH to minimize work accidents, it is also necessary to identify risks to tower cranes. This risk identification is done to find out what risks can occur during the work (Research et al., 2024) . Risk assessment is then carried out to determine the level of risk so that risk control can be carried out so that the level of risk can be minimized. Based on the Hazard Identification, Risk Assessment and Risk Control (HIRARC) method for 22 variables, a high risk category was obtained for 21 variables and medium for 1 variable. The high category means a Medical Treatment Case (MTC) or a work accident case that requires wound treatment from medical professionals, and the medium category means an accident that needs action to reduce the risk of work accidents. Based on the Hierarchy of Control, risk control is carried out to reduce the level of risk. As for additional management, a Job Safety Analysis (JSA) can be made of risks based on job steps that have a high level or category.

FURTHER RESEARCH

This research has limitations in terms of the number of respondents, location coverage, duration of implementation, and availability of funds. These factors affect the breadth of data that can be collected and analyzed. Therefore, it is recommended that future studies involve more diverse respondents, cover a wider area, and are supported by more adequate time and budget to obtain more representative results.

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