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Assessment of Occupational Health and Safety Risk in the Tukad Ayung Bridge Replacement Project

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Abstract: The replacement of the Tukad Ayung Bridge requires a study regarding Occupational Health and Safety risk assessment. Based on initial observations, in the Tukad Ayung bridge replacement project there were several causes of work accidents, such as workers not using complete personal protective equipment, heavy rain causing work to stop, activities adjacent to heavy equipment and so on. The use of heavy equipment and sophisticated machines requires expertise to use them correctly so as to reduce errors which have an impact on increasing the risk of work accidents. The existence of this bridge construction project can also cause disruption to the environment around the project. It is thought that the traffic engineering will trigger traffic jams and cause air pollution around the project location. The data used is qualitative and quantitative data with primary data sources and secondary data. The data collection techniques used were observation, interviews, questionnaires, literature study and documentation study. The data analysis technique used is Hazard Identification, Risk Assessment and Risk Control (HIRARC). The results of the research show that there are 24 types of work accident risks identified in the work of installing concrete girders in the Tukad Ayung bridge replacement project in seven stages of work, namely, the concrete girder preparation stage, making scaffolding (girder truss), erection (setting segmental girder), installing steel prestressing (strand), cable strand stressing work, concrete girder tendon grouting, and the diaphragm installation stage.

Keywords: Risk, Occupational Safety and Health, HIRARC, Tukad Ayung Bridge

1. Introduction

Occupational health and safety effects are important for organizations. Working in a safe environment leads to job satisfaction of employees. Leading to Job value, contentment, excitement, attachment to their job, reduced absenteeism, punctuality and low turnover rates [1]. Work safety issues are also part of project planning and management. The implementation of Occupational Health and Accidents in the workplace aims to create a safe, comfortable and healthy working atmosphere and environment for workers. The construction industry is considered to be the most prone to accidents, the most frequent causes of work accidents are human error, electric shock, and falls from heights [2]. The Tukad Ayung Bridge is one of the bridges undergoing replacement with the aim of improving bridge infrastructure. This project is also carried out to improve inter-regional connectivity as well as providing alternatives for residents to increase economic productivity. The Tukad Ayung Bridge was previously an Australian type steel truss bridge which had a pavement width of 7 meters (2 lanes). After the replacement, the bridge is now a concrete girder construction type so that its service life is stronger and longer lasting.

States that construction is a high hazard industry that comprises a wide range of activities involving construction, alteration or repair. Examples include residential construction, bridge erection, excavations, demolitions and large painting jobs. Hazard identification and risk analysis is carried for identification of undesirable events that can leads to a hazard. The analysis of hazard mechanism by which this undesirable event could occur and usually the estimation of extent, magnitude and likelihood of harmful effects [3]. Safety management can estimate risks and accidents that can occur that may endanger all workers so that work safety is very important to be able to minimize hazards and risks in a definite and structured manner, especially in construction work [4]. Accidents are unavoidable occurrences on construction site all over the world with a lot of research done on mitigating it from source. The regular practice of safety known to building contractors is basically provision of personal protective equipment [5].

Considering that the Tukad Ayung Bridge is the only access that connects areas on the Simpang Cokroaminoto-Simpang Tohpati bridge section, of course this bridge replacement project is very important to carry out. Apart from the important role of bridges, it is also important to identify possible risks that may arise in the Tukad Ayung bridge replacement project. There are many risks that may occur, both as a result of high rainfall causing flooding, water runoff that can sweep away passing motorists, and the risk of work accidents that can be experienced by project workers. In this regard, this research reviews the risk of work accidents on the Tukad Ayung Bridge replacement project, especially on concrete girder installation work.

Research conducted by which aims to determine the level of work accident risk in the Titian Panjang-Kayu Tanam bridge replacement construction project in West Sumatra, shows that 8 work items were identified using the hazard identification, risk and opportunity assessment methods, the work accident risk level results were obtained as follows: 44% major risk, 56% moderate risk, and 0% low risk [6].

In accordance with the identification of problems with the Tukad Ayung Bridge replacement project, a study regarding work accident risk analysis is required. Based on initial observations, in the Tukad Ayung bridge replacement project there were several causes of work accidents, such as workers not using complete personal protective equipment, heavy rain causing work to stop, activities adjacent to heavy equipment and so on. The use of heavy equipment and sophisticated machines requires expertise to use them correctly so as to reduce errors which have an impact on increasing the risk of work accidents. The existence of this bridge construction project can also cause disruption to the environment around the project.

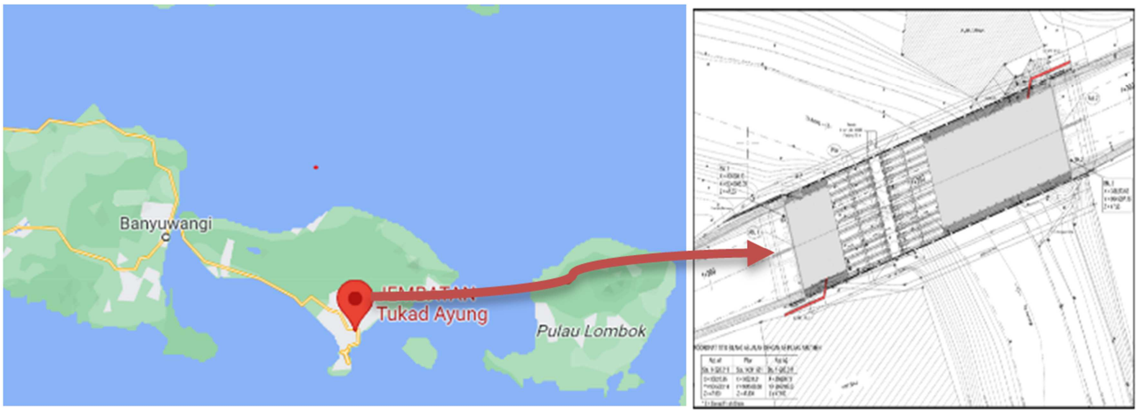

Figure 1. *Project Location.*

2. Method

In this research, it is related to the risk analysis of work accidents on the Tukad Ayung Bridge replacement project using the HIRARC method. The HIRARC method was chosen as a method for analyzing the risk of work accidents because the level of work accidents and various occupational safety and health threats is still quite high in the construction sector.

Work safety is intended to prevent, reduce, protect and even eliminate the risk of work accidents (zero accident) in the workforce by preventing work accidents that occur during activities. Therefore, every company that has a risk of work accidents can carry out hazard identification, assessment, and obtain risk control efforts through the Hazard Identification, Risk Assessment and Risk Control (HIRARC) method. HIRARC is a process of identifying hazards (Hazard Identification) that can occur in all company activities, then conducting a risk assessment (Risk Assessment) of the hazards that occur, then making hazard control (Risk Control) in order to minimize high risk levels to low [7].

2.1. Hazard Identification

Hazard identification is the first step in developing Occupational Health and Safety risk management. Hazard identification is a systematic effort to determine the existence of dangers in organizational activities. Risk identification is the foundation of risk management. Without identifying hazards, it is impossible to manage risks well. Hazard identification is the basis of an accident prevention or risk control program. The best method for identifying hazards is to be proactive, namely looking for hazards before they cause detrimental consequences or impacts.

2.2. Risk Assessment

In the risk assessment stage, after knowing the existence of sources of danger in the work environment, a risk assessment is carried out. This stage is carried out to determine the extent to which the risk of danger will occur, in other words, calculating the level or level of risk for each predetermined danger. In the AS/NZS4360 standard, there are 2 (two) parameters used for risk assessment, namely probability or likelihood of hazard and severity of hazard or level of possibility and severity.

The process of implementing the HIRARC method is in accordance with Figure 2 [8].

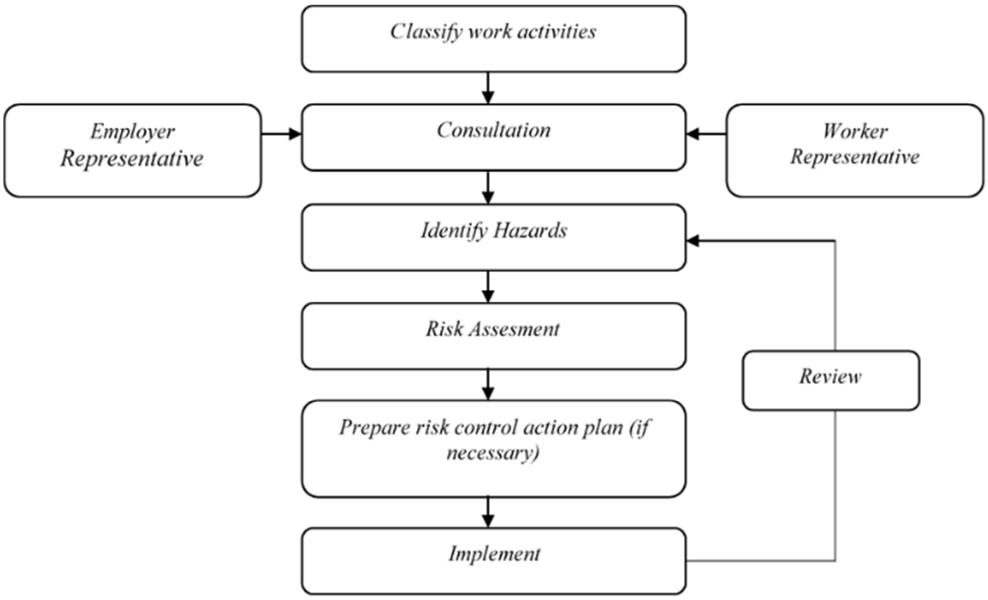

Figure 2. *HIRARC Implementation Stages.*

Risk assessment involves determining the impact level and recurrence of risk using available information. Moreover, in the risk analysis process, different factors, such as effects of recognized risks on project objectives, manageability, timing, the probability of occurrence, and relationship to other risks, must be considered. All these factors provide a better understanding of each risk type and increase the capacity for adoption of an adequate and appropriate approach to mitigating such risks [9].

Table 1. *Probability / Likelihood of Hazard Parameters.*

Level	Description	Information
5	*Almost certain*	Happens all the time
4	*Likely*	Often occur
3	*Prosibble*	Happens occasionally/sometimes
2	*Unlikely*	Rarely happening
1	*Rare*	Almost never happens

Source: Standard AS/NZS 4360

Table 2. *Severity of Hazard Parameters.*

Level	Description	Information
1	*Insignificant*	No injuries, minor financial loss
2	*Minor*	Minor injury, minor financial loss
3	*Moderate*	Moderate injuries requiring medical treatment, financial losses are quite large
4	*Major*	Serious injury that occurs to more than 1 person, loss large and there are production disruptions
5	*Catastrophic*	The victim died more than 1 person, the losses were very large, disrupting the entire process of company activities, the impact is very broad and comprehensive

Source: Standard AS/NZS 4360: 2004

From the two parameters presented in Table 1 and Table 2, the Risk Assessment Matix level is obtained as presented in Table 3 with an indication of the risk level in Table 3.

Table 3. *Risk Assessment Matrix.*

Probability / likelihood of danger	Severity of hazard				
	Insignificant	Minor	Moderate	Major	Catastrophic
Rare	1	2	3	4	5
Unlikely	2	4	6	8	10
Prosibble	3	6	9	12	15
Likely	4	8	12	16	20
Almost certain	5	10	15	20	25

Source: Standard AS/NZS 4360: 2004

Table 4. *Indication of risk level.*

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

Source: Standard AS/NZS 4360: 2004

2.3. Risk Control (Risk Control)

Risk control is a way to overcome potential dangers that exist in the work environment. Risk control can follow the Hierarchy of Control Approach. The risk control hierarchy is a sequence in preventing and controlling risks that may arise which consists of several levels sequentially.

3. Results and Discussion

3.1. Risk Identification

Identification of the risk of work accidents in concrete girder installation work on the Tukad Ayung Bridge replacement project based on the work implementation method which consists of seven work stages. The seven stages of work in the concrete girder installation work for the Tukad Ayung Bridge replacement project and the risks that may occur can be described as follows:

3.2. Girder Concrete Preparation Stage

Work on installing concrete girders or girders is carried out after the pillars and abutments have been completed. When carrying out concrete girder beam work, some are produced on site, and some are produced in factories or precast. In the Tukad Ayung Bridge replacement project, the girder concrete used is girder concrete that has been fabricated and produced in the factory and then brought to the work site. In the preparation stage for the concrete girder beams, there is work which includes the mobilization of the girder concrete. The tools used in the process of procuring or mobilizing girder concrete from the stock yard to the project location are large trucks (trailer trucks) and cranes to lift and lower girder concrete. In terms of implementation, it is necessary to consider the distance from the girder production site to the project location, road access must also be surveyed first, whether trucks carrying girders can pass through the road or not. The last thing to pay attention to is monitoring the girder material during the transportation process, to minimize careless work resulting in collisions or causing defects in the girder. At the girder concrete preparation stage, the risk of work accidents is identified. It is possible that workers will be scratched by pieces of material at the project site during the mobilization of concrete girders, causing workers to be injured or hit because the access road for mobilizing concrete girders is not suitable. This can also cause workers or local people to be hit by concrete girder beams when the mobilization of girder concrete does not comply with procedures. During the mobilization of concrete girders, there is also the possibility that the concrete girders will fall or be hit, causing equipment to be damaged and the possibility of traffic accidents where the falling concrete girders can hit surrounding public facilities. Collisions of heavy equipment or vehicles transporting girder concrete during the girder concrete mobilization process also allow damage to facilities, causing spills or broken pieces of concrete or reinforcing steel which can cause accidents, both for the surrounding community and workers at the site. During the mobilization of concrete girders, there is also the possibility that the concrete girders will fall or be hit, causing equipment to be damaged and the possibility of traffic accidents where the falling concrete girders can hit surrounding public facilities. Collisions of heavy equipment or vehicles transporting girder concrete during the girder concrete mobilization process also allow damage to facilities, causing spills or broken pieces of concrete or reinforcing steel which can cause accidents, both for the surrounding community and workers at the site. During the mobilization of concrete girders, there is also the possibility that the concrete girders will fall or be hit, causing equipment to be damaged and the possibility of traffic accidents where the falling concrete girders can hit surrounding public facilities. Collisions of heavy equipment or vehicles transporting girder concrete during the girder concrete mobilization process also allow damage to facilities, causing spills or broken pieces of concrete or reinforcing steel which can cause accidents, both for the surrounding community and workers at the site.

3.3. Stage of Making Scaffolding (Girder Truss)

This stage begins with the work of installing scaffolding poles (supports) for the truss girders as temporary stands for the concrete girder when launching or launching. The scaffolding and truss girders must be calculated to be able to carry the weight of the concrete girder itself, including other necessary loads. At this stage of work on making scaffolding or truss girders, there is the possibility of a risk of workers or the public being hit by beams, causing injury or damage. Apart from that, workers could be trapped by beams and equipment could be damaged due to inappropriate or excessive capacity or load. There is also the possibility of scaffolding (girder truss) falling on workers.

3.4. Erection Stage (Setting Segmental Girder)

At this stage, the girder concrete is placed in a flat position on the bridge opening which has been arranged in such a way that its level is so that segmental setting work can be carried out according to the plan. Setting the segmental girder starts from launching the beam segment at the farthest end from the oprit position where the concrete girder is placed. If the concrete girder at the far end is in the specified position, the next segment is launched.

This work is repeated until all segments in one span of the concrete girder beam are positioned according to the plan drawing. At the erection or segmental girder setting stage, possible risks are identified as a result of falling beams due to uneven and non-solid ground contours so that workers or the surrounding community may be hit by beams which will cause injury. When the segmental setting process is incorrect, it can cause girder concrete beams to fall, putting workers at risk of being crushed or crushed by the girder concrete. It is possible for equipment to transport girder concrete to be damaged when its capacity does not match the girder concrete being transported. Falling concrete girders or collisions between concrete girders and other facilities may also occur, causing the concrete girders to be damaged and destroyed.

3.5. Prestressed Steel Installation Stage (Strand Cable)

At the stage of installing prestressing steel (strand cables), starting with installing prestressing steel according to the plan drawing in terms of quantity and size including the required length, this is done for all tendons within one span of the girder concrete beam. The installation of the strand cable is followed by the installation of other equipment such as anchor heads and wedges to lock the ends of the strand cable. At this stage of installing prestressed steel (strands), there is the possibility of a risk of workers or the public being punctured by the strand cables, causing workers to be injured. The risk of workers falling from a height may also occur, causing workers to be hit by ejected materials or materials falling from a height.

3.6. Cable Strand Stressing Work Phase

This work begins with checking that all strands and accessories have been installed correctly. Then, the jack, stressing pump and accessories were installed at one end of the concrete girder beam so that the stressing work could be carried out safely. The hydraulic jack (jack) and stressing pump are driven by electric power. During the stressing process, the manometer readings and strand elongation that occur on the stressing form are recorded. The data that has been recorded is compared with theoretical calculations in accordance with the requirements of the job specifications. When carrying out girder concrete work in the stressing stage, the possible risk that occurs is the worker falling from a height during the stressing process which causes the possibility of injury or injury to the worker. Besides that, In the stressing process, it is also possible for the cable strand to break, the chain block chain to break, the stressing pump hose to leak and equipment or work machines to fall from a height. Broken strand cables cause damaged wedges, beam anchors and girder concrete are also damaged, so that nearby workers may be hit by ejections. Material from the direction of stress. Falling material from a height may also occur during this stressing stage.

3.7. Concrete Girder Tendon Grouting Stage

The grouting job is to fill the air cavity between the strand and the ducting or sleeve. The aim is to prevent the danger of corrosion and to bind the strand with the casing and the surrounding concrete into one unit. The grouting material consists of a mixture of cement and water and added additives. The water used for grouting is clean water in accordance with the provisions stipulated in the work specifications. This stage of work includes:

1. Cable cutting, where cutting is carried outcable 2 – 3 cm from the face of the widges using an electric grinding machine.
2. In the anchor grouting hole, a plastic pipe is installed to insert the grouting material. For grouting holes, you should use plastic pipes.
3. Make a mixture with a mixture of cement and chemicals/additives.
4. This mixture is fed into the grouting hole using a grouting pumpwith a pressure of 5 kg/cm^2.
5. After that, closure is carried out by tying the ends of the outer grouting pipe using wire.
6. After the grouting work is complete, the ends of the beams are covered with concrete material.

At this stage of grouting concrete girder beams, there is a possibility that workers will be exposed to chemicals when making the mortar. This causes workers to experience skin irritation due to exposure to chemicals. There is also the possibility of damage to the tool or work machine where the grinding tool may malfunction and the grouting pipe may leak. This can endanger workers or the surrounding community.

3.8. Diaphragm Installation Stage

A diaphragm is a structural element whose function is to provide a bond between the girders so that it will provide stability to each girder concrete girder beam in the transverse direction to the concrete girder beam. Diaphragm installation work is carried out by installing reinforced concrete in the transverse direction according to the plan drawing. At this stage of installing the diaphragm, there is a possibility that the worker will fall from a height, resulting in the worker being injured or injured. The possibility of workers being trapped when installing diaphragm formwork can also occur if they are not careful. The possibility of material falling during installation of the diaphragm can also occur, this causes the possibility of workers being hit by material falling from a height. Based on the description of work on concrete girders in the Tukad Ayung Bridge replacement project, it can be summarized what risks may occur or may arise. The identified risks are presented in Table 5.

Table 5. *Identification of Risks and Hazards.*

No.	Description	Risk Identification	Hazard Identification
1.	Girder concrete preparation	Workers were impaled by pieces of material Workers or people are crushed by concrete girders. Girders fall or are impacted.	1. Workers are injured/hit 2. Equipment is damaged due to excessive capacity 3. There was a traffic accident involving a public facility

No.	Description	Risk Identification	Hazard Identification
		Collision of heavy equipment/vehicles transporting girder concrete.	4. Damage to facilities occurs and fragments of broken concrete or reinforcing steel are scattered
2.	Stage of Making Scaffolding (girder truss)	Workers or people are hit by beams	1. Workers are injured/injured
		The worker was pinned down by a beam	2. Equipment is damaged due to excessive capacity
		Scaffolding fell on workers	3. Girders are damaged and destroyed
3.	Erection Stage (Setting segmental girder)	Workers or people are hit by beams	1. Workers are injured
		Worker falls from height	2. Being hit by ejected material or materials that fall and are crushed by the concrete girder
		Machine damage due to overload	3. Sling breaks and material falls from a height
4.	Prestressed Steel Installation Stage (Strand)	Workers or members of the public are punctured by prestressed steel	1. Workers are injured
		Worker falls from height	2. Being hit by a thrown or falling material
		Workers are exposed to grinding	3. Sling breaks and material falls from a height
5.	Cable Strand Stressing Work Phase	Worker falls from height	1. Workers are injured/injured
		Workers or the public are hit by loose strand cables	2. The chain block chain broke and the stressing pump hose leaked
		The worker was impaled by the end of the cable strand	3. Damaged wedges, damaged anchor blocks and damaged girder concrete
		Material falls from a height	
6.	Concrete girder beam tendon grouting stage	Workers are exposed to chemicals	1. Workers experience skin irritation due to exposure to chemicals
		Worker crushed by grouting machine	2. The grouting tool has malfunctioned and the grouting pipe is leaking
7.	Diaphragm Installation Stage	Worker falls from height	1. Workers are injured/injured
		Workers are squeezed	2. The machine malfunctions and the tool collapses
		Workers were crushed by falling machines	3. People are hit by falling material.
		Workers were crushed by diaphragm material	4. Workers fall and get stuck

3.9. Risk Assessment

This risk assessment is a way to determine risk categories into groups based on the level of risk. To determine the category of these variables, use the risk categorization table referring to AS/NZS 4360: 2004 [10]. Before conducting a risk level analysis, an assessment of the likelihood and severity levels is carried out based on the results of distributing questionnaires. The calculation begins by determining the percentage level of probability and severity of a risk, then continues by entering the probability level based on the percentage categories presented in Table 6.

Table 6. *Determination of Possibility and Severity Levels.*

Probability/Severity Value	Scoring scale	Levels
0% < n < 20%	Very Low (SR)	1
21% < n < 40%	Low (R)	2
41% < n < 60%	Medium (S)	3
61% < n < 80%	Height (T)	4
81% < n < 100%	Very High (ST)	5

The results of the overall level of Work Accident risk on the Tukad Ayung Bridge Replacement Project are in accordance with Table 7.

Table 7. *Risk Level.*

Code	Stage Work	Risk	L	S	Level Risk
R1	Girder concrete preparation	Workers were impaled by pieces of material	3	3	High
R2		Workers or people are crushed by concrete girders	4	2	High
R3		Girders fall or are impacted	2	3	Moderate
R4		Collision of heavy equipment/vehicles transporting girder concrete	2	2	Moderate
R5	Stage of Making Scaffolding (girder truss)	Workers or people are hit by beams	4	2	High
R6		The worker was pinned down by a beam	2	3	Moderate
R7		Scaffolding fell on workers	2	4	High
R8	Erection Stage (Setting segmental girder)	Workers or people are hit by beams	4	3	High
R9		Worker falls from height	4	2	High
R10		Machine damage due to overload	4	4	Extreme
R11	Prestressed Steel Installation Stage (Strand)	Workers or members of the public are punctured by prestressed steel	4	3	High
R12		Worker falls from height	4	2	High
R13		Workers are exposed to grinding	4	2	High
R14	Cable Strand Stressing Work Phase	Worker falls from height	3	2	Moderate
R15		Workers or the public are hit by broken strand cables	3	4	High
R16		The worker was impaled by the end of the cable strand	2	3	Moderate
R17		Material falls from a height	3	2	Moderate
R18	Concrete girder beam tendon grouting stage	Workers are exposed to chemicals	3	2	Moderate
R19		Worker crushed by grouting machine	2	3	Moderate
R20		Exposure to other materials/substances	2	3	Moderate
R21	Diaphragm Installation Stage	Worker falls from height	3	2	Moderate
R22		Workers are squeezed	4	2	High
R23		Workers were crushed by falling machines	2	3	Moderate

Code	Stage Work	Risk	L	S	Level Risk
R24		The worker was crushed by diaphragm material	3	2	Moderate

Based on Table 7, it can be seen that of the 24 risks identified, these risks are at moderate, high and extreme levels. The following presents a risk mapping based on the risk categories presented in Table 8. Based on table 8, it can be seen that the majority of risks identified in the concrete girder installation work in the Tukad Ayung Bridge replacement project are in the moderate category, namely 12 risks with a percentage of 50%. Furthermore, 11 risks are included in the high category with a percentage of 45.83%. Meanwhile, in the extreme category there is one risk with a percentage of 4.17%.

Table 8. *Risk Mapping Based on Risk Category.*

Probability / likelihood of danger	Severity of hazard Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Rare (1)					
Unlikely (2)		Moderate (R4)	Moderate (R3, R6, R16, R19, R20, R23)	High (R7)	
Prosibble (3)		Moderate (R14, R17, R18, R21, R24)	High (R1, R15)		
Likely (4)		High (R2, R5, R9, R12, R13 R22)	High (R11, R8)	Extreme (R10)	
Almost certain (5)					

4. Conclusion

Risk identification occurs at the girder concrete preparation stage, scaffolding construction stage, prestressing steel installation stage, cable strand stressing work stage and girder concrete tendon grouting stage. From the results of this study, 24 risks were identified with 12 risks in the moderate category, 11 risks in the high category and 1 risk in the extreme category. Risk control that can be carried out from the three levels of risk found is by reducing risk through administrative control, engineering control, and warning systems. To reduce risks during the installation of girder beams on the Tukad Ayung Bridge replacement project, it is necessary to carry out training related to. Occupational Safety and Health risks for each worker, implement a shift system and give workers alternate days off, carry out health checks, control the work environment dangerous which has a high risk.

Conflicts of Interest

The authors declare no conflict of interest.

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