INTERNATIONAL JOURNAL ON ADVANCED TECHNOLOGY, ENGINEERING, AND INFORMATION SYSTEM
(IJATEIS)

RISK ANALYSIS OF STEEL BOX GIRDER INSTALLATION USING HIRARC METHOD
(Case Study: Aloha Sidoarjo Flyover Construction Project)

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Abstract

Research on the Aloha flyover construction project aims to determine the risks that occur in the workmanship of installing steel box girder, knowing the level of risk that occurs in the workmanship of installing steel box girder and knowing how to control the risks that occur in the workmanship of installing steel box girder. The method used in this research is the Hazard Identification Risk Assessment and Risk Control (HIRARC) method guided by the Malaysia HIRARC Guidelines (2008). Starting from identifying hazards at each stage of the work activity, a risk assessment is carried out, the results of which can be used as a reference for risk control, so as to reduce the risk of work accidents. The results of the analysis from the identification of hazards and risks arising in 5 stages of work and a total of 11 potential hazard findings were obtained. (1) Preparation stage for steel box girder erection maneuver;(2) The process of leveling/compacting the erection area soil for preparation of crawler crane footing/foundation; (3) The process of mobilizing steel box girder material from stockyard to erection area; (4) Installing slings + seals that will be used during steel box girder erection; (5) The process of installing steel box girder using crawler crane.

Keywords: *Hazard, Flyover, HIRARC, Risk, Steel Box Girder*

1. INTRODUCTION

Construction projects, especially road construction in Indonesia, continue to increase every year and are carried out to the border areas of the country. This happens because the availability of roads greatly affects daily activities and can have many positive impacts on all Indonesian people. One of them is the national road in Indonesia whose development is growing every year. Based on data from the Public Works and Public Housing Infrastructure Statistics (2020), 92.81% of roads in Indonesia are in good condition. The achievement of this percentage is certainly supported by many factors, including human resources, namely workers who are the most important asset in construction work.

Every worker who does work, both indoors and in the open field, is potentially exposed to risks in the work caused by hazards that exist around the work area. Heavy equipment, machinery, materials, work environment and workers are some of the potential sources of hazards that can cause harm. Hazard risk itself includes various levels of risk, ranging from low risk to very high risk. Compared to workers in general, workers at construction sites have a risk level 2 to 4 times higher (Sucita & Broto, 2011). The impact of risk on construction projects can hamper project performance, affecting working time, quality of work and cost losses (Labombang, 2011). It is undeniable that the risk of accidents can occur and is difficult to eliminate completely. Risk arises because of uncertainty in a job. And the biggest risk in construction projects is workers who experience work accidents. With proper analysis, risks can be prevented and minimized.

Accidents are events that are not expected to occur and can occur unexpectedly and cause losses to activities, people, the environment, and company assets (Gunawan & Waluyo, 2015). Accidents can happen anywhere, to anyone and by anyone and can be caused by carelessness of oneself or others, or even caused by nature. In work, accidents can occur and can be called work accidents. Work accidents can be divided into 2 causes, namely the first cause due to unsafe acts caused by humans and the second cause due to unsafe acts caused by conditions (unsafe conditions) (Transportation, 2000). Putri et al (2018), said that the causes of work accidents need to be sought and observed, so that work accidents can be prevented and do not recur.

In Indonesia, cases of work accidents continue to increase every year. Data from the Social Security and Employment Organizing Agency (BPJS Ketenagakerjaan) shows that in 2022 work accidents increased by 13.26% compared to the previous year, namely in 2021 234,270 cases then increased in 2022 by 265,334 cases. The following is data on the increase in the number of work accidents in Indonesia over the past 6 years.

Based on BPJS Employment data, November 2022 the number of work accidents from 2017 to 2022, it can be seen that the number of work accidents from the pandemic in 2020 to 2022 has increased by around 200 thousand cases. In 2020 there were 221,740 cases of work accidents, while in 2021 this touched 234,270 cases. Until November 2022, work accidents reached 265,334 cases. This high increase in the number of work accidents makes the application of occupational safety and health (K3) a priority in order to realize increased work productivity (Juraman & Beatrix, 2023).

Safety and health is an important part that affects all areas of work, both in the office and in the field, because occupational(Ramli, 2010) safety and health can prevent and reduce the risk of accidents or disability due to work activities (Waruwu and Yuamita, 2016). Occupational health and safety in Indonesia is regulated in Law No. 1 of 1970 concerning Occupational Safety. This law regulates the responsibilities of companies and workers in achieving work safety(Lensun et al., 2022). The implementation of occupational safety and health in a company can be determined by several factors, namely worker participation in the implementation of occupational safety and health, management mechanisms established by the company, and occupational safety and health regulations issued by the company (Abidin & Mahhubah, 2021).

The construction of the Aloha Sidoarjo flyover is motivated by the frequent congestion around the Aloha area. Aloha area is one of the congestion points in Sidoarjo, precisely on the west side of Aloha gas station or next to Maspion from Surabaya towards Sidoarjo or towards Juanda Airport and also vice versa from Sidoarjo towards Surabaya. With the implementation of the construction of this flyover is expected to unravel the congestion that occurs on the Waru Highway (Direction from Sidoarjo to Surabaya), the reverse direction of the Letjen Suparman road (Direction from Surabaya to Sidoarjo), the direction from Surabaya to Juanda Airport, the direction from Juanda Airport to Surabaya, and several small roads around Aloha which have also been affected by the congestion. In addition, the construction of this flyover is part of the government's efforts to improve the quality of infrastructure, so that it can unravel congestion. As well as efforts to encourage economic recovery with the smoother movement of people and goods.

This project involves a lot of human resources, which is carried out in a fairly limited area, a fairly large work item, with limited implementation time and an accelerated work completion target due to the demands of the job holder. Then, the large number of workers and heavy equipment to achieve the target completion of this work will also increase the level of possibility of occupational accident risk. In addition, the risk analysis of work accidents on this project is quite important to do, because the elevated structure on this project passes through a highway that at certain times there is congestion, passes through active railroad lines, densely populated areas, and others that have greater risks.

Based on the explanation above, it can be seen that reducing the risk of work accidents is very important in a construction project, not least in the Aloha flyover construction project, especially in the implementation of steel box girder installation. And to reduce the risk of work accidents, identification of potential risks can be done by using the HIRARC (Hazard Identification Risk Assessment and Risk Control) method, starting from identifying hazards at each stage of work activities and then conducting risk assessments whose results can be used as a reference for risk control, so as to reduce the risk of work accidents (Purnama, 2015).

Based on the background that has been described above, the purpose of this study is to analyze the risks that occur in the workmanship of installing steel box girder on the Aloha flyover construction project, analyze the level of risk that occurs in the workmanship of installing steel box girder on the Aloha flyover construction project, and analyze how to control the risks that occur in the workmanship of installing steel box girder on the Aloha flyover construction project(Oetomo, 2014).

2. RESEARCH METHODS

The subject of this research is workers in the implementation of the installation of steel box girder on Aloha flyover construction project with Hazard Identification, Risk Assessment And Risk Control (HIRARC) method(Kanugrahan et al., 2022).

In this study the object of research focuses on the risk of hazards in the implementation of seel box girder installation on the Aloha flyover construction project . The research location of the Aloha Surabaya - Sidoarjo flyover construction project in Sidoarjo Regency, East Java Province which is geographically located at 7.3734°S 112.7258°E. The research instruments are as follows:

1. Hazard Identification, Risk Assessment, Priority Scale, Risk Control and Responsible Person,(SALSABILLA, 2023) namely the HIRARC (Hazard Identification, Risk Assessment and Risk Control) Table to identify hazards that exist in the Aloha flyover construction project which refers to the Minister of Public Works Regulation No. 05 of 2014(Moniaga & Rompis, 2019).
2. Stationery to record the results of observations and interviews
3. Camera to document observations.

The data collection procedures carried out in this study are primary data and secondary data. Primary data is obtained from direct observation or observation in the field, observations are made to find out and collect data about hazards and risks to workers on the work activity process of the construction project for the installation of steel box girder flyover Aloha using the HIRARC sheet by observing each stage of work on the project which will be used to identify hazards and risks(Hazani, 2008). Interviews were also conducted with OHS experts to support the completeness of data collection regarding hazards and risks. (Albani Musyafa, 2020) Secondary data was obtained from the application of SMK3 in the OHS policy and OHS Organization on the Aloha flyover construction project, including: implementation RKK document, Work RMPK document, methods/stages of work on the installation of steel box girde, and data on work accidents that have occurred during the implementation of steel box girder installation.

Processing in analyzing data is carried out using the HIRARC method guided by the Malaysia HIRARC Guidelines (Hazani binti Ismail, 2008), the following steps in data analysis are:

1) Classify all work activities by the degree of job similarity such as geographical or physical areas within or outside the job site, stages in the production or service process, and so on.
2) Identify the hazards of the work activity
   Hazard identification is prioritized on critical jobs that pose a significant risk to worker safety and health(RI, 2014).
3) Determining risk assessment can be done by analyzing and estimating the frequency value and severity value of each hazard, then calculated by multiplying 2 indicators of frequency value and severity value and producing a relative risk level value which is then used to determine the risk level.

   Here is the process for determining the risk assessment:

   a) Determine the likelihood value (K) of hazard occurrence
   b) Determine the severity (P) value of the hazard
   c) Calculate the relative risk level using the formula: Relative Risk Level (TR) = K x P
4) Risk Control

Project hazard controls are actions taken to minimize or eliminate the risk of occupational accidents. Risk control can be in the form of: elimination, substitution, engineering control, warning system, administrative control, and personal protective equipment (PPE).

3. RESULTS AND DISCUSSION

3.1. Steel Box Girder Erection Work Stage

The erection stage of the steel box girder on the Aloha flyover construction project, the procedure is the same as the installation of girders in general. The method of erection of steel box girder using the crawler crane method is using crawler cranes with a capacity of 200ton and 250ton each to lift the steel box girder material. Erection of steel box girder was attended by 1 field executor, 1 safety officer, 3 workers and 2 tool operators.

In the erection of steel box girder on Aloha flyover, there is a planning method of implementation starting from the preparation stage until the girder erection process is complete. The following is the planning method of erection of steel box girder in general as flowchart below:

Figure 1. Flowchart of steel box girder erection implementation
Source: Wika-Nindya KSO Implementation RKK Document

3.1.1. Preparatory Work

Determining the steel box girder assembly area at the project site and the installation of girder mounting jigs made of H-Beam and concrete soil reinforcement foundation. The delivery process of segmental steel box girder from the factory to the assembly area is carried out using a 12-meter flatbed truck with the help of a mobile crane with a capacity of 80 tons as a tool for lowering and arranging segmental girder.

Figure 2. Delivery of segmental steel box girder
Source: Wika-Nindya KSO Implementation RKK Document

3.1.2. Steel Box Girder Ground Assembly Work

Figure 3. Flowchart of steel box girder ground assembly
Source: Wika-Nindya KSO Implementation RKK Document

Girder assembly work begins with adjusting the alignment of segmental girder and chamber girder, then tightening the join bolts between girder segments.

Figure 4. Adjusting the chamber and tightening the segment join bolts
Source: Wika-Nindya KSO Implementation RKK Document

3.1.3. Erection Work

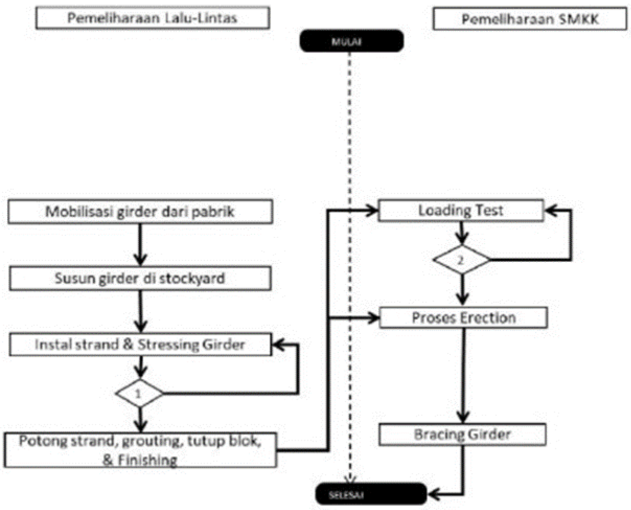

Figure 5. Stages of steel box girder erection work
Source: Wika-Nindya KSO Implementation RKK Document

The girder erection sequence process is carried out based on a predetermined sequence. The segmental girder is lifted from the bottom until it exceeds the pier height, then the segmental girder is lifted by crawler crane and placed on the pedestal.

When the crawler crane passes through the erection area, a platform/iron plate must be provided for the crawler crane's footing so that the ground passed by the crane does not shift or fall. After the girder is in position and is safe, then proceed with lifting the next segmental girder with the same steps and connecting the segmental girder above the pier.

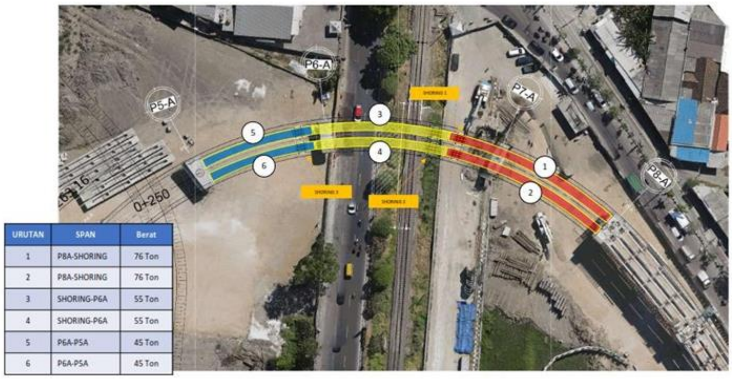

Figure 6. Layout of steel box girder installation sequence plan
Source: Wika-Nindya KSO Implementation RKK Document

3.2. HIRARC (Hazard Identification, Risk Assessment and Risk Control)

In this study, data analysis used the HIRARC method which was carried out from each stage of the work process on the construction of the Aloha flyover, especially on the installation of steel box girders(Hidayat & Nuruddin, 2022). The first step is to identify hazards, potential causes of hazards and risks that exist in the work activities of each stage of the work process. After knowing the hazards, potential causes of hazards and risks, a risk assessment is carried out which consists of a likelihood / frequency assessment (K) and a severity / severity assessment (P) where the assessment score is guided by the Malaysian HIRARC Guidelines (2008) table, and then multiplication will be carried out between the likelihood / frequency (K) and severity / severity assessment (P) to determine the level of risk (TR). after knowing the value of the risk level, then the risk assessment is carried out, After knowing the value of the risk level, it will be known the priority scale for taking further action in the low, medium, or high risk category, this is also guided by the Malaysian HIRARC Guidelines (2008)(Triswandana, 2020) table and the last is to carry out risk control either by elimination, substitution, engineering control, warning system, administrative control, personal protective equipment (PPE) to minimize the risk of work accidents.

3.2.1. Hazard Identification, Risk Assessment and Control of Steel Box Girder Installation

In the first stage of the HIRARC (Hazard Identification Risk Assessment and Risk Control) method, identification of hazards, potential causes of hazards and also risks in the installation of steel box girder construction of Aloha flyover from the beginning of preparation of steel box girder erection maneuvers to the process of installing steel box girder. The identification of hazards and risks is sorted according to the stages of work activities.

After identifying hazards, potential causes of hazards and risks, the next step is to carry out a risk assessment consisting of a likelihood / frequency assessment and a severity / severity assessment, which will then be assessed by multiplying the likelihood / frequency and severity / severity to determine the level of risk. The next step after obtaining the value of the risk level and knowing the risk level, risk control is carried out in accordance with the actions that can be taken to minimize the risk of work accidents.

3.2.2. Analysis of Hazard Identification, Risk Assessment and Control of the Steel Box Girder Erection Process

Based on the analysis of the Identification, Assessment and Risk Control of Steel Box Girder Installation, the results of observations that have been made there are 5 processes of the work stages of installing steel box girder for the construction of the Aloha flyover using the Hazard Identification, Risk Assessment and Risk Control (HIRARC) method, there are various potential hazards in the process of the work stages(Ilham, 2021). The results of the hazard identification that has been carried out, followed by a risk assessment by multiplying the frequency score with the severity score to determine the level/level of the risk using the Malaysia HIRARC Guidelines (2008) table, finally making recommendations/determinations for control of each risk. The following is an explanation of the hazard identification, risk assessment and risk control determination of the 5 stages of the steel box girder installation process, as follows:

1) Preparation for steel box girder erection maneuvers

During the preparation for maneuvering the steel box material, there are several tools and materials needed such as: flatbed truck, crawler crane, and steel box girder material. The person in charge of the preparation for the steel box girder erection maneuver is the K3 Officer and the Executor. The preparation stage for this steel box girder erection maneuver has hazards and risks, namely:

a. A 12-meter-long flatbed truck crashed into a water barrier

This hazard can occur because the opening of the water barrier is too little due to the narrow area so that it can cause the risk of falling steel box girder material when maneuvering. Risk assessment with a frequency value score of 4 (often), a severity value score of 3 (serious), a risk level value of 12 and a priority scale value of 2 in the (medium) category.

Risk controls that can be carried out are as follows:

- Engineering Control:
  - The position of the water barrier that blocks the access of flatbed trucks carrying steel box girder material is opened at least according to the length of the flatbed truck, which is 1 meter.
  - Install traffic management and ruber cones in accordance with the work traffic management plan (RMLL) document.
  - Installing Led hose lights along the entrance of flatbed trucks and placing rotary lights at the entrance of flatbed trucks.
  - Placing flagman at steel box girder erection site
  - Ensure the flatbed truck has a valid vehicle KIR test and is still valid
  - Conduct vehicle checks and checklists before operation
  - Ensure drivers have an appropriate and valid driver's license.
- Warning System: Install an alarm system on the flatbed truck in the form of a distance detector to determine the safe distance warning.
- Administrative Control:
  - Require flatbed truck drivers to have a driver's license in accordance with the type of vehicle and still valid.
  - Requiring trucks to have KIR
- PPE (Personal Protective Equipment): Using safety belts, safety shoes, safety gloves and vests.

2) The process of leveling/compacting the soil of the erection area in preparation for the crawler crane's footing/foundation.

In the process of leveling/compacting the soil of the erection area for the preparation of the crawler crane footing/foundation, there are several tools and materials needed such as: cylinders and steel platforms/plates. The person in charge of the process of leveling/compacting the soil of the erection area for the preparation of the crawler crane footing/foundation is the K3 Officer and the Executive. The stage of the process of leveling/compacting the ground of the erection area for the preparation of the crawler crane footing/foundation has hazards and risks, namely:

a. Crawler crane collapses and rolls over

This hazard can occur due to the condition of the soil that is not solid, causing the risk when the crawler crane lifts the steel box girder with unstable ground conditions that can cause the steel box girder to fall. Risk assessment with a frequency value score of 3

(quite often), a severity value score of 5 (disaster), a risk level value of 15 and a priority scale value of 1 is included in the category (high).
Risk controls that can be carried out are as follows:

- Engineering Control:
  - A steel platform is installed on the ground before the crawler crane passes.
  - Conduct soil bearing capacity (CBR) tests with values of 6% for subgrade, 95% for compacted soil.
  - Conduct a checklist of crawler crane conditions, crawler cranes must have an SIA (tool license), have a SILO (license worthy of operation) and crawler crane operators must have a competent SIO (operator license) in their field.
- Administrative Control:
  - Requires stable soil conditions with soil bearing capacity (CBR) results at 6% for subgrade, 95% for compacted soil by authorized experts.
  - Require a checklist of documents related to crawler cranes ranging from SIA (equipment license), SIO (operator license) who are competent in their fields, SILO (license worthy of operation), condition and history of cranes and other equipment.
- PPE (Personal Protective Equipment): Using safety belts and other equipment such as safety shoes, safety gloves, helmets, and vests.

3) Process of mobilizing steel box girder materials from stockyard to erection area

In the mobilization of steel box girder material from the stockyard to the erection area, there are several tools and materials needed such as: flatbed truck, crawler crane, boogie and steel box girder material. The person in charge of the steel box girder material mobilization process from the stockyard to the erection area is the K3 Officer and the Executor. This stage of the process of mobilizing steel box girder material from the stockyard to the erection area has hazards and risks, namely:

a. Flatbed truck carrying steel box girder crashes into another vehicle

This hazard can occur due to brake failure, operator incompetence, and operator drowsiness that can cause the risk of injury, fracture or death. Risk assessment with a frequency value score of 3 (quite often), a severity value score of 2 (minor), a risk level value of 6 and a priority scale value of 2 is included in the (medium) category.
Risk controls that can be carried out are as follows:

- Engineering Control:
  - Conduct traffic lane engineering in accordance with the Works Traffic Management Plan (RMLLP) document.
  - Placing flagman at steel box girder erection site
  - Conduct vehicle checks and checklists before operation
  - Ensure the flatbed truck has a valid vehicle KIR test and is still valid
  - Installed led hose lights on the flatbed truck body and placed rotary lights on the flatbed truck head.
- Warning System: Install an alarm system on the flatbed truck in the form of a distance detector to determine the safe distance warning.
- Administrative Control:

- Coordinate with all personnel participating in steel box girder erection work.
- Requires trucks to have KIR
- Require flatbed truck drivers to have a driver's license (surat izin mengemudi) in accordance with the type of vehicle and still valid.

• PPE (Personal Protective Equipment): Using safety belts and other equipment such as safety shoes, safety gloves, helmets, and vests.

4) Installing slings + seals that will be used during steel box girder erection.

The stage of installing slings + seals that will be used during the erection of steel box girder, there are several tools and materials needed such as: crawler crane, boogie, wire rop sling and seal. The person in charge of the stage of installing slings + seals that will be used during the erection of this steel box girder is the K3 Officer and the Executor(Asprila Akbar, 2019). The stage of installing slings + seals that will be used during the erection of steel box girder has hazards and risks, namely:

a. Worker fell from a height during installation and fastening of slings + seals

This hazard can occur because workers do not use full body harnesses so that they can pose a risk of work accidents. Risk assessment with a frequency value score of 3 (quite often), a severity value score of 5 (catastrophic), a risk level value of 15 and a priority scale value of 1 is included in the (high) category.
Risk controls that can be carried out are as follows:

- Engineering Control:
  - Install safety nets to protect workers if they fall.
  - Make a lifeline or railing to hook the full body harness.
  - Ensure workers have a Work at Height Permit and have a certificate of competency in working at height.
  - Ensure workers are in good health with a health check before work
- Administrative Control:
  - Toolbox meeting (explanation of the dangers of working at heights)
  - Require workers at heights to have a Work at Height Permit and have a certificate of competency to work at heights.
  - Requiring tests and health checks before work.
- PPE (Personal Protective Equipment): Using complete PPE ranging from safety shoes, safety gloves, helmets, and vests. Also, wearing a fullbody harness double lanyard with absorver.

5) Installation process of steel box girder using crawler crane

The process of installing steel box girder using crawler crane has several tools and materials needed such as: crawler crane, boogie and steel box girder material. The person in charge of the process of installing steel box girder using crawler crane is K3 Officer and Executor. The stage of the steel box girder installation process using a crawler crane has hazards and risks, namely:

a. Operators/workers experience fatigue/drowsiness while working

This hazard can occur due to working hours exceeding the limit and conditions lacking rest so that it can cause work accidents. Risk assessment with a frequency value score of 3 (quite often), a severity value score of 4 (fatal), a risk level value of 12 and a priority scale value of 2 in the (medium) category.
Risk controls that can be carried out are as follows:

- Engineering Control:
  - Ensure workers are in good health with a health check before work
  - Make a work schedule in accordance with the standard working hours a day, if overtime, a work shift schedule is made.
- Administrative Control:
  - Require a limit on working hours for workers by creating a work shift schedule.
  - Require regular health checks before carrying out work activities.
  - Conduct a toolbox meeting about existing hazards, as well as emergency response from the contractor before starting a job.
  - Providing warning signs "BEWARE NOT TO SLEEP WHILE WORKING"
- PPE (Personal Protective Equipment): Using safety belts and other equipment such as safety shoes, safety gloves, helmets, and vests.

b. Crawler crane overturned/slipped

This hazard can occur because the speed when using a crawler crane is not taken into account and does not check the condition of the engine, tires, or steering system so that it can pose a risk of work accidents. Risk assessment with a frequency value score of 3 (quite often), a severity value score of 2 (minor), a risk level value of 6 and a priority scale value of 2 is included in the category (medium).
Risk controls that can be carried out are as follows:

- Engineering Control:
  - Install "CAUTION MANUVERING HEAVY TOOLS" signs.
  - Strengthening the crawler crane platform by ensuring the position of the equipment is stable and installing a platform/iron plate under the crawler crane.
  - Ensure the level of the crawler crane is stable, then check the angle if it is appropriate read the table of guidelines for the maximum load capacity that can be transported and the angle of the boom, once it is appropriate do the angle log.
- Administrative Control:
  - Limit the maximum speed of the crawler crane according to SOPs
  - Require crawler cranes to have SIA (equipment license) and SILO (license worthy of operation), crawler crane operators must have SIO (operator license) and must be competent in their field.
  - Require checking of crawler cranes before use with a checklist of engine conditions, tires, steering systems etc.
  - Create a guideline table of maximum transportable load capacity and boom angle
  - Toolbox meeting about existing hazards, as well as emergency response from the contractor before starting a job.
  - Ensure the crane is in a condition fit for operation (passes the mutual test)

c. Sling or wire rope crane broke during steel box girder erection and hit a worker.

This hazard can occur because the lifting and transporting aircraft equipment is not functioning properly, the slings are not in good condition or are rusted and overloaded girders and binding errors so that they can pose a risk of injury, fracture or death. Risk assessment with a frequency value score of 2 (rare), a severity value score of 4 (fatal), a risk level value of 8 and a priority scale value of 2 is included in the (medium) category. Risk controls that can be carried out are as follows:

- Elimination: Discard slings that are no longer fit/standard
- Substitution: Sling replaced with a new one
- Engineering Control:
  - Ensure that the lifting and transporting equipment is in accordance with the load of the girder to be lifted.
  - Ensure lift and transport aircraft are in a fit for operation condition
  - Controlling slings by cleaning and checking their condition before use.
  - Ensure that slings or wire ropes are clean and safe/standard, by cleaning then tagging that the sling is suitable for use, and placed in a place that is suitable for use separated from slings that are no longer suitable, and the activity is carried out after each use.
  - Isolate the area by installing "NO ENTRY TO DANGEROUS AREA" signs.
- Administrative Control:
  - Tagging slings that are ready for use and also tagging slings that are not ready for use, and placed in different places so that they do not get mixed up.
  - Schedule regular condition control of all lift and transport aircraft, including lift and transport aids by competent operators.
  - Conduct Toolbox meetings about existing hazards, as well as emergency response from the contractor before starting a job.
  - Require crawler crane operators to have an SIO (operator's license) and be competent in their field.
- PPE (Personal Protective Equipment): Using complete PPE ranging from safety shoes, safety gloves, helmets, and vests.

d. Over swing and crawler crane overturned

This hazard can occur due to roads that collapse or are less dense and the limited skills of the operator when operating a crawler crane so that it can pose a risk of injury, fracture or death. Risk assessment with a frequency score of 2 (rare), a severity score of 3 (serious), a risk level value of 6 and a priority scale value of 2 is included in the category (medium). Risk controls that can be carried out are as follows:

- Engineering Control:
  - Conduct soil bearing capacity (CBR) tests with values of 6% subgrade, 95% for compacted soil
  - Monitoring wind speed before and during lifting
  - Ensure the tilt angle and boom length are in accordance with SOPs
- Administrative Control:
  - Conduct Toolbox meetings on the correct method before starting a job
  - Conduct safety induction to crawler crane operators, so that they are aware of existing hazards, such as collapse prone points.
  - Require crawler cranes to have a license to operate (SILO).

  - Require crane operators to have an SIO (operator's license), be able to operate it and have a certificate of competency.
  - Ensure the crane is in a condition fit for operation (passes the mutual test)
  - Placement of flagman personnel who are familiar with the work and always standby during steel box girder installation operations.
  - Placement of clear safety signs "CAUTION AGAIN", "NO ENTRY TO DANGEROUS AREA"
- PPE (Personal Protective Equipment): Using complete PPE ranging from safety shoes, safety gloves, helmets, and vests.

e. Failure in installation due to steel box girder material falling and hitting workers below

This hazard can occur due to the lack of operator skills in carrying out steel box girder installation work, steel box girder has not been tied firmly to the sling crane, lack of bracing reinforcement, and poor bolt stressing results that can pose a risk of injury, fracture or death. Risk assessment with a frequency value score of 4 (frequent), a severity value score of 5 (catastrophic), a risk level value of 20 and a priority scale value of 1 is included in the (high) category.
Risk controls that can be carried out are as follows:

- Engineering Control:
  - Installing slipper for steel box girder support and stiffening steel box girder using stiffner.
  - Installing steel box girder bracing
  - Marking the boundaries of the work area operation area
  - Make a lifting plan
- Administrative Control:
  - Require crane operators to have an SIO (operator's license), be able to operate it and have a certificate of competency.
  - Require steel box girder erection work permit and lifting work permit.
  - Require crawler crane condition check to be fit for operation (passed the mutual test)
  - Toolbox meeting about existing hazards, as well as emergency response from the contractor before starting a job.
  - Install warning signs "CAUTION GIRDER ERECTION WORK"
  - Isolate the area by installing "NO ENTRY TO DANGEROUS AREA" signs.
- PPE (Personal Protective Equipment): Using complete PPE ranging from safety shoes, safety gloves, helmets, and vests.

f. Crawler crane collapses during steel box girder erection

This hazard may occur because the ground is less dense, so it is not able to withstand the weight of the crane itself so that it can cause the risk of injury, fracture or death. Risk assessment with a frequency score of 4 (frequent), severity score of 4 (fatal), risk level value of 16 and priority scale value of 1 is included in the category (high).
Risk controls that can be carried out are as follows:

- Engineering Control:
  - Ensure the footing/foundation for the crawler crane is stable by providing a platform/iron plate under the crawler crane.

- Conduct soil bearing capacity (CBR) tests with values of 6% for subgrade, 95% for compacted soil.
- Ensure that the load of steel box girder material does not exceed the maximum carrying load of the crawler crane.

- Administrative Control:
  - Perform steel box girder erection inspection checklist
  - Require toolbox meetings on good and correct work methods to all heavy equipment operators before starting work.
  - Require crawler cranes to have a license to operate (SILO) from in good operating condition.
  - Require crane operators to have an SIO (operator's license), ensure operators are capable of operating it and have a certificate of competency.
  - Conduct safety induction on existing hazards, as well as emergency response.
- PPE (Personal Protective Equipment): Using a complete PPE safety belt ranging from safety shoes, safety gloves, helmets, and vest.

g. Worker falls from a height

This hazard can occur because the health and mental condition of workers is not good and the condition of the work floor is not strong and unsafe so that it cannot withstand the weight of the crane itself so that it can pose a risk of injury, fracture or death. Risk assessment with a frequency value score of 4 (frequent), a severity value score of 4 (fatal), a risk level value of 16 and a priority scale value of 1 is included in the (high) category.

Risk controls that can be carried out are as follows:

- Engineering Control:
  - Wearing a fullbody harness double lanyard with absorver.
  - Install safety nets to protect workers if they fall.
  - Make a lifeline or railing to hook the full body harness.
  - Ensure workers have a Work at Height Permit and have a certificate of competency in working at height.
  - Ensure workers are in good health with a health check before work
- Administrative Control:
  - Require regular health checks / health and mental checks before carrying out work activities
  - Requires workers at heights to have a Work at Height Permit and have a certificate of competency to work at heights.
  - Require a Toolbox meeting about existing hazards, as well as emergency response from the contractor before starting work.
- PPE (Personal Protective Equipment): Using complete PPE ranging from safety shoes, safety gloves, helmets, and vests. Also, wearing a fullbody harness double lanyard with absorver.

3.2.3. Recap of Analysis of Hazard Identification, Risk Assessment and Control of the Steel Box Girder Erection Process

From the overall analysis that has been carried out, there are 5 stages of the work process of installing steel box girder for the construction of the Aloha flyover using the

Hazard Identification, Risk Assessment and Risk Control (HIRARC) method, a recap of hazard identification and risk assessment can be seen(Suharni, 2020).

The results of the analysis show that the recap of hazard identification and risk assessment of the 5 stages of the work process, there are 5 hazards that fall into the high risk level category, namely the danger of crawler cranes collapsing and rolling over, workers falling from a height during installation and fastening of slings + seals, failure in installation due to steel box girder material falling and hitting workers below, crawler cranes collapsing during steel box girder erection and workers falling from a height. Then there are 6 hazards that fall into the medium risk level category, namely the danger of flatbed rucks with a length of 12 meters crashing into the water barrier, flatbed trucks carrying steel box girder crashing into other vehicles, operators / workers experiencing fatigue / drowsiness while working, crawler cranes overturning / slipping, slings or wire rope cranes breaking during erection of steel box girder and hitting workers, and over swing and finally crawler cranes overturning. Of the 5 stages of the work process, the total hazards and risks of installing steel box girder are 11 activities, and the total number of risk level values is 132, with an average value of 12, meaning that the installation of steel box girder is at a moderate level.

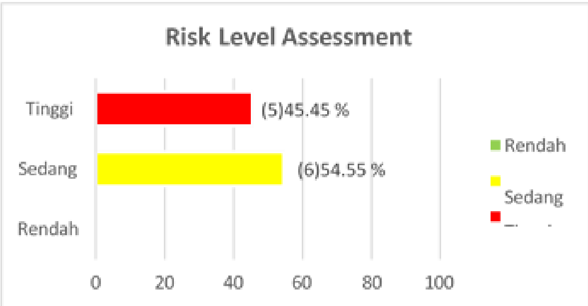

Figure 7. Percentage of Risk Score for Steel Box Girder Installation

In Figure 7 above is the percentage of risk value in the steel box girder installation work with a total of 11 potential hazards, obtained 5 potential hazards with a percentage of risk value of 45.54% which is at a high level and 6 potential hazards with a percentage of risk value of 54.55% which is at a moderate level.

Based on Table 2 below, it can be seen a recap of risk control from 5 stages of the steel box girder installation process, there are several risk controls that can be done either by elimination, substitution, engineering control, warning system, administrative control, and personal protective equipment (PPE) to minimize the risk of work accidents. In the results of the analysis of hazards that have a high risk, one of which is the danger of failure in installation because the steel box girder material falls and hits the workers below, controls that can be carried out engineerimg control as many as 4 activities such as: installing slippers for steel box girder support and stiffening steel box girder using stiffner, installing steel box girder bracing, providing signs of work area restrictions and making lifting plans, then also carried out administrative control as many as 6 activities such as: Requiring crane operators to have SIO (operator's license), able to operate it and have a certificate of competence requires making a steel box girder erection work permit and lifting work permit, requiring crawler crane condition checks worthy of operation (passing the mutual test), toolbox meetings about existing hazards, as well as emergency response from the contractor before starting a job, installing warning signs "CAUTION GIRDER ERECTION WORK", isolating the area by installing signs "PROHIBITED TO ENTER DANGEROUS AREA". And finally complete PPE (Personal Protective Equipment) control starting from safety shoes, safety gloves, helmets, and vests.

4. CONCLUSION

Based on the results of the analysis, several conclusions are obtained, namely:

1. The results of the analysis of the identification of hazards and risks arising there are 5 stages of work and obtained a total of 11 potential hazard findings. (1) Preparation stage for maneuvering steel box girder erection obtained potential hazards of flatbed trucks with a length of 12 meters crashing into water barriers; (2) The process of leveling/compacting the soil of the erection area in preparation for crawler crane footing/foundation obtained potential hazards of crawler cranes collapsing and overturning; (3) The process of mobilizing steel box girder materials from the stockyard to the erection area obtained the potential danger of flatbed trucks transporting steel box girder crashing into other vehicles; (4) Installing slings + seals that will be used during steel box girder erection obtained the potential danger of workers falling from a height during installation and binding of slings + seals; (5) The process of installing steel box girder using crawler cranes obtained potential hazards of operators / workers experiencing fatigue / drowsiness while working, crawler cranes rolled / slipped, slings or wire rope cranes broke during steel box girder erection and hit workers, over swing and crawler cranes rolled over, failure in installation due to steel box girder material falling and hitting workers below, crane collapse during steel box girder erection and workers fell from height.
2. The results of the analysis of the risk level assessment and priority scale there are 5 stages of work, obtained a total of 11 potential hazard findings with details of 5 potential hazards with a percentage of risk value of 45.54% which is at a high level and 6 potential hazards with a percentage of risk value of 54.55%. The total number of risk level values is 132, with an average value of 12, meaning that the installation of steel box girder is at a moderate level. Of the total 11 findings of potential hazards that fall into the high risk level category, 5 potential hazards are the danger of crawler cranes collapsing and rolling over, workers falling from a height during installation and fastening of slings + seals, failure in installation due to steel box girder material falling and hitting workers below, crawler cranes collapsing during erection of steel box girder and workers falling from a height. Then there are 6 potential hazards that fall into the medium risk level category, namely the danger of a flatbed ruck with a length of 12 meters crashing into a water barrier, a flatbed truck carrying steel box girder crashing into other vehicles, operators / workers experiencing fatigue / drowsiness while working, crawler cranes overturning / slipping, slings or wire rope cranes breaking during erection of steel box girder and hitting workers, and over swing and finally crawler cranes overturning.
3. The results of risk control recommendations after obtaining the risk level value and analyzing the risk value, obtained 6 types of risk control in accordance with the risk

control hierarchy, namely elimination, substitution, engineering control, warning system, administrative control, and personal protective equipment (PPE).

5. ADVICE

Suggestions that can be given by the author for the steel box girder installation work of the Aloha flyover construction project, are as follows:

1. Further researchers are expected to analyze related to the tendency of work accidents, namely Frequency Rate (FR) Analysis, Safety Rate (SR) Analysis and Safe T Score Analysis.
2. Future researchers are recommended to conduct thorough observations and analysis of hazards and risks at other stages of work in order to achieve zero accidents.
3. For practitioners in the installation of steel box girder which has a high risk level value, it is controlled by engineering control, administrative control and PPE (personal protective equipment).
4. The installation of steel box girders should not be carried out in bad weather or not after rain, as there are many potential hazards given the environmental conditions and embankment soil.

REFERENCES

Albani Musyafa, S. T. (2020). *Analisis Penerapan Sistem Manajemen Kesegedung Lamatan Dan Kesehatan Kerja (Smk3) Pada Proyek Konstruksi (Studi Kasus: Proyek Pembangunan Gedung Dprd Sleman, Yogyakarta)*.

Asprila Akbar, A. (2019). *Perencanaan Sistem Manajemen K3 (Smk3) Pada Pekerjaan Erection Girdr Proyek Relokasi Jalan Tol Ruas Porong-Kejapanan Dengan Identifikasi Bahaya, Penilaian Resiko Dan Pengendalian Resiko Metode (Hirarc)*. Institut Teknologi Sepuluh Nopember.

Hazani. (2008). *Guidelines For Hazard Identification, Risk Assessment And Risk Control (Hirarc)*. 20 Oktober 2015. Https://Www.Dosh.Gov.My/Index.Php/Competent-Person-Form/Occupational-Health/Guidelines/Hirarc-2/1846-01-Guidelines-For-Hazard-Identification-Risk-Assessment-And-Risk-Control-Hirarc-2008?Path=Guidelines/Hirarc-2

Hazani Binti Ismail. (2008). *Guidelines For Hazard Identification, Risk Assessment And Risk Control (Hirarc). Departemen Of Occupational Safety And Health Ministry Of Human Resources Malaysia*. 20 Oktober 2015. Https://Www.Dosh.Gov.My/Index.Php/Competent-Person-Form/Occupational-Health/Guidelines/Hirarc-2/1846-01-Guidelines-For-Hazard-Identification-Risk-Assessment-And-Risk-Control-Hirarc-2008?Path=Guidelines/Hirarc-2

Hidayat, M. C., & Nuruddin, M. (2022). Analisis Identifikasi Bahaya Kecelakaan Kerja Menggunakan Job Safety Analysis (Jsa) Dengan Pendekatan Hazard Identification, Risk Assessment And Risk Control (Hirarc)(Studi Kasus Pt. Smelting Plan Refinery). *Justi (Jurnal Sistem Dan Teknik Industri)*, *2*(4), 557–569.

Ilham, M. A. (2021). *Analisis Smk3 Terhadap Risiko Kecelakaan Kerja Pembangunan*

Jalan Tol Menggunakan Metode Hirarc. Universitas Medan Area.

Juraman, M. F. T., & Beatrix, M. (2023). Evaluasi Penerapan Keselamatan Dan Kesehatan Kerja (K3) Menggunakan Metode Hirarc Pada Proyek Preservasi Jalan Rigid Pavement Babat-Lamongan-Gresik. *Jurnal Taguchi: Jurnal Ilmiah Teknik Dan Manajemen Industri*, *3*(1), 462–473.

Kanugrahan, T. R., Puspita, A. D., & Sajiyo, S. (2022). Analisa Penerapan Sistem Manajemen Keselamatan Dan Kesehatan Kerja Menggunakan Metode Hirarc Di Pt. Agr Unit Arf. *Jiso: Journal Of Industrial And Systems Optimization*, *5*(2), 106–112.

Lensun, T. G. B., Inkiriwang, R. L., & Tjakra, J. (2022). Analisis Risiko Keselamatan Kesehatan Kerja Dan Lingkungan (K3l) Dengan Metode Hiradc Pada Proyek Pembangunan Jembatan Dan Oprit Boulevard Ii. *Tekno*, *20*(82), 957–971.

Moniaga, F., & Rompis, V. (2019). Analisa Sistem Manajemen Kesehatan Dan Keselamatan Kerja (Smk3) Proyek Konstruksi Menggunakan Metode Hazard Identification And Risk Assessment. *Jurnal Ilmiah Realtech*, *15*(2), 65–73.

Oetomo, W. (2014). Manajemen Proyek Dan Konstruksi Dalam Organisasi Kontemporer Bagian I. *Penerbit Pt Mediatama Saptakarya, Jakarta*.

Ramli, S. (2010). Sistem Manajemen Keselamatan Dan Kesehatan Kerja Ohsas 18001. *Jakarta: Dian Rakyat*.

Ri, K. P. U. (2014). Peraturan Menteri Pekerjaan Umum Nomor 05/Prt/M/2014 Tentang Pedoman Sistem Manajemen Keselamatan Dan Kesehatan Kerja (Smk3) Konstruksi Bidang Pekerjaan Umum. *Peraturan Menteri Pekerjaan Umum*, 41.

Salsabilla, F. R. A. Y. (2023). *Analisis Risiko Kesehatan Dan Keselamatan Kerja (K3) Menggunakan Metode Hirarc (Hazard Identification Risk Assessment And Risk Control) Pada Proyek Konstruksi Pembangunan Jalan Temajuk–Aruk*.

Suharni, S. (2020). Analisis Risiko K3 Dengan Metode Hirarc Pada Pekerja Pt. Varia Usaha Beton Makassar Tahun 2020. *Window Of Public Health Journal*, *1*(3), 2721–2920.

Triswandana, I. (2020). *Penilaian Risiko K3 Dengan Metode Hirarc. Ukarst: Universitas Kadiri Riset Teknik Sipil, 4 (1), 97–108*.

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