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Safety Risk Analysis of Cliff Landslide Handling Using The Hirarc (Hazard Identification, Risk Assessment, and Risk Control) to Reduce The Frequency of Mine Operational Incidents at PT Semen Gresik

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Abstract—Work safety is a crucial aspect of the Cement industry, especially in high-risk jobs such as handling cliff landslides. This study aims identify potential hazards, assess risks, and control them using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) method to reduce the frequency of operational incidents at PT Semen Gresik. The research employs field observations, interviews with workers, and data analysis using the HIRARC approach. Findings indicate that before implementing this method, several tasks were categorized as high risk and extreme risk. After risk control measures were applied, the level of risk was reduced to moderate risk and low risk. This study recommends changing the slope design from single slope to multi slope, which has been proven to increase the Safety Factor (SF) to 1.742. Additionally, improving work safety management is suggested through the promotion of Occupational Safety and Health (K3) and the installation of Extenso Meters to monitor ground movement.

Keywords: *Cliff Landslide, HIRARC, PT Semen Gresik, Risk Management, Work Safety*

I. INTRODUCTION

PT Semen Gresik is one of the largest cement producers in Indonesia, currently the Company's challenge is to maintain operational stability, the process of transporting the main raw materials of limestone and clay has a steep hauling road gradient with a slope of up to 18%, far from the standard ≤12% and landslide road cliffs, posing a high risk to work safety.[1]

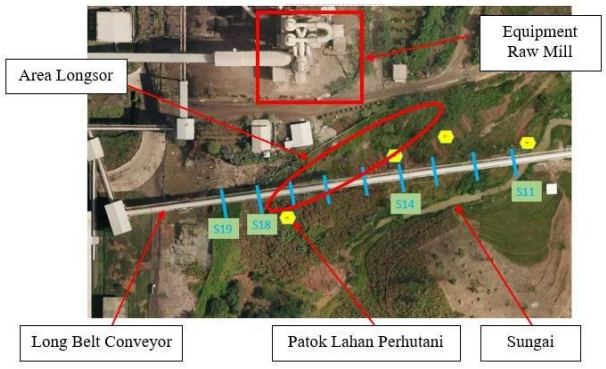

Figure 1.1 Location Map of Landslide Area

Incidents such as dump trucks skidding, losing control and failing to climb are common, especially during the rainy season. In addition, the area around the hauling road has different elevations, which increases the potential for landslides and threatens production continuity, damaging the environment and worker safety.[2]

This research discusses the factors that cause landslides and makes alternative clay hauling roads, by applying risk management with the HIRARC method starting from activity classification, hazard identification, hazard assessment to hazard risk control with the aim of reducing potential hazards and accidents in the workplace.

a. Occupational Safety and Health Management System (SMK3)

b. According to OHSAS 19001, the OHS management system consists of two main , namely the management process and its implementation elements. The SMK3 process explains how the management system is carried out or driven. Meanwhile, elements are key components that are integrated with one another to form a unified management system. These elements include responsibilities, authorities, relationships between functions, activities, processes, practices, procedures and resources. These elements are used to establish OHS policies, plans, objectives and OHS programs.[3]

b. Risk Assessment

According to OSHAS 18001 risk assessment involves calculating the magnitude of the risk and determining whether the risk is acceptable. Risk assessment consists of two stages, namely risk analysis and risk generation (risk assessment). This second step is important because it determines the stages and strategies of risk control. The purpose of risk analysis is to determine the magnitude of a risk, which is a combination of the likelihood of occurrence

(probability) and the severity of the risk (severity or consequence). Risk assessment is an assessment of whether a risk is acceptable by comparing it with applicable standards or the organization's ability to cope with the risk.[4]

c. Hazard Identification Risk Assessment and Risk Control (HIRARC)

HIRARC is a combination of hazard identification, risk assessment and risk control and is a method to prevent or minimize occupational accidents. HIRARC is a systematic, comprehensive and structured approach to examining the hazards of an activity or process that may pose a risk to people, facilities, the environment or existing systems, and then identifying the sources of the hazards to address those risks. Risk assessment and risk management then applied to reduce exposure to existing hazards. Hazard detection is the first phase or step of the HIRARC approach. Hazard identification is an examination of various work areas, aiming identify all hazards present in the workplace.[5]

II. RESEARCH METHOD

The research method is described by a flow chart which aims to display the steps to analyze in solving the problem in the research. The stages of problem solving are organized based on the background and research objectives with the support of relevant theories. Several stages are explained systematically, starting from preliminary studies, problem formulation, to the conclusion stage.

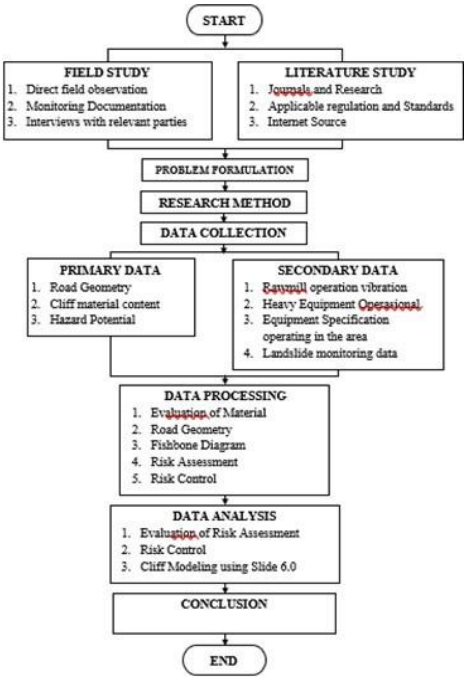

Figure 2.1 Research flowchart

2.1 Preliminary Study

The initial stage carried out in this research is to formulate the problems that form the basis of the research, namely by conducting literature studies and field studies. This stage can be explained as follows:

a. Field Study

This stage was carried out with a direct visit to the location of the problems that occurred at PT Semen Gresik Rembang to gain an understanding of the actual conditions in the field. From this study, researchers determined the focus area used as the research location, determined respondents, conducted observations, location documentation, and interviews with the responsible parties in the research area.

b. Literature Study

The next step involved collecting and reviewing various available sources of information, such as previous studies published in reputable scientific journals, theories described in reliable literature books, government regulatory data on mine road standards, and statistical data available on the internet. All these sources of information were selected based on credibility, relevance to the research topic, and accuracy of the data.

2.2 Problem Formulation

The problem formulation stage comes from the results of literature studies and field studies that have been carried out. Based on these two things, the problem formulation put forward by researchers in preventing work accidents during repairs is how to identify potential hazards, assess and control work safety risks with the HIRARC method.

2.3 Research Methods

At this stage, the researcher determines and selects the most suitable method to reduce the potential hazard of landslide handling. Based on more detailed problem identification, the researcher decided to use HIRARC as an approach in solving the existing problems.

2.4 Data Collection

At the data collection stage, it will be explained what data is needed for the next stage, namely data processing. The instrument used in collecting data for this research is an interview, which is one of the primary data collection techniques. Primary data is a data source that directly provides information to data collectors.

Required data:

a. Material evaluation
b. Road geometry
c. Documentation of findings in the field.

2.5 Data Processing

The next stage is identifying hazards, assessing hazards and controlling hazards. Based on the results of the literature study conducted by the researcher, methods were found that had been proposed by previous studies with similar topics. At this stage, researchers processed data using several PDCA methods combined with risk analysis methods using HIRARC.

2.6 Analysis and Interpretation of Results

After the hazard analysis results are identified, the next step is to analyze the potential hazards and assess the potential hazards that will occur. Next, the best hazard risk control is sought to solve the problem and improvement planning is carried out. This risk control aims to review and examine the research results in depth in order to obtain a comprehensive understanding.

2.7 Conclusion

The last stage contains conclusions and suggestions based on the results of the analysis of potential hazards in landslide handling in accordance with the objectives of the research. This section also explains the impact on employees, equipment, environment and the continuity of the company's operations after the potential hazards of landslide repair are properly controlled, as well as suggestions given by the researcher for solving landslide problems and securing further potential hazards.

III. ANALYSIS AND RESULTS

3.1 Hazard Risk Identification

Assessing risk means evaluating the potential impact and likelihood of a risk occurring Hazard identification is the process of identifying hazards in the workplace. This identification is carried out by looking at events and conditions that can potentially cause accidents and ultimately lead to work accidents. The process of handling this problem is divided into 4 major works that will be examined:

1. Road top layer security
2. Landslide Stripping
3. Boulder Arrangement
4. Final Works (Fireplace and Pavement)

The following is the identification of potential hazards and risk assessment on the handling of landslides and steep road gradients:

Table 3.1 Hazard identification and risk assessment

NO	Tahapan Pekerjaan	Bahaya		Efek Bahaya	Level Risiko
		Unsafe Condition	Unsafe Action		
1	Top Layer Security	Exposure to dust during soil stripping	Not wearing a mask while working	Respiratory system disorders, eye irritation	High
		Exposed to Excavator	Not maintaining safe operating distance of excavator	Falls, injuries to body parts	High
		Heat exposure	Not wearing protective clothing, helmets and safety shoes	Heat stress due to high working temperature, heat and fatigue	Moderate
2	Soil stripping Landslide	Exposure to dust from material excavation	Not wearing a mask while working	Respiratory system disorders, eye irritation	High
		Excavation waste	DT tub so it's open	Harm to road users, falls	High
			Repetitive motion	Fatigue	Moderate
		Pierced by sharp objects	Not wearing gloves while working	Hand and foot wounds	High
		Accident (hit by heavy equipment)	Disobeying the rules when driving	Injury, illness, death	High
3	Boulder arrangement	Housekeeping messy work area	Lack of understanding of the potential hazards posed	Tripped, hit by stone, injured	High
		Dust exposure during DT dumping	Not wearing PPE when working (mask)	Respiratory system disorders, eye irritation	Moderate
		Dump Truck Flips Over	Unskilled operator	Falls, injuries to body parts	High
		Hit by a dumptruck	Unskilled operator, not maintaining safe driving distance	, injury, limb injury	High
		Falling into an excavation pit	Unprotected hole	Injuries, wounds to body parts	High
		Pierced by sharp objects	Not using PPE while working	Hand and Foot cuts, abrasions	High
		Excavator overturned because the stand was not strong	Unskilled operator	Sores on body parts	High
		Exposure to heat and excessive workload during setup	Not using PPE protective clothing and safety shoes	Heat stress due to hot working temperature, fatigue while working, dehydration	Moderate
4	Final works (Firing and	Vibration from the compactor	Not wearing full PPE	Pain, dizziness, nervous disorders	High
	road compaction				
		Hit by a compactor	Unskilled operator, not maintaining safe driving distance	injury, limb injury	High
		Noise from equipment operation	Not wearing ear muffs/ear plugs	Hearing impairement	High
		Solar Usage	Smoking carelessly while at work	Fire	Moderate

Risk identification of landslide slope repair and clay hauling road was assessed and the risk assessment results are as follows:

a. High hazard category with 15 potential hazards.
b. Risk hazard category with moderate risk level there are 5 potential hazards
c. There is no potential danger from an assessment with a Low risk level.

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3.2 Risk Control

Based on the hazard control hierarchy, there are 20 potential hazard items that must be controlled, the purpose of risk control is to reduce the level of risk that will be caused by the following controls:

Table 3.2 Risk Assessment and Control

NO	Stages Job	Danger		Effect Danger	Risk Level	Assessment recommendation	Risk Level Assessment			
		Unsafe Condition	Unsafe Action				L	S	Value	Risk Level
1	Top Layer Security	Exposure to dust during soil stripping	Not wearing a mask while working	Respiratory system disorders, eye irritation	High	Conducting regular watering of the work site, installing work signs, wearing masks and goggles	1	3	3	Low
		Exposed to Excavator	Not maintaining safe operating distance of excavator	Falls, injuries to body parts	High	Isolation of heavy equipment work areas, Installation of signs, Induction of workers, Keep a safe distance from the excavator, Make sure the excavator mirrors are in good condition, Operators have SIO, wear complete PPE when working.	2	3	6	Moderate
		Heat exposure	Not wearing protective clothing, helmets and safety shoes	Heat stress due to high working temperature heat and fatigue	Moderate	Wear reflective long sleeves, provide water around the project area, and wear full PPE	1	2	2	Low
2	Soil stripping Landslide	Exposure to dust from material excavation	Not wearing a mask while working	Respiratory system disorders, eye irritation	High	Watering the work site regularly, installing signs and wearing masks and goggles	1	3	3	Low
		Excavation waste	DT tub so it's open	Harm to road users, falls	High	Transportation of materials in accordance with DT capacity, Comply with maximum speed limits on public roads	3	3	6	Moderate
			Repetitive motion	Fatigue	Moderate	Ergonomic work posters, Stretching, shift work	1	3	3	Moderate
		Pierced by sharp objects	Not wearing while working	Hand and foot wounds	High	Cleaning the work area regularly, wearing gloves and safety shoes	2	2	4	Low
		Accident (hit by heavy equipment)	Disobeying the rules when driving	Injury, illness, death	High	Implementation of traffic management, Placement of flagman, Check the condition of DT before use, DT is in good condition, has a driver's license, Installation of signs, Comply with traffic signs, Ensure the condition of the driver is healthy, Safety belt.	3	3	9	Moderate
3	Boulder arrangement	Housekeeping messy work area	Lack of understanding of the potential hazards posed	Tripped, hit by stone, injured	High	Determine the collection area for dismantled materials, using PPE shoes and gloves.	2	2	4	Low
		Dust exposure during DT dumping	Not wearing PPE when working (mask)	Dust exposure during DT dumping	Moderate	Watering the location of the dumping point, ensuring the flag man is careful about dumping, installing signs and wearing masks and goggles.	1	2	2	Low
		Dump Truck Flips Over	Unskilled operator	Falls, injuries to body parts	High	Implementation of dumping procedures, Placement of flagman before dumping is carried out, DT conditions are feasible, have a driver's license, Installation of signs, Comply with traffic signs, Ensure the condition of the driver is healthy, Safety belt.	3	4	12	Moderate
		Hit by a dumptruck	Unskilled operator, not maintaining safe driving distance	Death, injury, limb injury	High	Installation of barriers in the DT operational area, reverse alarm & mirrors functioning properly, placement of flagman, check the condition of the DT before use, the driver has a driver's license, install signs, reflector vests, helmets.	4	3	12	Moderate
		Falling into an excavation pit	Unprotected hole	Injuries, wounds	High	Protect the hole, install barricades, install safety signs	4	2	8	Moderate
		Pierced by sharp objects	Not using PPE while working	Hand and Foot cuts, abrasions	High	Cleaning the work area regularly, wearing gloves and safety shoes	2	2	4	Low
		Excavator overturned because the stand was not strong	Unskilled operator	Sores on body parts	High	Provide safe access for heavy equipment, periodic maintenance of equipment, installation of signs, safety belts	3	4	12	Moderate
		Exposure to heat and excessive workload during setup	Not using PPE	Exposure to heat and excessive workload during setup	Moderate	Work in shifts, use protective clothing, provide water in the project area, as well as safety shoes and gloves.	1	2	2	Low
4	Final works (Firing and road compactio n	Vibration from the compactor	Not wearing full PPE	Pain, dizziness, nervous disorders	High	Ensure the operator seat suspense is still good, provide padding on the work tool (Stamper), wear gloves, glasses and safety shoes.	4	2	8	Moderate
		Hit by a compactor	Unskilled operator, not maintaining safe driving distance	Death, injury, limb injury	High	Installation of barriers in the Compactor operational area, reverse alarm & mirrors functioning properly, placement of flagmen, install signs, reflector vests, helmets.	3	3	9	Moderate
		Noise from equipment operation	Not wearing ear muffs/ear plugs	Hearing impairment	High	Perform engine maintenance, use engine silencers Attach signs, ear muffs/ear plugs	3	3	9	Moderate
		Solar Usage	Smoking carelessly while at work	Fire	Moderate	No smoking while working, provide smoking area, fire extinguisher	2	2	4	Low

Description: L : Likelihood, S: Saverity/Consequences

The stages of landslide handling work starting from securing the top layer, stripping landslides, arranging boulders and finishing road compaction are dominated by unsafe acts.

Unsafe actions occur due to a lack of worker awareness about the importance of worker safety. The impact of high potential hazards can harm workers, damage to materials and equipment, and companies in terms of implementing occupational safety and health management systems.

3.3 Analysis and Evaluation

The analysis is carried out to evaluate the minimization of potential hazards by determining the control carried out in each work sequence. This evaluation is carried out at an intolerable risk level starting from the extreme risk value level, high, to the medium risk value level, while the low risk level can still be tolerated by the company.

The evaluation analysis of the proposed improvements by determining control was conducted for all machines including:

1. Elimination
   Control by eliminating the source of the hazard so that the impact is zero.
2. Substitution
   Hazard control by replacing a hazardous tool, material, system or procedure with a safer or less hazardous one.
3. Engineering control
   Modifying the design to eliminate hazards, e.g. replacing dirt roads with cast/asphalt etc.
4. Administration control
   Establish some systems in the form of procedures to ensure safe work, such as signage, set work schedules, standard safe work procedures, equipment

checks, rotations or health checks.

5. Personal protective equipment (PPE)

   The final option to control hazards is to wear personal protective equipment such as head protection, face protection, eye protection, gloves, respiratory protection, hearing protection, body protection, hand protection, drowning protection, fall protection, and foot protection.

3.4 Analysis of Risk Control Results

Based on the results of the risk analysis using the HIRARC method, remediation measures were developed to reduce the level of hazard in the work area. Implementation of the remediation strategy was done through:[6]

1. Slope Infrastructure Improvement
   a. Adopt multi slope design to improve cliff stability.
   b. Installed Extenso Meter for real-time monitoring of ground movement.
   c. Improve the drainage system to reduce erosion due to accumulated rainwater.
2. Improved Operational Safety
   a. Stricter implementation of safety procedures in the operation of heavy equipment
   b. Creation of emergency evacuation routes and improvement of safety signage.
   c. Training workers in the use of personal protective equipment (PPE) and emergency response procedures.
3. Continuous Monitoring and Evaluation
   a. Conduct periodic inspections of slope and hauling road conditions.
   b. Using geotechnical monitoring technology to identify potential ground movement.
   c. Evaluating effectiveness control measures and adjust mitigation strategies if necessary

Continued implementation of these measures is expected to reduce operational incidents and improve safety levels at PT Semen Gresik.

3.5 Results of HIRARC Method Implementation

The analysis results show that before the implementation of HIRARC, the main risks in landslide management works include:

1. **Extreme Risk**: Sudden landslide, heavy equipment derailment.
2. **High Risk**: Dump truck fails to go uphill, slippery road during rain.
3. **Moderate Risk**: Workers slipped on the cliff area. Application of the HIRARC method, steps are carried out

Applying the HIRARC method, control measures such as:

1. Change the design of single slope to multi slope to improve stability.
2. Installation of Extenso Meter to monitor ground movement.
3. Improved drainage system to reduce water accumulation that triggers landslides.
4. Refreshment K3 training and socialization for all employees.

The evaluation results show a significant reduction in risk levels, with most risks in the **low risk** category.[7]

Figure 3.1 Improvement Results

3.6 Improvement Impact Analysis with PQCDSME

Using the PQCDSME analysis method, the author defines the detailed benefits of the work performed, the existing problems are categorized into so that they are more manageable, detailed and easy to understand, making it easier to analyze, here is an analysis using the PQCDSME method:

1. Productivity
   - Before:
     Landslides that occur south of the rawmill can disrupt the productivity of clay raw material supply to the storage.
   - After:
     Increased productivity of raw material delivery from clay to clay storage.
2. Quality
   - Before:
     Delays in the supply of raw materials can result in the quality of the mixpile material not being as planned because there is no variation in the quality of the clay.
   - After:
     Variations in clay quality (Higj Al and High Si) are always available in the clay storage so that it does not affect the non-achievement of quality in the mixpile.
3. Cost
   - Before:
     Landslide repair is , Potential for land repair in case of recurring problems

- After:
  Landslide handling cost becomes 0 (because it is self- managed by utilizing heavy equipment, as well as available materials and continuous monitoring of the area because it is used as an operational road.

4. Delivery
   - Before:
     The process of hauling material from the mine site to storage is often hampered because DT is not able to pass through steep road gradients (>10%)
   - After:
     The material hauling process is not disturbed because the road is no longer steep, having a gradient of only 4- 7%.
5. Safety
   - Before:
     The factory area is traversed by mining operational vehicles so that there is the potential for work accidents between factory workers and DT operating hauling clay.
   - After:
     Road gradient <10% as per standard, There is a separation between the factory area and the mine hauling road.
6. Morale
   - Before:
     Anxiety in case of landslides and DTs not being able to pass through roads with high gradient.
   - After:
     The condition of the employees is better and the DT operator does not feel anxious because the new road is more gentle and comfortable to pass.
7. Environment
   - Before:
     Disturbing land owned by residents and forestry companies, the factory area through which DT's operational vehicles pass becomes dirty.
   - After:

There is no disturbance to the environment due to landslides on non-company-owned land because the area no longer has the potential for landslides, and the area is cleaner and greener because of the separation between the factory area and the road, mining operations as well as tree planting and covercropping at the remediation site

IV. CONCLUSIONS

This research shows that the application of the HIRARC method in occupational safety risk management can reduce the level of accident risk at PT Semen Gresik. Implementation of the reference using multi slope cliff design is proven to increase the Safety Factor (SF) to 1.742[8], making it more stable than single slope.[9]

Continuous implementation of Occupational Safety and Health (OHS) training, geotechnical monitoring, and strengthening of hauling road infrastructure are recommended to improve occupational safety in the work environment.[10]

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