FINAL PROJECT

ANALYSIS OF CAUSES OF WORK ACCIDENTS IN GABION WORK WITH USING FAULT TREE ANALYSIS METHOD (FTA) (Case Study: Tawang-Ngalang Segment IV Road and Bridge Construction Project)

Submitted to Universitas Islam Indonesia Yogyakarta to Fulfil the Requirement to obtain Bachelor of Civil Engineering Degree

Muhammad Naufal Dzikri Akbar
19511064

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Arranged by:

Muhammad Naufal Dzikri Akbar
19511064

Accepted as one of the requirements to obtain the degree of Bachelor of Civil Engineering

Tested on 14th October 2024

By the board of examiners:

Supervisor	Examiner I	Examiner II
Ir. F.Nugraheni, S.T., M.T., Ph.D.,IPM.	Ir. Tri Nugroho S., S.T., M.T.	Ir. Vendie Abma, S.T., M.T., IPM.
NIK: 005110101	NIK: 195110502	NIK: 155111310

Authorizing,
Head of Civil Engineering Program

Ir. Yunalia Muntafi S.T., M.T., Ph.D.,(Eng).,IPM.
NIK : 095110101

FREE PLAGIARISM STATEMENT

I hereby declare in all conscience that Final Project report that I made to fulfill one of the requirements of Civil Engineering Study Program of Universitas Islam Indonesia is my own work. As for parts of my research that quoted from somebody else's work has been written in the source very clearly based on norm, rules, and ethics of scientific writing. If in the future, it is found that all or partial part of this Final Project report is not my own work or there is plagiarism in certain parts, I am willing to accept sanctions, including the revocation of my academic title in accordance with applicable laws.

Yogyakarta, 3 October 2024

Statement maker,



Muhammad Naufal Dzikri Akbar

(19511064)

PREFACE

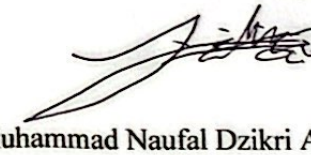
Praise and Gratitude the author prays to the presence of Allah SWT. Because of his blessing and mercy, the author can complete the final project under the title of Analysis of Causes of Work Accidents in Gabion Work with Using Faul Tree Analysis Method (FTA) (Case Study: Tawang-Ngalang Segment IV Road and Bridge Construction Project) to fulfill the requirements to obtain the bachelor's degree in Civil Engineering Study Program.

The preparation of this Final Project Report was met with numerous challenges. However, with valuable suggestions, constructive criticism, and continuous encouragement from various individuals, Alhamdulillah, this Final Project Report has been successfully completed. In this regard, the author would like to extend the deepest gratitude to:

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Yogyakarta, 14th October 2024

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Muhammad Naufal Dzikri Akbar

(19511064)

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ABSTRACT

According to BPJS Ketenagakerjaan in 2023, Indonesia experienced 265,334 workplace accidents between January and November 2022, marking a 13.26% rise from 234,270 cases in 2021. The construction sector was identified as one of the industries with a high accident rate. In this research, Fault Tree Analysis (FTA) was applied to examine the causes, focusing on finding the chain of factors that led to the accident.

This research aims to identify the combination of contributing events behind workplace accidents in the Tawang-Ngalang Segment IV Road and Bridge Construction Project by utilizing the Fault Tree Analysis (FTA) method. The study identifies basic events from the top event, applies Boolean algebra to find the minimal cut set to determine the combination events that cause the top event, and then formulates risk control measures in compliance with hierarchical frameworks.

The results of this study identified the primary root causes of the slope landslide in the Tawang-Ngalang Segment IV Road and Bridge Construction Project using the Fault Tree Analysis method. The main factors contributing to the landslide are outlined as follows. Insufficient competency and comprehension of workers in executing their assigned work. (1) Insufficient competency and comprehension of workers in executing their assigned work. (2) Poor supervision is attributed to the insufficient discipline and awareness exhibited by the workers, (3) Insufficient information outreach and communication across teams have caused workers to be uninformed about any changes that have been agreed upon. (4) Extreme weather conditions are compounded by inadequate soil stability.

Keyword: Gabion installation, Work accident, Fault Tree Analysis (FTA)

CHAPTER I
PRELIMINARY

1.1 Background

Occupational Safety and Health (OSH), commonly referred to as workplace safety and health, is a multifaceted discipline focused on protecting individuals' welfare, security, and health in their work environments. It encompasses a broad range of methods, protocols, and regulations to prevent workplace accidents, injuries, and illnesses while fostering a safety-conscious workplace culture. This is particularly important because work accidents remain prevalent in the construction sector. According to (Silverstein, 2015), "a work accident is defined as an unexpected event that results in injury, illness, or damage while an employee is performing work-related duties, often due to unsafe working conditions or practices." Supporting this, data from (Badan Penyelenggara Jaminan Sosial (BPJS), 2013) for Employment recorded 265,334 cases of work accidents in Indonesia from January to November 2022, marking a 13.26% increase from 234,270 cases in 2021. This statistic highlights Indonesia as one of the countries with a high incidence of work-related accidents, underscoring the urgent need to prioritize efforts to reduce their frequency.

Tawang-Ngalang Segment IV Road and Bridge Construction Project serves as an example of a project where accidents occurred during the installation of slope protection structures. One common method for slope stabilization is the use of gabions. According to SNI 03-0090-1999, gabions are box-shaped containers made from woven, zinc-coated steel wire, filled with stones to prevent erosion, and are typically installed on cliffs and riverbanks using machines. Accidents that may occur during the installation of these slope protection structures include landslides, falls, and accidents involving heavy machinery.

Work accidents in Tawang-Ngalang Segment IV Road and Bridge Construction Project especially in gabion installation work will be analyzed to find out the root of the problem to find out preventive measures so that they do not occur again using the Fault Tree Analysis method. Fault Tree Analysis is an analytical tool that translates graphically combinations of errors that cause work accident. This technique is useful for describing and assessing events in the system according to (Foster, 2004). When it comes to uncovering the reasons behind accidents, Fault Tree Analysis proves to be a highly effective method. This approach thoroughly investigates all potential causes of undesirable events or losses, and it represents visually the relationships between causal factors in the form of a straightforward fault tree.

The Fault Tree Analysis method was utilized in Mita Nur Fadillah's final project to determine the causes of scaffolding work accidents in the UII Hospital Project. In her final project, opinions about the Fault Tree Analysis method were provided by Mita Nur Fadillah, according to (Fadillah, 2023) The application of the fault tree analysis method in accident analysis is considered very useful, it can increase caution and increase knowledge regarding risk control, which ultimately leads to a reduction in work accidents.

In this research, the author will analyze the work accidents in the context of gabion installation in Tawang-Ngalang Segment IV Road and Bridge Construction Project by using the Fault Tree Analysis (FTA) method. This research is aimed to uncover the root causes of work accidents accidents occurring on the construction field, with the hope that the same accident will not occur again.

1.2 Problem Statement

Based on the background above, the research problem to be addressed by the researcher is as follows:

What factors contributed to workplace accidents during the gabion installation on segment IV of the Tawang-Ngalang project?

1.3 Research Objective

Based on the problem statement outlined above, the objectives of this research are as follows:

Identifying the root causes of accidents during gabion installation in the Tawang-Ngalang Segment IV Project.

1.4 Benefits of Research

The benefits of this final project are as follows.

1. This research can serve as a reference for contractors in the construction of gabions.
2. For students, this can be used as a reference for assignments, final projects, or as knowledge in the field of Occupational Safety and Health (OSH).

1.5 Limit

For the writing of the final project proposal to be structured, the following observations limits are made.

1. Analysis was carried out on the Tawang-Ngalang road and bridge segment IV construction project. The research focus on work accident that have occurred on gabion work in theTawang-Ngalang road segment IV.
2. The research using the FTA (Fault Tree Analysis) method

CHAPTER II
LITERATURE REVIEW

2.1 General Review

In construction project work, preventing work accidents is very important, as the occurrence of a work accident can result in significant losses across various sectors. To identify effective methods for preventing work accidents, it is essential to understand the basic causes of these accidents and conduct a thorough study. The existing literature offers references that can be utilized as a foundation for researching to ascertain the causes of work accidents.

2.2 Previous Research

(Aal et al., 2019) conducted research entitled Energy Dissipation and Discharge Coefficient Over Stepped Gabion and Buttress Gabion Spillway. This research aims to study the Energy Dissipation and Discharge Coefficient over the Stepped Gabion spillway and a suggested new Gabison style. The results of these tests used dimensional analysis to correlate the different parameters affecting the studied phenomena. It was found that using large particle increases energydissipation and coefficient of discharge. Also, as the number of buttress walls increasesthe energy dissipation coefficient of discharge decreases.

Analisis Efektivitas Pengendalian Risiko Kecelakaan Kerja Pada Pekerja

ProyekKonstruksi Menggunakan Metode Fine dan Fault Tree Analysis. This research was conducted by (Ginting et al., 2020). This research aims to analyze the effectiveness of risk control in the J-Box Jakarta office building construction project. The use of the SPSS (Statistical Product and Service Solution) program is needed to analyze and verify data and then assess the risk of work accidents using the Fine method and provide solutions using the Fault Tree Analysis method to reduce the risk of work accidents. The results of this research show that the value of the potential accident risk is less than 20, indicating that measures have been taken to minimize therisk. Common work accidents include fingers getting caught in metal, tripping over work materials, and experiencing skin and eye irritation due to dust when cleaning thefoundry site with an air compressor. Then, the error diagram is analyzed to formulate specific solutions for reducing workplace injuries, including the implementation of safe work methods for all jobs, the conduct of regular work meetings before commencing work, the utilization of personal protective equipment during work, the installation of OSH signs at each job, and oversight by the Health and Safety Executive.

(Cho et al.,2021) conducted research entitled "Effectiveness of filter gabions against slope failure due to heavy rainfall". This research aims to preventing this initial failure from leading to overall slope failure. Theresult of this research has 2 tests. First, 1 g model tests, called G series tests, were conducted. In the tests, a gabion filled with filter materials was placed at the slopetoe of each model for reinforcement and to drain the accumulated rainwater from the slope toe. Filter gabions have been found to shrink the failure regions and to significantly extend the time until slope failures occur. The failure mechanism in the Gseries tests was almost similar to that in cases without filter gabions if focus was placedon the slope above the filter gabions. However, the drainage effect was small. Secondly, P series tests, in which a filter gabion with a pipe was introduced for each model, wereconducted. The results of these tests indicated that the displacements significantly decreased as the diameter of

the pipe and the depth of the pipe's insertion to the surfacelayer increased. Water did not discharge through the pipe until the pore water pressurearound the pipe reached positive values. The failures always started when a phreatic surface appeared on the slope surface. Thus, it is very important to prevent a phreatic surface from forming on the slope surface. The adequate arrangement of a filter gabionwith a drainage pipe may increase the potential for slope stability.

(Fadilah, 2023) conducted research entitled "*Analisis Penyebab Kecelakaan Kerja Pada Pekerjaan Scaffolding Dengan Menggunakan Metode Fault Tree Analysis(FTA)".* This research aims to find probability values and identify the root causes of work failures/accidents in scaffolding work that have occurred, namely, scaffolding falls, and provide risk control by control hierarchy guidelines. The results of this research were that the main root causes of scaffolding fall accidents on the UII HospitalProject were found, including (1) lack of skills and knowledge due to not taking a fieldthat suits their expertise, (2) lack of skills and knowledge due to inexperience, lack of supervision due to lack of discipline/awareness among workers, (3) tools that do not meet standards due to the load of material being lifted being too heavy, lack of maintenance, tools that are old/aged, and tools not being renewed.

(Rizky Z, 2023) conducted research entitled *"Analisis Faktor-Faktor Penyebab Kecelakaan Kerja Pada Pekerjaan Pembangunan Jembatan Sekarteja Lombok TimurMenggunakan Metode Fault Tree Analysis".* The aim of this research is to identify the factors that caused work accidents on the scaffolding work for the Sekarteja bridge project, which collapsed during the construction of the bridge. The results of this research indicate that there are four main factors in these accidents: worker factors, material factors, management factors, and environmental factors. This resulted in eightfailures based on the FTA results, namely, lack of knowledge and lack of skill in installing scaffolding caused by no experience, not according to the workers' skills, lack of education, wrong work methods due to sudden technical changes in installing scaffolding without warning from supervisors and foremen who

lack of discipline, notaccording to size due to using used scaffolding materials to reduce the budget, the ageof the wood that used is still young due to underestimating procedures and not analyzing materials, lack of supervision due to a lack of discipline and no HSE team insupervision due to no budget for supervision, lack of socialization and counseling dueto no special schedule or time and no training, extreme and high work areas, etc. Additionally, there is also a spring that flow

2.3 Research Comparison

Table 2.1 Comparison of Previous and Current Research About Fault Tree Analysis

Researcher	Ginting et al., (2020).	Rizky Z, (2023)	Fadilah, (2023)
Title	Analisis Efektivitas Pengendalian Risiko Kecelakaan Kerja Pada Pekerja Proyek Konstruksi Menggunakan Metode Fine dan Fault Tree Analysis	Analisis faktor penyeba kecelakaan kerja pada pekerjaan perancah menggunakan metode fault tree analysis (Studi kasus: Proyek jembatan sekarteja).	Analisis Penyebab Kecelakaan Kerja pada Pekerjaan Scaffolding dengan Menggunakan Metode Fault Tree Analysis (FTA) (Studi Kasus: Proyek RS UII)
Objectives	The aim of this research is to analyze the effectiveness of risk control in the J-Box Jakarta office building construction project.	The aim of this research is to identify the factors that caused work accidents on the scaffolding work for the Sekarteja bridge project, which collapsed during the construction of the bridge.	The research objective employed in this research is to determine the root cause of work accidents in scaffolding work at the UII Hospital Project.

Continuation Table 2.1 Comparison of Previous and Current Research About Fault Tree Analysis

Researcher	Ginting et al., (2020).	Rizky Z, (2023)	Fadilah, (2023)
Methods	Fault Tree Analysis (FTA)	Fault Tree Analysis (FTA)	Fault Tree Analysis (FTA)
results	The value of the potential accident risk is less than 20, indicating that measures have been taken to minimize the risk. Common work accidents include fingers getting caught in metal, tripping over work materials, and experiencing skin and eye irritation due to dust when cleaning the foundry site with an air compressor. Then, the error diagram is analyzed to formulate specific solutions for reducing workplace injuries,including the implementation of safe work methods for all jobs, the conduct of regular work meetings before	The results of this research indicate that there are four main factors in these accidents: worker factors, material factors, management factors, and environmental factors. This resulted in eight failures based on the FTA results, namely, lack of knowledge and lack of skill in installing scaffolding caused byno experience, not according to the workers' skills, lack of education, wrong work methods due to sudden technical changes in installing scaffolding without warning from supervisors and foremen who lack of discipline, not according to size due to using used scaffolding materials to	The results of this research were that the main root causes of scaffolding fall accidents on the UII Hospital Project were found, including (1) lack of skills and knowledge due to not taking a field that suits their expertise, (2) lackof skills and knowledge due to inexperience, due to lack of supervision lack of discipline/awareness among workers, (3) tools that do not meet standards due to the load of material being lifted being too heavy, lack of maintenance, tools that are old/aged, and

Continuation Table 2.1 Comparison of Previous and Current Research About Fault Tree Analysis

Researcher	Ginting et al., (2020).	Rizky Z, (2023)	Fadilah, (2023)
Methods	Fault Tree Analysis (FTA)	Fault Tree Analysis (FTA)	Fault Tree Analysis (FTA)
results	commencing work, the utilization of personal protective equipment during work, the installation of OSH signs at each job, and oversight by the Health and Safety Executive.	reduce the budget, the age of the wood that used is still young due to underestimating procedures and not analyzing materials, lack of supervision due to a lack of discipline and no HSE team in supervision due to no budget for supervision, lack of socialization and counseling due to no special schedule or time and no training, extreme and high work areas, etc. Additionally, there is alsoa spring that flows.	tools not being renewed

Table 2.2 Comparison of Previous and Current Research about Gabion

Researcher	Aal et al., (2019)	Cho et al., (2021)	Akbar, (2023)
Title	Energy Dissipation and Discharge Coefficient Over Stepped Gabion and Buttress Gabion Spillway.	Effectiveness of filter gabions against slope failure due to heavy rainfall	Analysis of the Causes of Work Accidents in Gabion Work Using the Fault Tree Analysis Method (FTA)
Objectives	This research aims to study the Energy Dissipation and Discharge Coefficient over the Stepped Gabion spillway and a suggested new Gabion style.	The aim of this research is to preventing this initial failure from leading to overall slope failure	The aim of this research is to find out the root of the problem of work accidents in gabion work at the Tawang-Ngalang Segment IV Project obtained through the Fault Tree Analysis method (FTA).
Methods	Dimensional Analysis Method	G series and P series test	Fault Tree Analysis (FTA)

Continuation Table 2.2 Comparison of Previous and Current Research about Gabion

Researcher	Aal et al., (2019)	Cho et al., (2021)	Akbar, (2023)
results	It was found that using large particle increases energy dissipation and coefficient of discharge. Also, as the number of buttress walls increases the energy dissipation coefficient of discharge decreases.	The results of these tests indicated that the displacements significantly decreased as the diameter of the pipe and the depth of the pipe's insertion to the surface layer increased. Water did not discharge through the pipe until the pore water pressure around the pipe reached positive values. The failures always started when a phreatic surface appeared on the slope surface. Thus, it is very important to prevent a phreatic surface from forming on the slope surface. The adequatearrangement of a filter gabion with a drainage pipe may increase the potential for slope stability.	The research leads to several conclusions. An analysis of the causes of accidents in gabion work at the Tawang-Ngalang Segment IV Road and Bridge Construction Project, carried out using the Fault Tree Analysis (FTA) method, has revealed primary issues that contributed to the gabion collapse during installation. These primary causes are detailed as follows. 1. Insufficient competency and comprehension of workers in executing their assigned work.

Continuation Table 2.2 Comparison of Previous and Current Research about Gabion

Researcher	Aal et al., (2019)	Cho et al., (2021)	Akbar, (2023)
results			2. Poor supervision is attributed to the insufficient discipline and awareness exhibited by the workers. 3. Insufficient information outreach and communication across teams have caused workers to be uninformed about any changes that have been agreed upon. 4. Extreme weather conditions are compounded by inadequate soil stability.

CHAPTER III
BASIC THEORY

3.1 Project

An activity that involves a specific time period and limited resources for carrying out outlined tasks can be interpreted as a project. The definition of a project is stated by some experts as follows:

Based on (Budihartono, 2008). A project is an activity or undertaking designed to be completed within a specified timeframe, with costs allocated accordingly. According to (Lester, 2014), A project can be described as a distinct set of coordinated tasks with clear start and end points, carried out by an individual or organization to achieve specified objectives within established time, cost, and performance limits.

3.2 Construction Project

According to (Ervianto, 2002), a construction project is a series of activities that are typically executed only once and generally have a short duration. The sequence of events involved in construction projects entails a process in which project resources are converted into a concrete outcome in the form of a building. The arrangement of activities linked to the construction of a building is considered a pivotal task in the domains of civil engineering and architecture, the successful execution often necessitates the participation of other parties such as industrial engineering, mechanical engineering, electrical engineering, landscaping, and geotechnical engineering.

Construction projects are complex endeavors that require a range of resources, including human resources, materials, machinery, financial resources, information, and time. To ensure the success of a construction

project, it is crucial to consider three important aspects: time, cost, and quality, as pointed out by (Kerzner, 2006). The relationships between the parties involved in a construction project can be classified into two distinct types: functional relationships and working relationships. Due to the multitude of parties involved, it is common for conflicts to arise during construction activities, (Ervianto, 2005).

3.3 Types of Construction Projects

According to (Budi, 2012), the types of construction projects can be categorized into several categories, among them as follows

1. Building Construction Projects

   Building Construction Projects are building construction projects which include office buildings, schools, commercial buildings, hospitals, residential houses, and the like. In terms of cost and technology, it ranges from low to medium and high scale. Usually, building construction project planning is more comprehensive and detailed. For government projects (in Indonesia), supervision and management of this building construction project is under the supervision of the Civil Works sub-directorate of the Department of Public Works (DPU).

2. Residential construction

   Residential construction is differentiated in detail from building construction projects, based on their construction class, concurrently with the provision of supporting infrastructures. Thus, it necessitates the planning of infrastructure for the respective housing (transfusion networks, water networks, and other facilities). The development projects for settlements range from very simple houses to luxurious residences and apartment buildings. In Indonesia, supervision is conducted under the Directorate of Civil Works sub-division.

3. Heavy Engineering Construction Projects

   Heavy engineering construction projects generally include infrastructure projects such as dam projects, highway projects, bridges, tunnels, railways, ports, and others. Projects falling under this category are typically large-scale and require advanced technology.

4. Industrial Construction Projects

   Projects falling under this category usually include industrial projects that require specific specifications and requirements, such as oil refineries, mining, nuclear facilities, and the like. The planning and execution of these projects require precision and expertise, along with specific technologies.

3.3.1 Construction Project Stages

The stages of a construction project will help in creating a good design, thus facilitating all involved parties before commencing the project construction. Without asolid design, the realization of a construction project may face obstacles or accidents. The stages of the construction project that need to be followed include the following.

1. Planning

   Most construction projects begin with a plan or concept based on needs. Several ideas are typically articulated by the project owner, who is actively involved in the initial stages.

2. Feasibility Study

   The process involves convincing the project owner that the project is feasible and should be implemented. The activities carried out in this stage of construction project planning include drafting rough plans based on cost estimates, benefit predictions, feasibility analyses, and their impacts.

3. Briefing

   The project owner will explain the project's functions and costs, which will laterbe interpreted by the planning consultant. Several activities to be

conducted at this stage include the formulation of plans with experts, consideration of needs and location, preparation of the scope of work, and sketch creation.

4. Design

   In accordance with the project owner's preferences, the detailed design process is undertaken. It is expected that the project team completes the project summary, addresses technical issues, and seeks final approval from the project owner. During this stage of construction project planning, the preparation of detailed designs, working drawings (including schedules and specifications), quantity lists, and final cost estimates.

   a. Tender

      At this stage, the willingness of the contractor to undertake the construction project is identified, with the possibility of involving subcontractors if necessary. Activities at this stage include prequalification, which is a strict evaluation process to ensure that the requirements are met by prospective contractors, and the preparation of contract documents is encompassed in the activities at this stage

   b. Construction

      In this stage, the building construction process is implemented as agreed upon by the project owner, based on the costs and time prepared by the consultant. This stage encompasses planning, control, and coordination related to activities that will take place in the field.

   c. Maintenance and Start Up

      In this phase, inspection will be conducted to ensure compliance of the building with the agreed-upon contract. Subsequently, an examination of implementation data, building inspection, damage

repair, and training for staff responsible for building maintenance will be undertaken.

3.3.2 Work Safety

According to (Suma'mur, 2001), work safety is a series of efforts to create a safeand peaceful work atmosphere for employees who work at the company concerned. Itconcludes that work safety is considered an effort to prevent all potential workplace accidents. This is also in alignment with the contents of Law (*Undang-Undang*) of theRepublic of Indonesia No. 1 (1970) "Every citizen has the right to work and protection that is decent for humanity, therefore the Work Safety Law was created which aims to improve welfare and increase national production and productivity.". The success of projects can also be heightened by worksafety, as projects can be executed seamlessly, creating a safe and secure work environment, thereby enabling workers to operate more optimally.

3.4 Slope Protection

In every construction development in an area with slopes in the project area, efforts are required to secure the slopes to prevent accidents and activities around the slopes during construction and when utilizing the infrastructure that has been built.

3.4.1 Slope Protection Explanation

Slope protection refers to the process of enhancing the stability of existing unstable slopes or preventing instability on slopes. This process aims to obtain safe slopes by ensuring that the load applied to the slope is sufficiently supported with a high Factor of Safety. Various methods, such as gabion installation, shotcrete application, and retaining wall construction, can be employed to achieve slope protection.

3.4.2 Type of Slope Protection

1. Cantilever Retaining Wall

Cantilever retaining wall is a type of retaining wall that is supported by a structureof beams and pillars embedded in the ground. This structure is designed in sucha way that the retaining wall can withstand soil loads and air pressure without requiring support at the back of the wall.

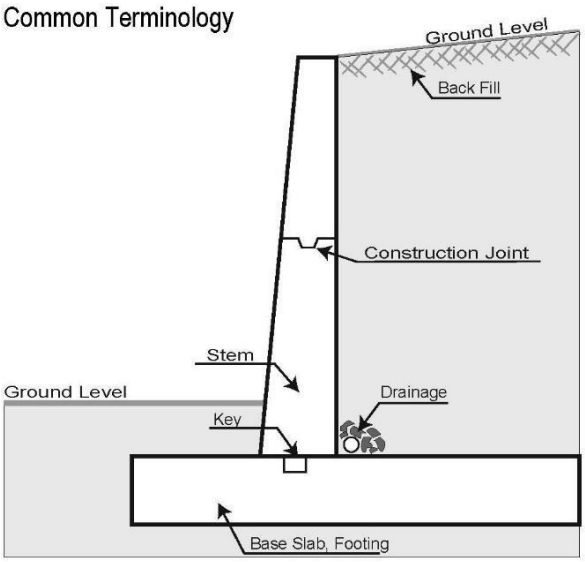


Figure 3.1 Retaining Wall

(source: Lees, 2021**)**

2. Segmental Retaining Wall

Segmental Retaining Wall is a type of retaining wall constructed from precast concrete or natural stone materials and designed to withstand soil loads and airpressure. This structure is composed of concrete or stone blocks with cavities, which are then stacked and interconnected using special locks designed to prevent shifting.



Figure 3.2 Segmental Retaining Wall

(source: Alsirawan et al., 2022)

3. Gravity Retaining Wall

   Gravity Retaining Wall is a type of retaining wall designed to withstand soil pressure and other loads by utilizing its own weight as a resisting force. Theseretaining walls are typically constructed from heavy materials.

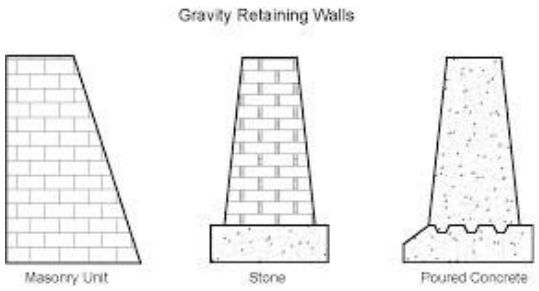


Figure 3.3 Gravity Retaining Wall

(source: Lees, 2021)

4. Gabion

   Gabions is a type of earth-retaining structure comprised of wire mesh boxesfilled with stone or other natural materials. The square or rectangular wire mesh boxes are then arranged in a stack and joined with a wire that is welded or spuninto one unit.



Figure 3.4 Gabion

(source: Ganesh c et al., 2019)

5. Pile retaining wall

Pile retaining wall is constructed by excavating the soil and inserting piles made of reinforced concrete or steel at specific distances as per the structural design.The concrete is then cast around the piles to create a structural element that retains the soil on the outer surface of the piles.



Figure 3.5 Pile retaining wall

(source: Man et al., 2019)

6. Anchored Retaining Wall

Anchored Retaining Wall is a type of retaining wall that employs a bolt systemas a locking mechanism to resist soil pressure from the slope.

Cables or bolts are inserted into the ground at the rear of the wall at a specific angle of inclination and then subjected to a tension load substantial enough to withstandthe soil pressure occurring in retaining walls. This wall structure comprises a concrete wall or gabion wall equipped with steel cables or bolts as supporting elements.



Figure 3.6 Anchored retaining wall

(source: Juntao et al., 2019)

7. Shotcrete

Shotcrete is a liquid concrete material that is applied by being sprayed at high speed. The main components of shotcrete are aggregate, cement, and water, andit is also used with fine materials, chemical additives, and reinforcing fibers.



Figure 3.7 Shotcrete

(source: Carnio et al., 2004)

3.4.3 Type of Gabion

1. Basket Gabion

This type of gabion is the most frequently utilized. Gabion baskets are box- shaped steel wire mesh made in various sizes. The basket is filled with stones and used on a slope.



Figure 3.8 Basket Gabion

(source: Toprak et al., 2016)

2. Sack Gabion

Sack gabion is a form of cylindrical gabion crafted from double-twisted galvanized steel, sometimes including a PVC layer. Typically employed in hydraulic works.



Figure 3. 9 Sack Gabion

(source: Toprak et al., 2016)

3. Mattresses Gabion

Another type of box gabion structure is represented by mattresses Gabion. Whatsets these gabions apart is that they possess a lower height compared to other types of gabions.



Figure 3.10 Mattresses Gabion

(source: Toprak et al., 2016)

5. Gabion Wall

Apart from being employed for slope protection, this type of gabion is alsofrequently utilized as decoration due to its inherent aesthetic value.



Figure 3.11 Gabion Wall

(source: Toprak et al., 2016)

3.5 Risk and Hazard

3.5.1 Risk

According to (Yasa et al., 2013), risk is a potential event that could be detrimental due to uncertainty regarding the occurrence of an event. The

definition of risk according to (Keown, 2000) is the prospect of an unfavorable outcome. It can be concluded that risk is the probability of undesirable events occurring, which could lead to losses such as company assets, liabilities, and employees.

Risk encompasses the potential for loss or harm, analyzed through various interdisciplinary perspectives, including statistics, psychology, and ethics, highlighting its complexity beyond mere financial considerations, according to (Hansson, 2024) The risk analysis process is perhaps the most crucial stage, as it is during this phase that all existing or potential risks associated with the project must be identified. According to (Darmawi, 2008), risk can be defined in two ways:

1. Risk as Opportunity for Loss:

   Risk refers to the likelihood of a loss occurring, where the term "opportunity for loss" typically describes situations where the potential for loss exists. Conversely, in statistical terms, "likelihood" often represents the probability of a particular situation arising.

2. Risk as the Possibility of Loss:

   This definition suggests that a loss may happen if the relevant risk is not promptly addressed.

The concept of risk in this context refers to the certainty of risk, which arises from uncertainty. In essence, risk involves potential consequences that may occur during processes, leading to negative effects that can result in both financial and non-financial losses.

3.5.2 Hazard

According to (Wijanarko, 2017), hazards can be classified into two categories:

1. Safety Hazard

It is a Hazard that can lead to accidents, resulting in fatalities and damage to company property.

2. Health Hazard

   Health hazards threaten health, potentially causing occupational diseases and worker health problems.

3.6 Domino Theory

The Domino Theory by Heinrich (1931) is a well-known theory that explains the occurrence of workplace accidents. According to Heinrich, 88% of accidents are caused by unsafe human behavior (unsafe acts), while the remaining incidents are attributed to factors unrelated to human error, with 10% due to unsafe conditions and 2% attributed to fate. Heinrich emphasized that workplace accidents are primarily caused by human mistakes or errors. He further argued that unsafe behavior and conditions occur when human errors are made, which are ultimately influenced by the individual's characteristics, shaped by both ancestry and their environment.

In Heinrich's Domino Theory, accidents are composed of five interrelated factors, which are:

1. First Domino: Ancestry and Social Environment

   The work conditions encompass an individual's background, such as a lack of knowledge, and may also include personal traits, such as stubbornness.

2. Second Domino: Human Error

   Human negligence includes factors such as a lack of motivation, stress, issues related to the worker's physical condition, inadequate skills, and other related concerns.

3. Third Domino: Unsafe Acts and Unsafe Conditions

   Unsafe behaviors include carelessness, failure to follow work procedures, not wearing personal protective equipment (PPE), disregarding safety signs in the workplace, and engaging in high-risk tasks without the necessary hazardous work permits.

4. Fourth Domino: Accidents

   Workplace accidents, such as slips, burns, and being struck by objects, occur when individuals are exposed to hazardous sources.

5. Fifth Domino: Injuries

   The impacts of these accidents can result in:

   a. Workers: Injuries, disabilities, or fatalities.

   b. Employers: Direct and indirect costs.

   c. Consumers: Availability of products.

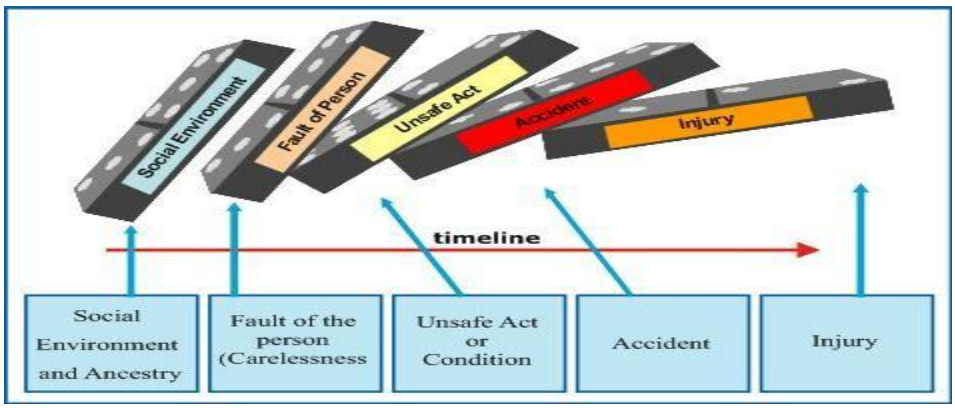


Figure 3. 12 Heinrich Domino Theory

(Source: Tim K3 FT UNY, 2014 in Benadikta 2020)

These five factors resemble a standing set of dominoes. When one domino falls, it will touch another domino, causing all five to fall in succession. This analogy is similar to the well-known domino effect, where the collapse of one structure triggers a series of subsequent collapses of other structures.

The key to preventing workplace injuries is to eliminate unsafe behaviors and conditions (the third card). Using the domino effect analogy, if the third card is removed, even if the first and second cards fall, the entire sequence will not collapse. There is a gap between the second and fourth cards, which means that the second card's fall will not impact the subsequent cards or the fourth card itself. Consequently, this can help avoid accidents (the fourth card) and their associated consequences (the fifth card).

3.7 Theories of Work Accident Causation

According to Benadikta (2020), workplace accidents are generally attributed to several factors, with tools, technology, work environment, and the employees themselves identified as the primary components. Production incidents are typically the result of multiple events and often have various causes. Although workers may be aware of the associated dangers, unsafe activities are frequently undertaken, potentially leading to construction accidents. Statistics indicate that 85% of workplace accidents can be traced back to human error. When investigating the root causes, it becomes evident that all triggers point to failures in management. The factors directly related to accidents in production are classified as direct causes, while those resulting from other influences are considered indirect causes. The underlying theories of these accidents are presented as follows:

1. Pure Chance Theory

   Accidents occur due to fate, leading to the absence of a clear system within the sequence of events. These accidents happen unintentionally.

2. Accident Prone Theory

   The reasons why workers frequently experience work injuries lie within the individuals themselves.

3. Three Main Factor Theory

This theory explains that accidents are caused by human factors, which include equipment, the environment, and workers.

4. Two Factor Theory

   Accidents are caused by hazardous conditions and unsafe behaviors.

5. Human Factor Theory

   It emphasizes that, ultimately, all industrial accidents are caused directly or indirectly by human error. The theory developed by H.W. Heinrich regarding the occurrence of production accidents essentially represents a sequence of production-related incidents.

3.8 Fault Tree Analysis

According to (Kristiansen, 2005), Fault Tree Analysis is an analysis method in which an undesired event that occurs in the system. The system is then analyzed with the existing environmental and operational conditions to identify all possible ways it can occur, ultimately leading to the occurrence of the undesired event.

In the fault tree analysis method causal factors are identified and organized logistically and then represented pictorially in a tree diagram that depicts the causal factors and their logistical relationships with the peak event. The factors identified in the fault tree analysis method include the work environment, work tools used, human error, and factors that may be the cause of accidents.

3.8.1 Advantages and Disadvantages of Fault Tree Analysis

According to (Kuo, 2007), advantages and disadvantages exist in fault tree analysis, namely:

1. Advantages:
   a. In the case of a complex system, fault tree analysis provides a good

and logicalway to integrate the various causes. The construction of fault tree diagrams can determine the probability of values and contribute to a better understanding ofa system.

b. Sensitivity analysis can also be performed using fault analysis trees, allowing for the comparison of differences between various causes and the analysis of their impact on the overall system by examining these changes with possible values.

2. Disadvantages

a. Creating a proper fault tree requires a significant amount of experience and knowledge. Errors in inputting causal factors into the fault tree can lead to incorrect results.

b. Choosing the most suitable logic gate for the connecting channel can be difficult, which often results in many variations in the output values.

3.8.2 Basic Rules of Fault Tree Analysis

Before creating a Fault Tree Analysis, we should understand what basic rules are needed to create a fault tree. According to the NASA Fault Tree Handbook (2002), these basic rules include:

1. The procedures and nomenclature by which events and gates are named in the Fault Tree are determined by, among other things, the following.

a. Creating a fault tree that is easy to understand is very important.

b. Ensuring that the correct cut sets and probabilities are calculated is important if the gate or basic event occurs more than once in the model.

c. Provides consistency between different fault trees, especially when developed by different individuals.

The following is a summary table of symbol images used in Fault Tree Analysis,especially for event symbols, gate symbols, and transfer symbols.

Table 3.1 Event Symbols of Fault Tree Analysis

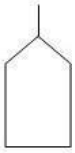
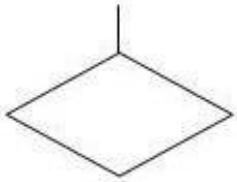
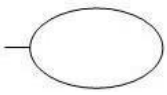
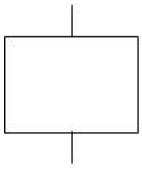
Symbol	Name	Meaning
	Basic event	failure in a component or system element
	External event	Attributed to external factors beyond one's control, such as meteorological conditions, and not stemming from any culpable actions.
	Undeveloped event	Occurrences characterized by alack of adequate information.
	Conditioning event	Conditions that constrain or impact a logic gate.
	Intermediate event/ Event box	Can be positioned just above the main event to allow additional space for entering the failure event description.

Table 3.2 Gate Symbols of Fault Tree Analysis

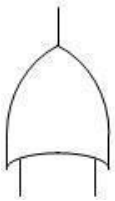
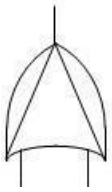
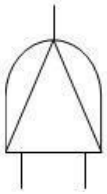
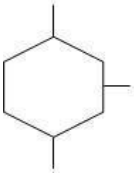
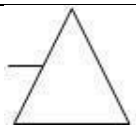
Symbol	Name	Meaning
	OR gate	output will occur if there is input.
	AND gate	output occurs only if all inputs occur, but the outputs are independent of the source.
	Exclusive OR gate	output that occurs if exactly one input occurs.
	Priority AND gate	The output occurs if the inputs occur in a specific order determined by the conditioning event.
	Inhibit gate	The output occurs if the input occurs under the activating conditions defined by the conditioning event.

Table 3.3 Transfer Symbols of Fault Tree Analysis

Symbol	Name	Meaning
	Transfer in	Shows the Fault Tree in relation to other Fault Tree pages.

Continuation of Table 3.3 Transfer Symbols of Fault Tree Analysis

Symbol	Name	Meaning
	Transfer out	hows the Fault Tree associated with a higher Fault Tree level

2. A way to model recurring events and Common Cause Factors (CCF) is employed.
3. Ways to model human error are considered.
4. Exclusion of success states is minimized since the failure probability of non- failed items is usually close to 1. This exclusion does not affect the quantification of the fault tree but simplifies its construction form.

3.8.3 Validation of Fault Tree Analysis Data

The stage of validating Fault Tree Analysis is divided into 3, namely:

1. Reliability Validation

Reliability validation is to ensure that the target Safety can be achieved throughtwo perspectives, namely:

a. Check whether the FT graphics correspond to actual events by using AND gates to ensure independence.
b. select appropriate subsystems and components to form basic events in fault treeanalysis

Checklists, system schematics, and a thorough check of the fault tree analysis logicare often utilized to achieve these adjustments, ensuring that all permutations have been included. Validation is performed by populating the fault tree analysis with failure probability data to determine whether security targets will be achieved. However, sincethe fault tree only represents the occurrence of two states (TRUE or FALSE), implementation of Boolean algebra rules is required in fault tree analysis.

Table 3.4 Algebra Table

Name	Example	Function
associative law	A×(B×C) = (A×B) × C A+(B+C) = (A+B) + C	Normal algebra can be used to expand terms, and order is not important.
distributive law	A×(B+C) = A×B+A×C	
commutative law	A×B=B×AA+B=B+A	
idempotent law	A×A=AA+A=A	An event combined (AND or OR) with itself is just that event itself.
absorption law	A×(A+B) = A A+(A×B) = A	If an event is combined with a combination of itself and another independent event, it is irrelevant whether that other event occurs because the first event will produce the next higher event.

(source: Kritzinger, 2017)

According to (Ramli, 2010), Fault Tree Analysis employs a deductive analysis method. It begins with an event caused by preceding occurrences. These prior events result from other events, component failures, or operator errors. Each error undergoesfurther analysis for its root causes to determine the state of the main event. By identifying the top events likely to occur in the system or process, all events that can lead to consequences from the top event are then identified in the form of a downwardlogic tree. This quantitative approach yields more useful results but demands more timefor data collection and experienced individuals.

Applying the laws of idempotency and absorption is crucial in fault tree analysis to ensure that probability estimates are accurate. By implementing the rules of Boolean Algebra, failure probabilities can be integrated into the basic events, allowing for the calculation of the top event's probability by sequentially determining the probability ofeach gate until the probability of the top event is determined. If all basic events are identified, probability can be determined through the multiplication of

the inputs to the AND gate and the summation of the inputs to the OR gate. Typically, expressing the target probability as a failure rate, rather than an absolute failure probability, is preferred, and this is easily achieved when all basic events are expressed as failure rates.

1. Development Assurance Level Validation

   Validation is based on safety standards adjusted for severity.

2. Human Error Validation

   This validation ensures that normal human interaction is maintained even in hazardous situations, enabling individuals to respond to failures. It is imperative to validate this to minimize failures and comprehend appropriate responses in the event of a failure that could pose a safety threat.

3.8.4 Verify Fault Tree Analysis Data

Verification of fault tree analysis data is undertaken to confirm that the graphical fault tree analysis model accurately represents the event configuration andbehavior of the final design solution. The methods employed for verification in faulttree analysis encompass the following.

1. Inspection and review of graphical fault tree analysis
2. Analyze fault tree analysis with failure events that match actual events.
3. Simulated failure mode testing, etc.

Once the fault tree analysis is verified, the analysis is documented in a report for evaluating failure security. This report should contain an index of the analyzed failure conditions, including the defined probability targets. In essence, the fault tree analysis report must yield results that incorporate a summary of the fault tree outcomes. If the analysis aligns with the desired target, then the top event with a disaster severity levelis identified as a single-point failure that has occurred and is detailed. Moreover, the report should outline any maintenance actions needed to mitigate the effects ofpotential failures.

3.8.5 Stages of Fault Tree Analysis

The following are the steps in carrying out fault tree analysis according to (Relawati, 2018).

1. The problem to be analyzed is determined.
2. A graphic model of fault tree analysis construction is created, progressing from thetop event, then to the next event, and finally to the basic event. Fault Trees must becompleted at each level up to the basic event.
3. Find answers to fault tree analysis problems that are found, which are various possible risk combinations that could occur, if they all occur or exist directly at thesame time, it will cause a top event to occur by determining the minimum cut set ranking.
4. The steps for determining the minimum cut set include:
    a. Modification of fault tree analysis into AND as well as OR gates.
    b. Naming each event.
    c. Conversion of failure tree logic into Boolean equations.
    d. Determination of the minimum cut set by simplifying the Boolean equationinto a simple form using Boolean algebra.

The following is an example of Fault Tree Analysis modeling.

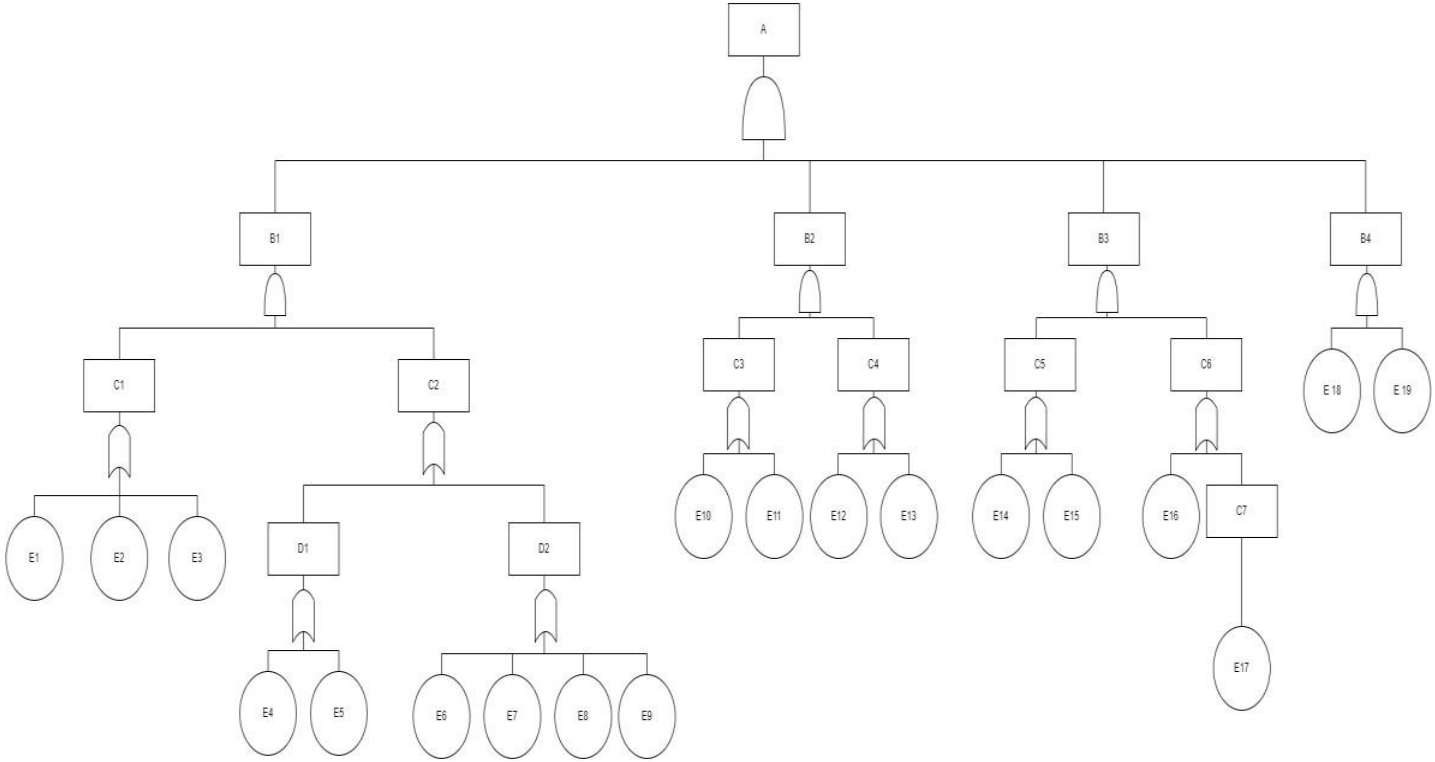


Figure 3.13 Fault Tree Analysis modelling

(source: Rizky Z, 2023)

CHAPTER IV
METHODOLOGY

4.1 Research Subjects and Objects

To achieve a comprehensive understanding of research, familiarization with the subject and object is considered important. These two elements are crucial components for forming a complete picture of the research. Through the study of the relationships between subjects and objects, relevant information can be sought efficiently, and data can be organized to suit research needs.

4.1.1 Subject

Research Subject according to (Sugiyono, 2013), "The research subject is an attribute or trait or value of a person, object or activity that has certain variables that are determined to be studied and conclusions drawn." In a research study, the analysis of research subjects is required to obtain variable data thatwill be further utilized for research or analysis, with occupational Safety and Health being the focus in this case. The observation of this research subject involves the identification of the causes of work accidents and the control of the risk associated withthese causes, utilizing the Fault Tree Analysis method based on predetermined limits set by the researchers.

4.1.2 Object

Based on (Sugiyono, 2017), the meaning of research object is "an attribute or trait or value of a person, object or activity that has certain variations determined by the researcher to be studied and then drawn conclusions". The object of research in this case is the gabion project where a landslide occurred during construction on the Tawang-Ngalang Segment IV Project. The installation of gabions and the analysis of the factors causing work accidents in the installation of gabions using the fault Tree Analysis (FTA) method.

4.2 Data and Data Collection

4.2.1 Data

According to (Arikunto, 2002), "data is all facts and figures that can be used as material to compile information, while information is the result of data processing that is used for a purpose.". Data collection in this research was carried out using the interview method and according to the limitations of the problem, the data collected included primary and secondary data. The explanation is as follows:

1. Primary Data

   Based on (Arikunto, 2013) "primary data is data collected through a first party, usually through interviews, polls and so on". The accuracy of this data is ensured by involving researchers directly in the data collection process. The primary data collection method employed in this research is interviews and discussions with Occupational Safety and Health experts to further explore aspects of Occupational Safety and Health.

2. Secondary Data

   According (Sugiyono, 2018), "secondary data is a data source that does not directly provide data to the data collector, for example via other people or via documents". Documents in the form of photos and existing data were used by the author as a reference in obtaining data in this research.

4.2.2 Data collection method

According to (Sugiyono, 2019), data collection techniques are the most importantstep in research, because the main aim of research is to obtain data. Data collection canbe done in various settings, various sources, and various ways. To obtain the data needed for the fault tree analysis method used in this research regarding work accidents during gabion installation work in the Tawang-Ngalang Segment IV project. The datacollection method used in this research is as follows:

1. Study Literature

Based on (Ruslan, 2008) Literature studies are carried out by searching for research data or information through reading scientific journals, reference books andpublication materials available in the library. The aim of the literature study is to alignthe discussion point of view with theories that are relevant to the problem being studied. It can also be used as a reference when discussing research results. This method uses relevant books, international and national journals, previous researchpapers, as well as international and national operational standards as literature.

2. Interview

According to (Bungi, 2013), an interview is the process of obtaining information forresearch purposes by means of face-to-face questions and answers between the interviewer and the person being interviewed. This research involved conducting interviews with relevant stakeholders to collect important data for the research, and tovalidate the information collected interviews was also conducted with experts who specialize in occupational safety and health.

4.3 Data Analysis

Data analysis according to (Sugiyono, 2016), *"*data analysis is a process to group data sorting into existing conditions to obtain results according to the data that has been obtained".

The data analysis stage in this research begins with identifying the work involved in analyzing the causes of landslides in gabion works, After identifying the work accidents that have occurred, an analysis will be conducted using the Fault Tree Analysis (FTA) method. The FTA method is employed to determine the root causes of work accidents, particularly in gabion installation work.

Once all data has been collected, including both secondary and primary data,

the next step is to perform data analysis. The systematic approach for data analysis is as follows:

4.3.1 Analysis Steps

When the required data has been collected, the data analysis will be conductedas follows:

1. Explaining work accidents occurring in gabion work to derive the top events thatwill be utilized as a topic in the fault tree analysis graphic design model.
2. Create a Fault Tree Analysis graphic design. A Fault Tree Analysis graphic design is created by describing the fault events that occur based on the top events. The fault events are then evaluated for appropriateness, and they are completed with logic gates to connect the possibilities that occur between fault events.
3. Analyze and calculate the minimum cut set using Boolean algebra. Which serves to simplify logical comprehension. By employing Boolean algebra combine the failures that occurred is ultimately concluded.
4. Determine risk controls that are appropriate to the combination of failuresrequired according to the risk control hierarchy.

4.4 Research Stage

In the research stage, the next steps in the search process are explained as part ofthe research stages which are carried out systematically and consistently. Starting withthe identification of a research topic, its development involves setting objectives and reviewing literature that is identical or related to the research. Next, project data is collected and analyzed to reach the final research results. A detailed explanation of the research stages provides a thorough reflection of the entire research process, thereby facilitating a better understanding of the researcher's intentions. Below is a brief overview with a research flowchart which outlines the research stages that will be carried out in this research in sequence.

1. Determining The Problem Topic

To identify problem topics that want to be addressed, especially those directly related to work safety through a study entitled "Fault Tree Analysis". The research entitled, “Analysis of The Causes of Work Accidents In Gabion Work With Fault Tree Analysis Method".

2. Determining The Objective

Determine the research objectives as a reference in conducting research to determine the factors that causes work accidents on the Tawang-Ngalang Segment IV gabion installation project landslides occured during gabion installation.

3. Literature Review

Find literature reviews which related to the research being studied. The literature review used can include similar methods, data and theories regarding "Analysis of Factors Causing Work Accidents Using the Fault Tree Analysis Method".

4. Data Collection

The data that has been collected is divided into two types. There are primary and secondary data. The explanation as follows

a) Primary Data

Interview were held with the contractor and worker. In this research, interviews were conducted with internal project parties, especially the Project Manager from the Tawang-Ngalang Segment IV project who was interviewed regarding incidents duringwork accidents to serve as sources for this research. External parties interviewed in this research included occupational safety and health (OSH) experts to provide reference suggestions and validate the data in this research.

b) Secondary Data

In this research, secondary data was obtained from various sources, including existing research listed in Chapter 2, the PUPR Ministry website, literature reviews, aswell as books related to fault tree analysis method, to support the consideration of construction work safety.

5. Data Analysis and Data Processing

The data analysis was conducted using the fault tree analysis method. What needs to be done first is to identify the top events which are work accidents during gabion installation work. Subsequently, the determination of the basic event, which is the possibility of the occurrence of the top event, is carried out. These basic events constitute the root causes of the top event that transpires. Based on the identified basicevents, the appropriate solution can be determined to prevent work accidents from recurring.

6. Analysis Results and Conclusion

The results of the discussion are the part that discusses the main points that have been obtained from previous data analysis processing and provides answers to theproblem formulation that has been determined at the beginning according to the research results obtained. So, a conclusion was obtained regarding "Analysis of Causes of Work Accidents in Gabion Works by Using Fault Tree Analysis (FTA) Method (Case Study: Tawang-Ngalang Road and Bridge Construction Project Segment IV)".

4.5 Research Flow chart

According to (Indrajani, 2011), the meaning of a flowchart is a graphic depiction of the steps and sequence of procedures in a program. Flowcharts functions are to describe a research process from the beginning to the end of the research, aiming to be a guide in the research so that it is in accordance with the research plan and increases the reader's understanding. The research flow diagram can be seen in Figure 4.1.

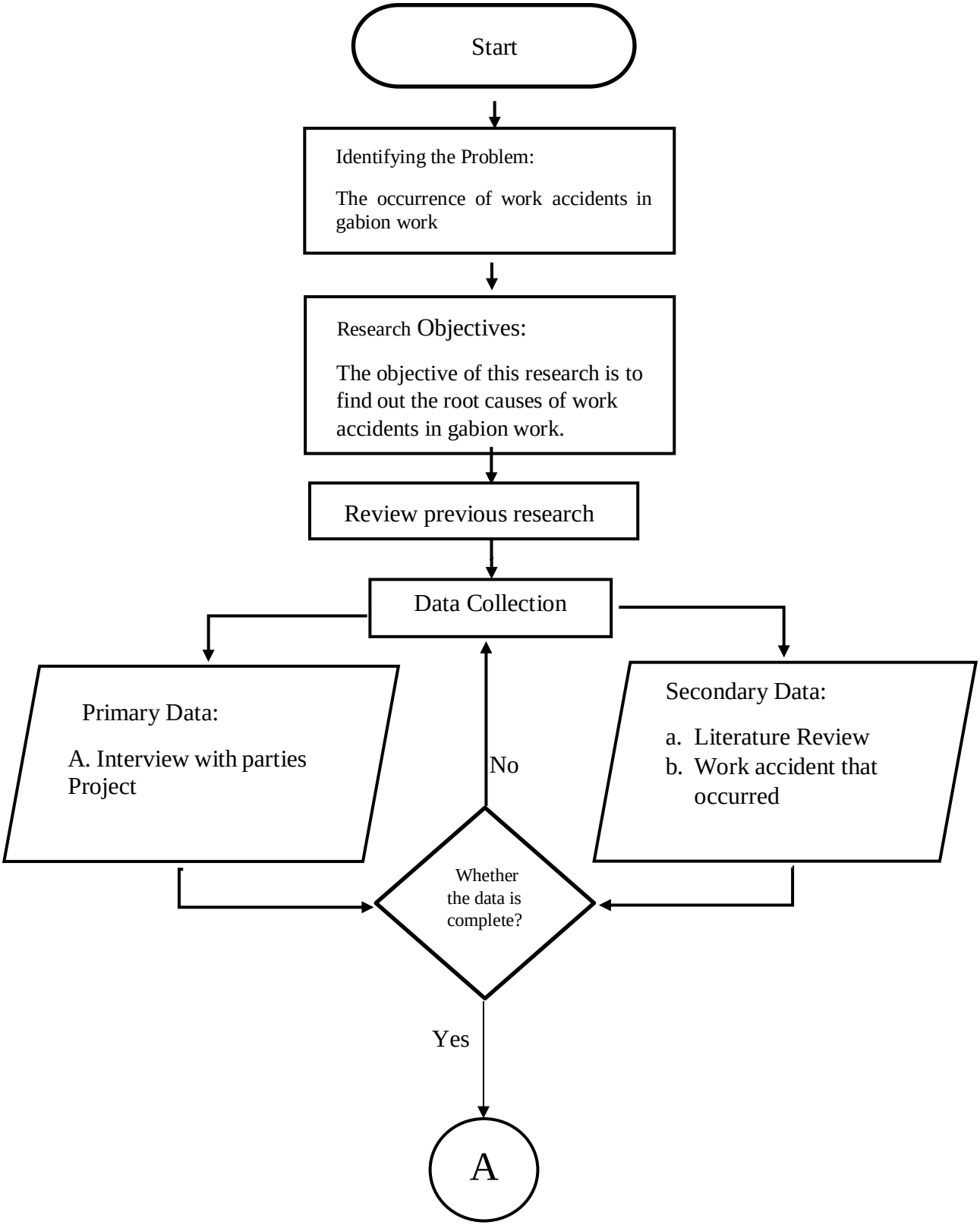


figure 4. 1 Research Flow Chart

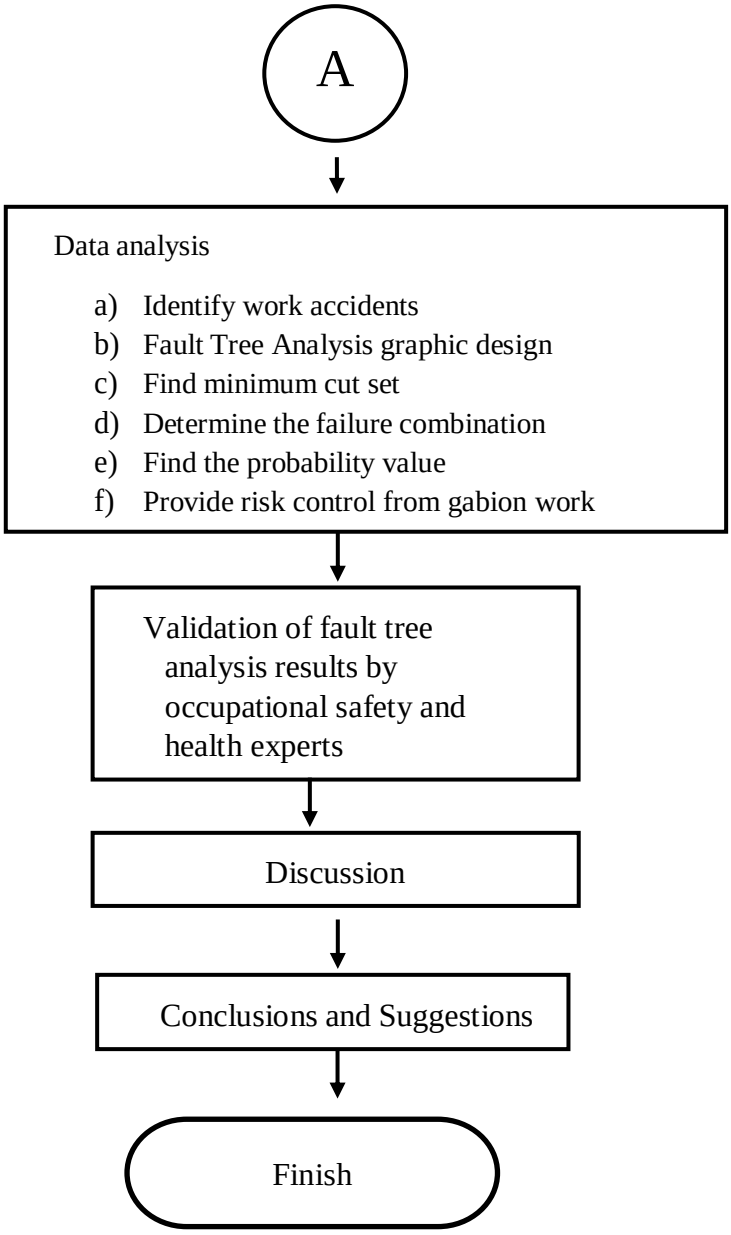


figure 4. 3 Research Flow Chart (continued)

CHAPTER V
ANALYSIS AND DISCUSSION

5.1 Project Overview

This research is conducted on a case study of the Tawang-Ngalang HighwayConstruction Project, segment IV, located in Gunungkidul Regency, Special Region of Yogyakarta. The construction project was carried out in 2022. This project is owned by the Department of Public Works, Housing, and Mineral Resources Energy of D.I. Yogyakarta and is executed by PT. Bumi Selatan Perkasa – PT. Citra Mataram Konstruksi KSO.

5.1.1 Project Data

Project Name	: Pembangunan Jalan dan Jembatan Tawang Ngalang Segmen IV.
Project Locarion	: Kec. Gedangsari Gunungkidul
Project owner	: Dinas PUP & ESDM DI Yogyakrta
Contract Value	: Rp. 77.333.171.909,80
Contractor	: PT. Bumi Selatan perkasa - PT. Citra Mataram Konstruksi KSO
Project Planner	: PT. TRI PATRA KONSULTAN
Supervisory Consultant	: PT. TRI PATRA KONSULTAN
Implementation time plan	: 270 hari

Data collection was performed by interviewing the site engineer on the Tawang-Ngalang Highway Construction Project, segment IV. The purpose of the interview was to ensure the occurrence of potential workplace accidents during the construction of the retaining wall and to obtain new information about the project while it was ongoing. The interview was conducted on 7 august 2024 in Yogyakarta. The interviewee was Dedy Eka Setiawan.

5.1.2 Project Locaton

The location of the research object is in the Tawang-Ngalang road and brigde construction project which is in Nglegi, Kapanewon Patuk, Gunungkidul. The location of the research can be seen in Figure 4.1.

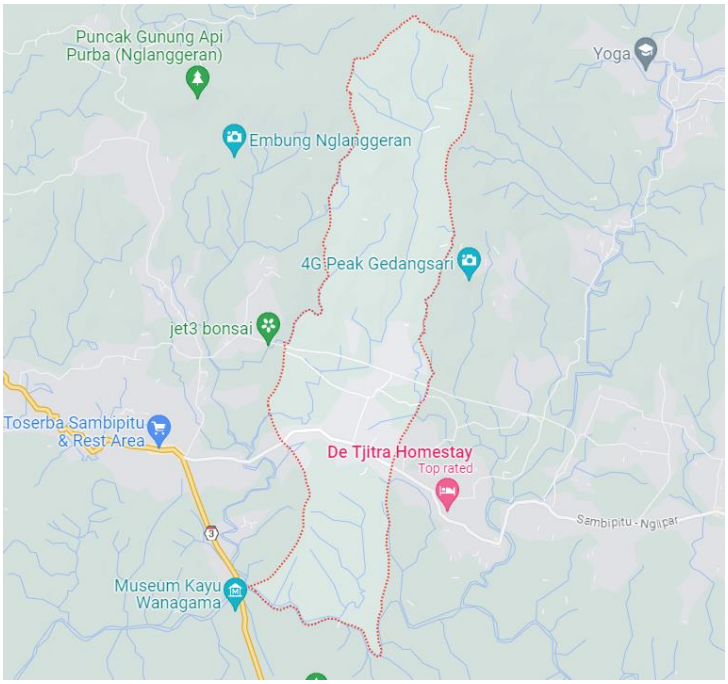


Figure 5. 1 Project Location

(Source: Google Earth, 2023)

5.2 Data Analysis

The data analysis conducted involves mapping the work accident that occurred during the gabion work and identifying the "top event" of the accident. Subsequently, an FTA (Fault Tree Analysis) is created based on the 'top event' to determine the root cause of the accident. The identified root cause represents the 'basic event' and can be concluded as the reason for the accident. The potential occurrences at the time of the accident are then determined and verified with safety experts for possible combinations.

5.3 Fault Tree Analysis Work

1. Top Event Identification

This stage is designed to determine the type of failure that has occurred and to identify system errors. A comprehensive understanding of the system is achieved by thoroughly examining all information and data related to the working system and its scope. The focus is on identifying the subject of analysis or the top event tobe researched. Problems or major incidents of workplace accidents are identified in this research.

2. Determining the Factors that Cause Accidents

After identifying the top event, the factors causing work accidents are to be determined. These causal factors will subsequently become intermediate events, which provide a general overview of the top event. The intermediate events are then further refined to identify basic events that align with field conditions or are validated through interviews with experts in the field.

The objective of identifying accident causes is to facilitate the creation of a graphical Fault Tree Analysis (FTA) structure and to understand the sequence of workplace accidents. This approach, by identifying causal factors, allows for the analysis of various topics and interactions, resulting in diagrams that can explain the causes of workplace accidents through the combination of events that occur.

In the workplace accident case involving the Tawang-Ngalang Road Segment IV project, three main factors were identified as the primary causes: worker-related worker factors, management factors, and environmental factors. Each of these factors is crucial for the successful execution of the project. These factors, classified as intermediate events, can be simplified into basic events, representing the fundamental causes that cannot be further subdivided.

Table 5.1 Factors that cause work accidents

Intermediate event	Cause of Accident
Worker Factors	• Lack of experience and skills among workers. • Incorrect working method
Management Factors	• Lack of supervision • inadequate coordination between teams.
Environmental factors	• Poor soil condition • Extreme weather condition

The data presented above is derived from interviews conducted by the researcher with informants and the results of a literature review. In this workplace accident study, several crucial factors were identified that have the greatest impact on the occurrence of workplace accidents, such as humanfactors and technical factors.

The following is a graphic plan for modeling the collapse of the gabion.

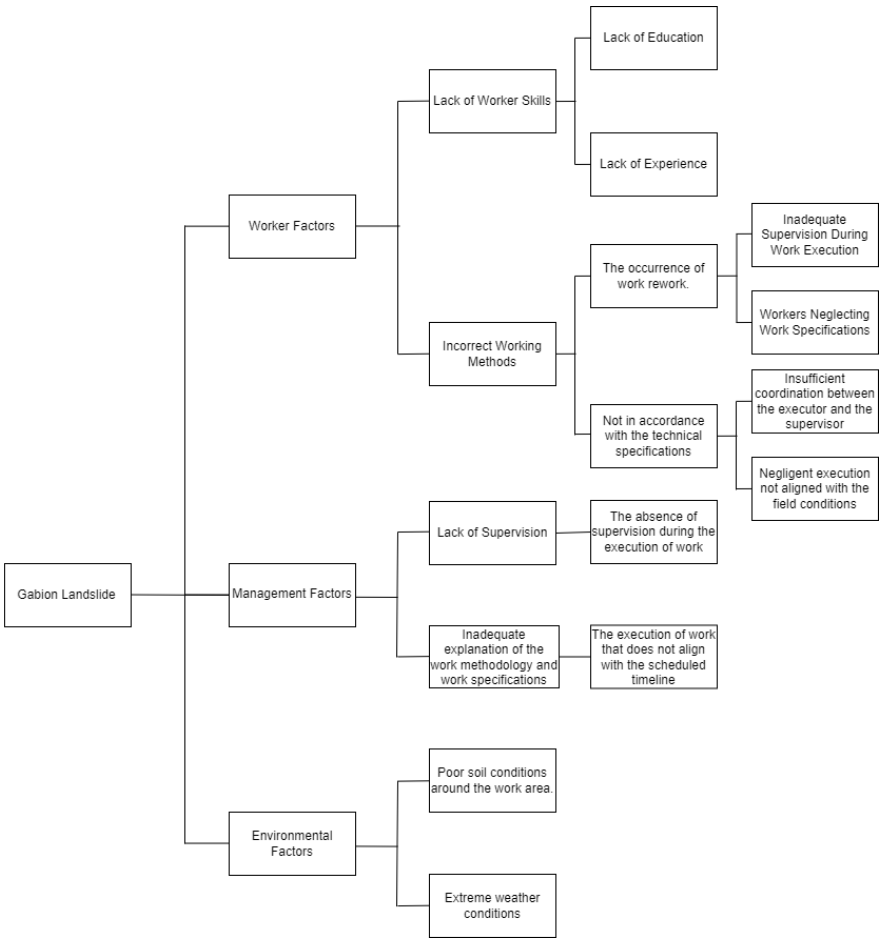


Figure 5.2 Graphic plan of Gabion Collapse Modeling

3. Fault Tree Analysis Drawing

The creation of a fault tree diagram based on the identified top event, intermediate event, and basic event involves the use of logic gates, as explainedin Chapter 3, to connect events and facilitate the notation of letters or numbersfor subsequent stages. This stage involves analyzing the diagram using Methodfor Obtaining Cut Sets to identify unknown causes of the workplace accident. Initially, the diagram includes the top event, followed by the intermediate and basic events.

In the diagram, the basic event or root cause is represented by a circle and positioned at the bottom of the graphic. Intermediate events and the top event are depicted as rectangles. The intermediate event signifies the

transition between the top event and the basic event, while the top event itself is the critical incident, which in this case is the collapse of the gabion structure.

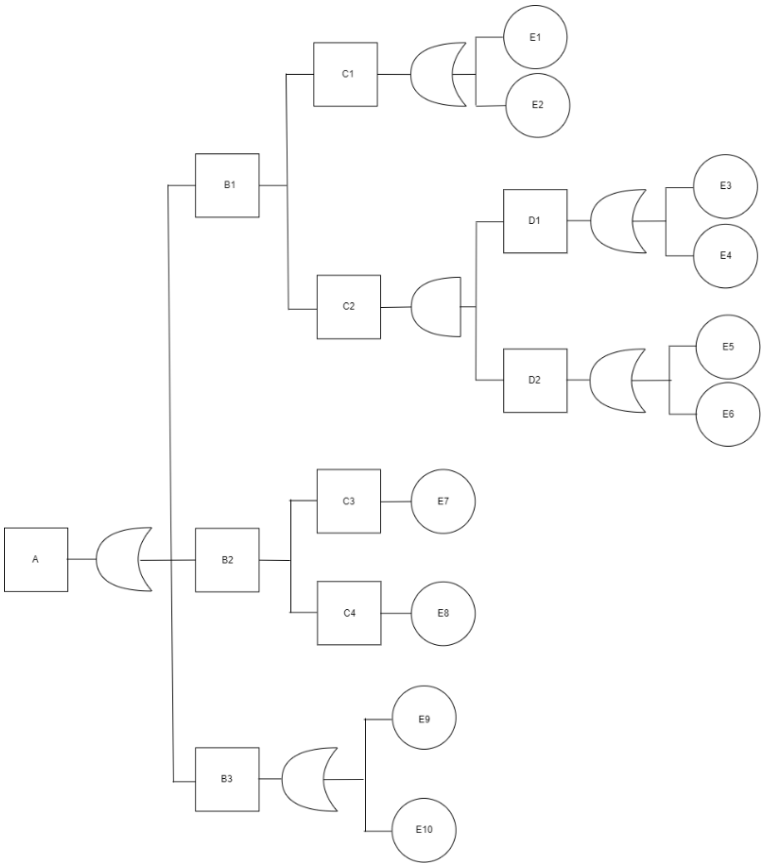


Figure 5.3 Fault Tree Analysis Diagram for Gabion Collapse

Table 5.2 Letter and Number Notations

No	Notation	Description
1	A	Gabion Collapse
2	B1	Worker Factors
3	B2	Management Factors
4	B3	Environmental Factors
5	C1	Lack of Worker Skills
6	C2	Incorrect Working Methods
7	C3	Lack of Supervision

Continuation of Table 5.2 Letter and Number Notations

No	Notation	Description
8	C4	Inadequate explanation of the work methodology and work specifications
9	D1	The occurrence of work rework
10	D2	Not in accordance with the technical specifications
11	E1	Lack of Experience
12	E2	Lack of Experience
13	E3	Inadequate Supervision During Work Execution
14	E4	Workers Neglecting Work Specifications
15	E5	Insufficient coordination between the executor and the supervisor
16	E6	Negligent execution not aligned with the field conditions
17	E7	The absence of supervision during the execution of work
18	E8	The execution of work that does not align with the scheduled timeline
19	E9	Poor soil conditions around the work area.
20	E10	Extreme weather conditions

4. Combination of Basic Events

After constructing the Fault Tree Analysis (FTA), the next phase involves identifying the cut sets. A cut set refers to a combination of basic events that, if they all occur, will lead to the top event. The next step is to find the minimal cut sets, which are those that cannot be simplified further. These cut sets and minimal cut sets are derived using the Method for Obtaining Cut Sets, which applies Boolean Algebra. The process begins with an analysis of the basic events that lead to the top event, determining cut sets through the distributive property of Boolean Algebra. In Boolean terms, an OR gate is denoted by (+) and an AND gate by (.) or multiplication.

Table 5.3 Boolean Algebra Cut Set

A	= B1. B2. B3
B1	= C1.C2
B2	= C3.C4
B3	= E9+E10
C1	= E1+E2
C2	= D1.D2
C3	= E7
C4	= E8
D1	= E3+E4
D2	= E5+E6

After determining the cut sets, the next step is to identify the combinations of events that yield results that cannot be further simplified. Thefinal outcome of these combinations represents the primary events leading to the top event, or peak event, as derived from the resulting event combinations,as detailed below.

A = B1.B2.B3

= (C1.C2).(C3.C4).(E9+E10)

A =((E1+E2).(D1.2)).(E7.E8).(E9+E10)

=((E1+E2).(E3+E4).(E5+E6))).(E7.E8).(E9+E10)

=(E1+E2).(E3+E4).(E5+E6).(E7.E8).(E9+E10)

By applying distributive Boolean algebra to the event combinations, 5 minimal cut sets were derived. Initially, 5 basic eventsor root causes were identified in the fault tree analysis diagram. Subsequently, 10 failure combinations were determined using method for obtaining cut sets and the application of Boolean algebra.

5. Fault Tree Analysis Data Validation

The function of validating Fault Tree Analysis is to verify the Fault Tree Analysis that has been constructed and to align it with the incidents that occurred on the field. The failure combinations obtained can describe the

natureof the failures and provide risk control based on these combinations, as detailedin the table below.

Table 5.4 Results of Combination Analysis of Failure and Risk Control conclusion from the table

No	Event	Description	Risk management
1	E1, E2	The occurrence of gabion collapse is a potential risk in the gabion work. This is caused by workers who are deficient in knowledge and have minimal work experience, particularly in gabion work.	• Providing training on gabion construction techniques. • Hiring workers with expertise in slope protection construction
2	E3, E4	The occurrence of gabion collapse is a potential risk in the gabion work. Inadequate supervision of workers and insufficient coordination between lines.	• Workers must be closely supervised to ensure tasks are carried out according to agreed procedures. • Establishing good coordination ensures that contractors, foremen, and supervisors are aware of any changes to the slope protection plan.
3	E5, E6	The occurrence of gabion collapse is a potential risk in the gabion work. Inadequate oversight of the workers has resulted in the job being completed in a way that does not align with the approved specifications.	• Routine briefings are to be organized for each worker to ensure that the procedures to be executed are comprehensively understood. • Regular inspections of work progress are to be conducted to ensure that the work follows the specified requirements.
4	E7, E8	The occurrence of gabion collapse is a potential risk in the gabion work. The issue arose due to poor management in monitoring and communicating updates to the work specifications and project timelines.	• The presence of a supervisor at each job site is to be ensured. • Work reports and coordination sessions between the contractor and supervisor must be organized. • Warnings will be given to workers who do not comply with work procedures.

Continuation of Table 5.4 Results of Combination Analysis of Failure and Risk Control conclusion from the table

No	Event	Description	Risk management
5	E9, E10	The occurrence of gabion collapse is a potential risk in the gabion work. The factors contributing to this include environmental factors such as extreme weather and inadequate soil conditions.	• Adjusting the specifications and work methods promptly to align with the field's soil conditions. • The work schedule must get adjusted based on the actual weather conditions encountered in the field. • The work schedule will be organized with careful attention to field conditions and possible workplace accidents.

4 failure combinations and risk controls related to workplace accidents have been identified based on the table above. The risk controls outlined in the table are categorized according to the hierarchy of control levels and the domino theory discussed in Chapter 3.

5.4 OSH Experts Validations

The data from the Fault Tree Analysis obtained in this research was evaluated through discussions with Occupational Health and Safety (OSH) experts. The results were validated and confirmed by OSH specialists to ensure data accuracy and correctness, with oversight from OSH experts. Supporting evidence from the OSH professionals is included in the appendix.

5.5 Discussion

This research was conducted on the Tawang-Ngalang Segment IV Road and Bridge Construction Project, carried out in 2022. The study focuses solely on work-related accidents during the gabion installation process. Based on interviews with Riyanto Amin Nugroho and Dedy Eka Setiawan, as the Site

manager and Occupational Safety and Health (OSH) certified, it was revealed that there were errors in the work methods, job specifications, scheduling, and a lack of communication between departments. These issues led to work that did not align with the meeting outcomes, resulting in rework during extreme weather conditions, which ultimately caused a landslide. There were no casualties in this workplace accident but financial and material losses.

The research identified the top event in the Fault Tree Analysis as the collapse of the gabion during the Tawang-Ngalang Segment IV Road and Bridge Construction Project. Once the top event was established, the focus shifted to identifying the basic events or root causes that may have contributed to the workplace accident during the gabion installation. These basic events were derived from information gathered through interviews, input from workers, and data from online sources.

After identifying the basic events, the next step is to create a graphical model of the Fault Tree Analysis. In this model, letter and number notations are assigned to help determine the result of the minimal cut set and identify the appropriate logic gates based on the graphical model previously created. The researcher then constructs the Fault Tree Analysis diagram and proceeds with the cut set identification using Boolean algebra, as explained in Chapter 3.

The results of the minimal cut sets are derived from the event combinations discussed in the analysis subsection above. These combinations produce minimal cut sets, which identify the root causes of the workplace accident (top event), as illustrated in the fault tree analysis diagram. From these event combinations, it can be concluded that the failure combination leading to the top event—namely, the collapse of the gabion during installation—was due to three key failure factors. Each of these failure factors has its root cause and corresponding risk control measures based on the hierarchy levels outlined in Chapter 3, as follows:

1. Worker Factor

Due to limited experience cause workers lack of skills for gabion installation. This aligns with the First Domino theory: Ancestry and Social Environment, prompting the implementation of the risk management actions as follows:

1) Providing training or workshops on gabion installation work.
2) Engaging qualified workers or involving experts in the installation of gabions.

Risk controls 1 and 2 are classified as administrative controls, as the efforts focus on managing aspects related to workers to mitigate the potential for hazards.

The incorrect work method was a result of changes in technical specifications due to poor soil conditions caused by extreme weather, as well as the absence of warnings from the supervisors. This scenario aligns with the second domino theory: fault of a person. Furthermore, the failure to adhere to predetermined technical specifications was attributed to a lack of coordination between the contractor and supervisor, which aligns with the third domino theory: unsafe acts and unsafe conditions. Risk control measures have been identified as follows.

1) Organize consistent briefing sessions before beginning work to facilitate a comprehensive understanding of the work specifications and timeline among the contractor, foreman, and supervisor.
2) Enforce strict supervision to ensure all tasks are executed under the work specifications.
3) Workers should be warned when the work does not meet the agreed specifications.
4) Regular inspections must be conducted.

The risk control measures from the 4 points above are determined as administrative controls, as they focus on managing risks by implementing

policies aimed at workers. These policies are designed to ensure that workers perform their tasks in accordance with the job specifications. Such controls establish a work system that minimizes the likelihood of hazards occurring.

2. Management Factor

A. The lack of supervision was due to the supervisor's lack of discipline in supervising the work and the absence of supervision during the execution of tasks. This situation is categorized under the second domino theory: fault of a person. Therefore, the following risk control measures can be implemented as follows:

1) The presence of a supervisor at each job site is to be ensured.

2) Supervisors should be warned if they are not disciplined.

The risk control measures outlined in the 2 points above are categorized as administrative controls, as they are applied to ensure that supervisors maintain discipline in overseeing the workforce.

B. The lack of coordination among the contractor, supervision, and foreman resulted in miscommunication, which in turn led to errors in the execution of work by the workers. This situation is categorized under the second domino theory: fault of a person. Therefore, the following risk control measures can be implemented as follows:

1) Ensuring between the contractor, supervisor and foreman fully understand the updated work specifications.

2) Organize regular coordination sessions and reporting mechanisms to ensure work is under the work methods and timeline compliance.

Risk controls 1 and 2 are considered administrative controls, as they are implemented from the worker’s side.

3. Environmental factor

Extreme weather conditions caused work to be delayed and caused the ground conditions in the field to worsen. This situation is determined as the second domino theory: fault of a person. Therefore, the following risk control measures can be implemented as follows:

1) Adjustments to the work specifications should be made promptly and considering the latest soil conditions.

2) Adjustments to the work schedule must be made in the event of any inconsistencies with the prior schedule, with careful consideration of extreme weather factors.

Risk controls 1 and 2 are classified as a substitution strategy, as it involves changing the work method to minimize potential hazards.

Based on the identified failures, risk control measures have been implemented according to the observed incidents. These risk control strategies were derived from discussions between the researcher and Occupational Health and Safety (OSH) experts. The failures mentioned led to the occurrence of the fourth domino: accidents, resulting in the fifth domino: injuries, which manifest as costs, material losses, time delays, and potential loss of life. Given all the identified failures, it is imperative to establish risk control measures as previously outlined. These controls employ a hierarchical approach, allowing for classification based on their level of effectiveness and enabling an assessment of their efficacy according to the established hierarchy.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The research leads to several conclusions. An analysis of the causes of accidents in gabion work at the Tawang-Ngalang Segment IV Road and Bridge Construction Project, carried out using the Fault Tree Analysis (FTA) method, has revealed primary issues that contributed to the gabion collapse during installation. These primary causes are detailed as follows.

1. Insufficient competency and comprehension of workers in executing their assigned work.
2. Poor supervision is attributed to the insufficient discipline and awareness exhibited by the workers.
3. Insufficient information outreach and communication across teams have caused workers to be uninformed about any changes that have been agreed upon.
4. Extreme weather conditions are compounded by inadequate soil stability.

6.2 Recommendation

1. In the execution of a project, communication and discipline in the workplace should be treated as critical factors to mitigate the incidence of workplace accidents and potential hazards.
2. For future research on similar topics, it is advisable to collect more detailed data in identifying workplace accidents in specific work aspects being studied, so that the observations can be analyzed in broader and more varied outcomes.

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APPENDIX

Appendix 1 Interview Permission



FAKULTAS
TEKNIK SIPIL
& PERENCANAAN

Nomor : 260/Sek. Prodi PSTS/20/TA/IX/2024
Hal : Permohonan Izin Wawancara

Kepada Yth.
Bapak Dedy Eka Setiawan, S.T.
Ahli K3 Proyek Pembangunan Tawang – Ngalang Segment IV
Rejowinangun, Kotagede, Yogyakarta

Assalamu'alaikum Warrahmatullahi wabaraktuh,

Untuk memenuhi salah satu syarat guna menyelesaikan studi pada Prodi Teknik Sipil Program Sarjana, setiap mahasiswa wajib melaksanakan penelitian Tugas akhir yang berkaitan dengan ketekniksipilan. Dalam proses tersebut diperlukan data - data dari kontraktor, konsultan, perencana baik dari instansi pemerintah (BUMN) maupun perusahaan swasta/Proyek.

Berdasarkan hal tersebut, kami mohon izin kepada Bapak/Ibu Pimpinan Perusahaan untuk dapat **melakukan wawancara** yang hasilnya akan digunakan untuk keperluan penyusunan Tugas Akhir bagi mahasiswa Prodi Teknik Sipil Program Sarjana Jurusan Teknik Sipil Fakultas Teknik Sipil dan Perencanaan Universitas Islam Indonesia Yogyakarta. Adapun nama mahasiswa tersebut adalah:

Nama	:	**Muhammad Naufal Dzikri Akbar**
NIM	:	**19511064**
CP Mahasiswa	:	**082143148605**
Judul Tugas Akhir	:	***Analysis of The Causes of Work Accident in Gabion Work with Using Fault Tree Analysis Method (FTA)***

Demikian permohonan ini kami sampaikan, atas bantuan dan kerjasamanya kami ucapkan terima kasih.

Wassalamu'alaikum Warrahmatullahi Wabarakatuh.

Yogyakarta, 27 September 2024
Dosen Pembimbing Tugas Akhir,

Sek. Prodi Teknik Sipil – Program Sarjana,

Dinia Anggraheni, S.T., M. Eng

Ir. Fitri Nugraheni, S.T., M.T., Ph.D

Appendix 2 Interview Confirmation Letter

SURAT BUKTI WAWANCARA

Yang bertanda tangan di bawah ini :

Nama : Dedy Eka Setiawan, S.T.

Jabatan : Ahli K3

Dengan ini menyatakan bahwa mahasiswa di bawah ini :

Nama : Muhammad Naufal Dzikri Akbar

NIM : 19511064

Program Studi : Tehnik Sipil

Fakultas : Tehnik sipil dan Perencanaan

Universitas : Universitas Islam Indonesia

Telah melakukan wawancara untuk pengambilan data penelitian Tugas Akhir yang berjudul "Analysis of Causes of Work Accidents in Gabion Work with Using Fault Tree Analysis Method(FTA)(Study Case: Tawang-Ngalang Segment IV Road and Bridge Construction Project)"pada Tanggal 27 September 2024.

Demikian surat bukti wawancara ini untuk di pergunakan sebagaimana mestinya

Yogyakarya 27 september 2024

Tertanda



Dedy Eka Setiawan, S.T.

Appendix 3 Accident Documentation



Appendix 4 Certificate of competence



F6874098

BADAN NASIONAL SERTIFIKASI PROFESI
INDONESIA PROFESSIONAL CERTIFICATION AUTHORITY

SERTIFIKAT KOMPETENSI
CERTIFICATE OF COMPETENCE

Nomor Sertifikat / *Certificate Number*
74321 2263.02 7 00007219 2022

Dengan ini menyatakan bahwa,
This is to certify that,

DEDY EKA SETIAWAN

No. Reg. F 1994 07219 2022 0039484 MP 01

Telah Kompeten pada bidang:
Is competent in the area of:

Jasa Konstruksi
Construction Services

Dengan Kualifikasi / Kompetensi:
With Qualification / Competency:

Ahli Muda K3 Konstruksi
Safety Construction Junior Expert

Sertifikat ini berlaku untuk 5 (lima) tahun
This certificate is valid for 5 (five) years

Atas nama Badan Nasional Sertifikasi Profesi
On Behalf of Indonesia Professional Certification Authority

Lembaga Sertifikasi Profesi Gataki Konstruksi Mandiri
Gataki Konstruksi Mandiri Professional Certification Agency

Ade Setiawan
Ketua LSP
Chairman PCA

Appendix 5 Certificate of competence

LEMBAGA PENGEMBANGAN JASA KONSTRUKSI
CONSTRUCTION SERVICES DEVELOPMENT BOARD

Daftar Unit Kompetensi:
List of Unit(s) of Competency:

Klasifikasi	:	Manajemen Pelaksanaan
Classification	:	*EXECUTIVE MANAGEMENT*
Subklasifikasi	:	Keselamatan Konstruksi
Subclassification	:	*Construction Safety*
Kualifikasi	:	Ahli
Qualification	:	*Expert*
Jenjang	:	7 (Tujuh)
Level	:	*7 (Seven)*
Okupasi	:	Ahli Muda K3 Konstruksi
Occupation	:	*Safety Construction Junior Expert*

Ditetapkan di Jakarta, 13 Desember 2022
Enacted in Jakarta, December 13, 2022



DEDY EKA SETIAWAN

Keterangan / *Remarks* :

1. Sertifikat ini sah berlaku setelah tercatat yang dibuktikan dengan nomor registrasi Sertifikat Kompetensi Kerja Konstruksi. / *This certificate is valid upon being registered as evidenced by registration number of Certificate of Competency of Construction Works.*
2. QR Code dan Data yang tertera dalam sertifikat ini dapat diverifikasi melalui sistem informasi jasa konstruksi terintegrasi. / *QR Code and Data contained herein may be verified through an integrated information system of construction service.*

Appendix 6 interview transcript

Interviewer : Muhammad Naufal Dzikri Akbar

Interviewee : Dedy Eka Setiawan S.T.

Location : Yogyakarta

Time : Friday, September 27 2024

Interviewer : Bagaimana gambaran umum tentang proyek Tawang-Ngalang segment IV jalan dan jembatan ini?

Interviewee : Ini adalah proyek lanjutan dari proyek Tawang-Ngalang segment II yang terletak di Gunung Kidul dan sudah beroperasional

Interviewer : Bagaimana kronologis tanah longsor tersebut?

Interviewee : Pada saat penggalian tanah lebih dalam pembuatan ulang pondasi bronjong yang sesuai dengan standar yang di tetapkan sudah di sore hari ketika selesai melakukan pembersihan. Lalu pada pagi hari ketika kembali kelapangan tanah sudah ambrol dan menyebabkan rumah diatasnya longsor.

Interviewer : Kenapa harus di lakukan pengerjaan ulang untuk instalasi bronjongnya?

Interviewee : pada awalnya sudah terpasang shotcrete dilereng tetapi dengan kondisi tanah yang buruk dan ada bangunan diatasnya mengharuskan dirubahnya perencanaan dari yang awalnya shotcrete ke bronjong dengan pondasi yang lebih dalam.

Interviewer : Faktor apa saja yang mempengaruhi kecelakaan tersebut?

Interviewee : Pertama karena cuaca yang sangat ekstrem sehingga membuat tanah menjadi lebih buruk dan membuat jadwal pekerjaan menjadi berantakan sehingga menyebabkan pengerjaan tidak selesai dengan waktu yang di tentukan sehingga pekerjaan harus di lanjut pada hari selanjutnya. Kurangnya komunikasi antar lini sehingga sub kontraktor tidak mengetahui apabila ada perubahan rencana tidak seperti yang sudah di sepakati sebelumnya. Dan kurangnya pengawasan dari pengawas ketika melakukan pekerjaan instalasi bronjong.

Interviewer : untuk bapak sendiri posisinya pada saat proyek itu sebagai apa?

Interviewee :saya selaku site engineer