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*(Research Article)*

# Analysis of the Effectiveness of Material Selection for Riverside Stabilization Using *the Analytical Hierarchy Process* (AHP) Method (Case Study: PT. Tondano Nusajaya Mine)

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**Abstract:** This research aims to evaluate the effectiveness of retaining wall construction materials for riverbank slopes at PT. Tambang Tondano Nusajaya, Likupang, North Minahasa, using the Analytical Hierarchy Process (AHP) method. The analysis was conducted on three alternative materials geocell concrete, wiremesh concrete, and reinforced steel based on three criteria: structural strength, cost efficiency, and installation speed. The AHP results indicated geocell concrete as the selected material with the highest global priority score of 0,624, excelling in installation speed 0,480 and cost efficiency 0,405, while reinforced steel and wiremesh concrete obtained lower scores of 0,164 and 0,213, respectively. The findings suggest that although reinforced steel possesses high structural reliability, operational considerations regarding time acceleration and cost optimization are more dominant in this project context. Geocell Concrete is recommended as the most effective and efficient solution for riverbank retaining wall material application at the study location, with an important note regarding the necessity of further investigation concerning long-term performance and adaptation to local environmental conditions.

**Keywords:** Cost Efficiency; Installation Speed; Retaining Wall Materials; Riverbank Protection; Structural Strength.

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## 1. Introduction

River slopes are particularly vulnerable to erosion, abrasion, and hydraulic forces of river flows, especially in areas with high rainfall and open-flow systems that experience extreme discharge fluctuations (Aswarni & Hermawan, 2025; Martini, 2019). Riverside erosion not only causes soil loss and changes in river morphology, but also results in infrastructure damage, a decline in ecosystem quality, and threats to community safety around riverbanks (Martini, 2019). In some extreme cases, riverbank collapse can trigger flash flooding, excessive sedimentation, and damage to public facilities such as roads and bridges in downstream areas (Aswarni & Hermawan, 2025; Martini, 2019).

Efforts to strengthen the river slope are generally carried out using conventional methods, such as the installation of revetment with river stones, gabions, or reinforced concrete construction. However, these conventional methods often have disadvantages, such as high development costs, limitations in adapting to changes in land shape, and negative impacts on the natural ecosystems around rivers. Along with the development of materials technology, the use of geosynthetics is becoming increasingly popular as a more efficient, flexible, and environmentally friendly alternative in various civil engineering projects, including riverside protection (Koerner, 2012).

The main problems faced in the development of riversides in PT. The Tondano Nusajaya Mine is a conventional material non-optimal in meeting the demands of the project that requires a balance between technical and operational aspects. Although conventional reinforced concrete has high structural reliability, it faces significant constraints in terms of cost efficiency and speed of implementation in the field. On the other hand, alternative methods such as wiremesh have not been able to fully answer the need for materials that have adequate strength and practicality in their application. This creates a dilemma in determining the most appropriate material that can meet the criteria of structural strength, cost efficiency, and installation speed simultaneously, so a comprehensive evaluation is required to find the optimal solution.

This study aims to conduct an analysis related to the effectiveness of the selection of stabilization materials in the construction of riversides in PT. Tondano Nusajaya Mine, Likupang, North Minahasa. Using a systems approach, this study evaluates the performance of riverbank stabilization materials in several key aspects, including structural strength, material cost and mobilization, and practicality and efficiency.

In this context, the research uses the Analytical Hierarchy Process (AHP) method. The AHP approach was chosen because of its ability to systematically outline complex problems into a decision hierarchy, while assessing alternative options with measurable criteria (Leal, 2020; Supriadi et al., 2018). Other research shows that the AHP method improves the quality of decision-making involving many criteria, such as strength, cost, practicality and efficiency. AHP has been widely used in various fields, ranging from the selection of construction materials, project evaluation, to the determination of competitiveness strategies (Supriadi et al., 2018; Utami et al., 2021).

In contrast to these studies, AHP in this study was used to assess the effectiveness of the use of geocell concrete, concrete wiremesh, and iron concrete materials in the construction of riverbank stabilization, reviewed from structural strength, material cost and mobilization, as well as practicality and efficiency. The entire analysis process was carried out using Microsoft Excel software for priority assessment between criteria and alternatives.

## 2. Literature Review

Riversides are areas that are vulnerable to erosion and morphological changes due to the influence of water flow, rainfall, and soil characteristics, so stabilization efforts are needed to prevent damage to the surrounding land, environment, and infrastructure (Martini, 2019). Conventional stabilization methods such as gabions, masonry, and concrete have been widely used and have good structural strength, but often face obstacles in the form of high costs, lack of flexibility to changes in field conditions, and relatively longer installation times (Aswarni & Hermawan, 2025). Alternatively, the use of geosynthetic materials such as geocells is becoming increasingly popular because it has high adaptability, cost efficiency, and ease of installation in various ground surface conditions (Koerner, 2012).

In the process of selecting stabilization materials, there are three main criteria that are commonly used, namely structural strength, cost efficiency, and installation speed (Supriadi et al., 2018). To determine the material that best suits the field conditions and project needs, the Analytical Hierarchy Process (AHP) method is used because it is able to break down complex problems into hierarchical structures and assign priority weights based on paired comparisons between criteria and alternatives (Saaty, 2000, 2008). The results of the application of AHP in the study on the document show that geocell concrete gets the highest priority with a value of 0.624, mainly due to its advantages in cost efficiency and installation speed, while concrete iron excels in terms of strength but requires greater installation cost and time. These findings confirm that the selection of stabilization materials should not only consider structural strength, but must also take into account operational conditions, budget allocation, and project implementation time.

## 3. Method

The data collection process begins with obtaining primary data through observation activities that are carried out based on research needs and actual field conditions (Sugiyono, 2018, 2020). The collected data was then analyzed using the Analytical Hierarchy Process (AHP) approach, as described in previous research (De Oliveira et al., 2019; Supriadi et al., 2018). The AHP method was developed by Thomas L. Saaty as a systematic technique to support decision-making involving multiple criteria through a structured and logical pair-matching process (Saaty, 2000, 2008). This approach allows for the objective prioritization of alternatives by combining rational and intuitive considerations to obtain the best decision among the various options available (Fauzi et al., 2017; Utami et al., 2021).

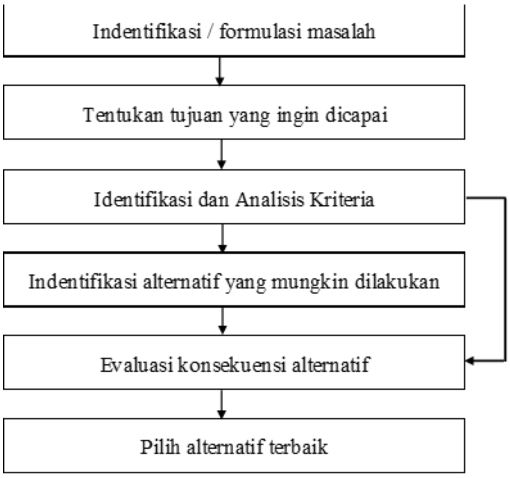



**Figure 1.** Decision support procedures.

Effective decision-making begins with understanding the problem and setting goals to be achieved. After that, various possible alternative actions are identified and the consequences they cause. To determine the best alternative, each option needs to be evaluated against a specific measurement standard so that the highest-scoring alternative is considered to provide the most optimal benefit (Saaty, 2000; Sugiyono, 2020).

In the process of evaluating various options, assessment criteria are needed that can be used as a reference in assessing the impact of each alternative. The analysis of this criterion aims to determine the weight of interests as the basis for comparison between alternatives (Supriadi et al., 2018; Utami et al., 2021). These criteria are then used as the foundation of a Multi-Criteria Decision Making (MCDM) system, which allows for a thorough assessment of complex options. In general, the AHP-based evaluation procedure includes several steps, namely: (1) identification and weighting of criteria, (2) alternative assessment based on criteria, (3) calculation of the weight of evaluation results, and (4) determination of the best alternative based on the highest total value (Saaty, 2000; Supriadi et al., 2018). This approach is comprehensive because it is able to deal with multi-objective and multi-criteria problems that often arise in the decision-making process (Fauzi et al., 2017).

From the mathematical side, the basic formulation of the AHP method is manifested in the form of a paired comparison matrix, where each element is compared based on the level of importance. The results of this comparison produce the eigenvector value as a priority weight that describes the relative influence of each criterion or alternative (Saaty, 2000; Supriadi et al., 2018; Utami et al., 2021).

**Table 2.** Pair-Comparison Rating Scale

| Importance of importance | Information | Explanation |
|---|---|---|
| 1 | Both elements are equally important | Two elements have an equally great influence on the purpose |
| 3 | One element is slightly more important than the other other | Experience and a little evaluation support one element compared to other elements |
| 5 | One element is more important than the other | Experience and assessment are very Strongly supports one element over another |

| | | |
|---|---|---|
| 7 | One element is clearly more absolute important than the other | One strongly supported and dominant element is seen in practice |
| 9 | One element is absolutely more important than the other | Evidence that supports one element against another has the highest level of affirmation possible Strengthen |
| 2,4,6,8 | Values between two adjacent consideration values | This value is given when there are two compromises between two options |

The AHP method uses two main approaches to measure alternatives to a criterion, namely relative assessment and absolute assessment. In relative assessment, each alternative is compared in pairs based on a ratio of importance levels to determine the priority weight of each element, while absolute assessment is done by assessing each alternative independently using a quantitative scale (usually between 1 to 9) to objectively obtain a priority order (Saaty, 2008; Sianturi, 2011). This approach allows for more accurate decision-making because it takes into account the degree of relative importance between alternatives as well as the absolute value of each option (Sianturi, 2011; Supriadi et al., 2018).

In the context of this study, the AHP method was applied to determine the best stabilization material alternatives in the construction of riverside retaining wall construction in PT. The Tondano Nusajaya Mine, Likupang, North Minahasa, takes into account aspects of strength, material cost and mobilization, as well as practicality and efficiency.

## 4. Results and Discussion

### 4.1 Result

***Evaluation of Criteria***

$$\begin{array}{l} \\ \text{Strength} \\ \text{Cost} \\ \text{Installation} \end{array} \begin{pmatrix} \text{Strength} & \text{Cost} & \text{Installation} \\ 1/1 & 1/3 & 1/5 \\ 3/1 & 1/1 & 1/1 \\ 5/1 & 1/1 & 1/1 \end{pmatrix} \quad (1)$$

By multiplying the matrix until it reaches a stable EigenVector value, the following criteria are obtained.

$$\begin{array}{l} \text{Kekuatan} \\ \text{Biaya} \\ \text{Pemasangan} \end{array} \begin{pmatrix} 0{,}115 \\ 0{,}406 \\ 0{,}480 \end{pmatrix}$$

Alternative Assessment of the Strength Aspect

$$\begin{array}{l} \\ \text{Geocell Concrete} \\ \text{Wiremesh} \\ \text{Besi Beton} \end{array} \begin{pmatrix} \text{Geocell Concrete} & \text{Wiremesh} & \text{Besi Beton} \\ 1/1 & 5/1 & 1/2 \\ 1/5 & 1/1 & 1/5 \\ 2/1 & 5/1 & 1/1 \end{pmatrix}$$

By multiplying the matrix until it reaches a stable EigenVector value, the following criteria are obtained.

| | |
|---|---|
| Geocell Concrete | 0,354 |
| Wiremesh | 0,090 |
| Besi Beton | 0,556 |

Alternative Assessment of the cost aspect

| | Geocell Concrete | Wiremesh | Besi Beton |
|---|---|---|---|
| Geocell Concrete | 1/1 | 3/1 | 5/1 |
| Wiremesh | 1/3 | 1/1 | 3/1 |
| Besi Beton | 1/5 | 1/3 | 1/1 |

By multiplying the matrix until it reaches a stable *Eigenvector* value, the following criteria are obtained.

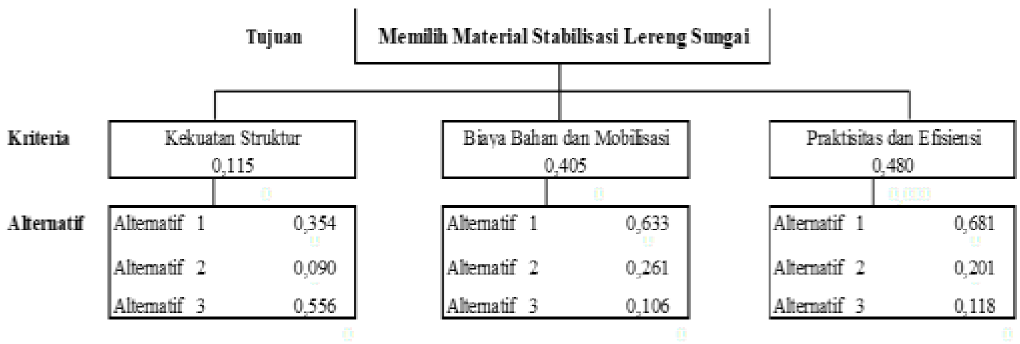
| | |
|---|---|
| Geocell | 0,633 |
| Wiremesh | 0,261 |
| Besi Beton | 0,106 |

Alternative Assessment of Practicality and Efficiency

| | Geocell Concrete | Wiremesh | Besi Beton |
|---|---|---|---|
| Geocell Concrete | 1/1 | 4/1 | 5/1 |
| Wiremesh | 1/4 | 1/1 | 2/1 |
| Besi Beton | 1/5 | 1/2 | 1/1 |

By multiplying the matrix until it reaches a stable EigenVector value, the following criteria are obtained

| | |
|---|---|
| Geocell Concrete | 0,681 |
| Wiremesh | 0,201 |
| Besi Beton | 0,118 |




Bobot kriteria dan alternatif

| | Kekuatan | Biaya | Pemasangan | | Kriteria |
|---|---|---|---|---|---|
| Geocell Concrete | 0,354 | 0,633 | 0,681 | | 0,115 |
| Wiremesh | 0,090 | 0,261 | 0,201 | X | 0,405 |
| Besi Beton | 0,556 | 0,106 | 0,118 | | 0,480 |

The alternative ranking of the action is obtained by multiplying the action alternative weight matrix with the criterion weight matrix.

| | Kekuatan | Biaya | Pemasangan | Kriteria |
|---|---|---|---|---|
| Geocell Concrete | 0,354 | 0,633 | 0,681 | 0,115 |
| Wiremesh | 0,090 | 0,261 | 0,201 | 0,406 |
| Besi Beton | 0,556 | 0,106 | 0,118 | 0,480 |

The result of matrix multiplication gives weight to each alternative, namely:

- Geocell Concrete Alternative 1 $\Psi = 0.624$
- Wiremesh Alternative 2 $\Psi = 0.213$
- Wiremesh Alternative 3 $\Psi = 0.164$

### 4.2 Discussion

The complexity of physical systems demands a decision-making mechanism that has a similar level of complexity. Therefore, solving complex problems requires a decision system equipped with a methodological approach that is able to accommodate the various parties, perceptions, and interests involved. This kind of system approach is used to apply scientific analysis in the management and development of operational systems, as well as in the design of information systems for the decision-making process (Handayani & Angreni, 2020; Setiawan & Ariadi, 2012; Tantyonimpuno & Retnaningtias, 2006; Tanubrata & Setiaputri, 2019). The decision is essentially the end result of the process of analyzing the several available options (Oetomo & Susanto, 2011; Tominanto, 2012). The decision-making process itself includes the mechanism of selecting the best alternative from a number of options that have the possibility to be considered. One of the methods often used in this context is the Analytical Hierarchy Process (AHP), a multi-criteria evaluation technique that measures the priority of various alternatives based on a number of criteria and assigns a relative weight of value to each alternative (Shvetsova et al., 2021; Yu et al., 2023).

In the context of this study, the data studied is in the form of the design of the river slope retaining wall construction project at PT. Tondano Nusajaya Mine, Likupang, North Minahasa. The assessment is carried out taking into account technical aspects, material and mobilization costs, as well as practicality and efficiency factors. Some of the structural materials used in the project include geocell concrete, concrete wiremesh, and concrete iron, each of which has different characteristics in supporting the river wall structure. The AHP method is used to obtain the most optimal ratio value through paired comparisons, both discretely and continuously. This approach is considered ideal because it is flexible and effective in determining decision priorities based on various aspects and views of decision-makers. By arranging them into hierarchical forms, AHP allows for a systematic weighting process to determine the best alternatives (Dehghanian et al., 2012; Leal, 2020).

## 5. Conclusion

Based on the application of the Analytical Hierarchy Process (AHP) method in evaluating the effectiveness of materials for the construction of riverside retaining walls at PT. Tondano Nusajaya Mine, Likupang, North Minahasa, the results of the study identified Geocell Concrete as the selected material with the highest global priority value, which is 0.624. The advantage of this material mainly lies in the aspect of installation speed, which obtains a weight of 0.480 and cost efficiency with a weight of 0.405, two criteria that are the main determinants in the implementation of the project. Meanwhile, comparative materials such as conventional Concrete Iron and Concrete Wiremesh obtained significantly lower values of 0.164 and 0.213, respectively, placing the two alternatives in the rankings below Geocell Concrete.

These findings indicate that although Concrete Iron is recognized to have high structural reliability, operational considerations such as acceleration of implementation time and budget control are more dominant in the context of the project being analyzed. Therefore, Geocell Concrete is recommended as the most effective and efficient solution to be applied as a stabilization of riverside walls at the study site, without ignoring the need for further studies related to long-term performance and adaptation to specific environmental conditions in the region. Further research is expected to be further developed by reviewing alternative uses of other riverside retaining wall materials.

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**Conflict of Interest:** The author declares that he has no conflict of interest in researching, writing, or publishing this article.

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