International Journal of Civil Engineering (IJCE)
ISSN (P): 2278–9987; ISSN (E): 2278–9995
Vol. 14, Issue 2, Jul–Dec 2025; 1–10

International Academy of Science, Engineering and Technology
IASET
Connecting Researchers; Nurturing Innovations

STABILITY AND REINFORCEMENT ANALYSIS OF GABION RETAINING WALLS IN TOLOKIBIT, BANGGAI LAUT

Syaiful Ibrahim[1], A. Rahayu[2] & S. Nurdin[3]

[1,2]Master of Civil Engineering, Tadulako University, Palu, Indonesia

[3]Associate Professor, Department of Civil Engineering, Tadulako University, Palu, Indonesia

ABSTRACT

Banggai Laut Regency is an archipelago with a high level of vulnerability to landslides, particularly on the banks of the Tolokibit River in the village of the same name. Landslides are typically triggered by seasonal flooding and fluctuations in river water levels, which cause soil saturation and decrease slope stability. This study aims to analyze the stability of river walls and evaluate the effectiveness of gabion structures as a slope reinforcement solution against landslides and erosion. The methods used include calculating peak flood discharge with a 10-year return period using the Rational method, as well as modeling the stability of slopes and gabion structures using Geo5 software. The analysis results show that the peak flood discharge of 54.5282 m³/s with a water level between 1.407–1.512 m produces significant hydrostatic and erosional forces on the river slope. The designed gabion groyne structure is able to withstand these pressures with a safety factor (Fs) value between 1.81–4.77, exceeding the safe threshold. Fluctuations in groundwater levels have been shown to significantly affect the overturning and sliding Fs values, where increasing fluctuations cause a decrease in stability. Of the two gabion configurations tested, Model 2 was deemed optimal due to its high stability, material efficiency, and ease of construction. This study recommends implementing Model 2 as a practical and effective solution for landslide mitigation in the Tolokibit Village River area, reducing the risk of infrastructure damage and socio-economic impacts on the local community.

KEYWORDS: *River Landslide, Gabion Stability, Water Level Fluctuation.*

Article History

Received: 13 Dec 2025 | Revised: 16 Dec 2025 | Accepted: 20 Dec 2025

INTRODUCTION

Banggai Laut Regency is an archipelago with a high level of vulnerability to natural disasters, particularly landslides. The undulating to hilly terrain and high rainfall are the main factors contributing to the formation of landslide-prone zones. Based on the official thematic map of the Banggai Laut Regency Government, a vulnerability analysis was conducted taking into account geological parameters, slope gradient, land cover, and rainfall. The overlay results show that high landslide hazard zones are widespread across four large islands: Banggai, Bangkurung, Labobo, and Bokan Islands. This vulnerability is further increased by human activities that affect land stability.

The Tolokibit River in Tolokibit Village is one of the locations severely impacted by landslides, particularly on the riverbanks, caused by seasonal flooding over the past decade. From May to September 2024, extensive damage occurred, including infrastructure damage, economic disruption, and a decline in land values in the surrounding area. Several homes were even swept away by floodwaters and landslides. Geotechnically, the landslide was triggered by a sudden rise in river water levels, which saturated the riverbanks, reduced soil shear strength, and increased current pressure and riverbed erosion.

Given these conditions, technical analysis-based mitigation efforts are necessary, as outlined in a study entitled "River Wall Stability Analysis and Reinforcement in Tolokibit Village, Banggai Laut Regency." This study aims to identify the causes of bank instability and design effective reinforcement solutions to prevent future landslides. By strengthening the river wall using hydrological, geotechnical, and structural engineering approaches, it is hoped that material losses and safety risks to the Tolokibit Village community can be minimized.

RESEARCH METHODS

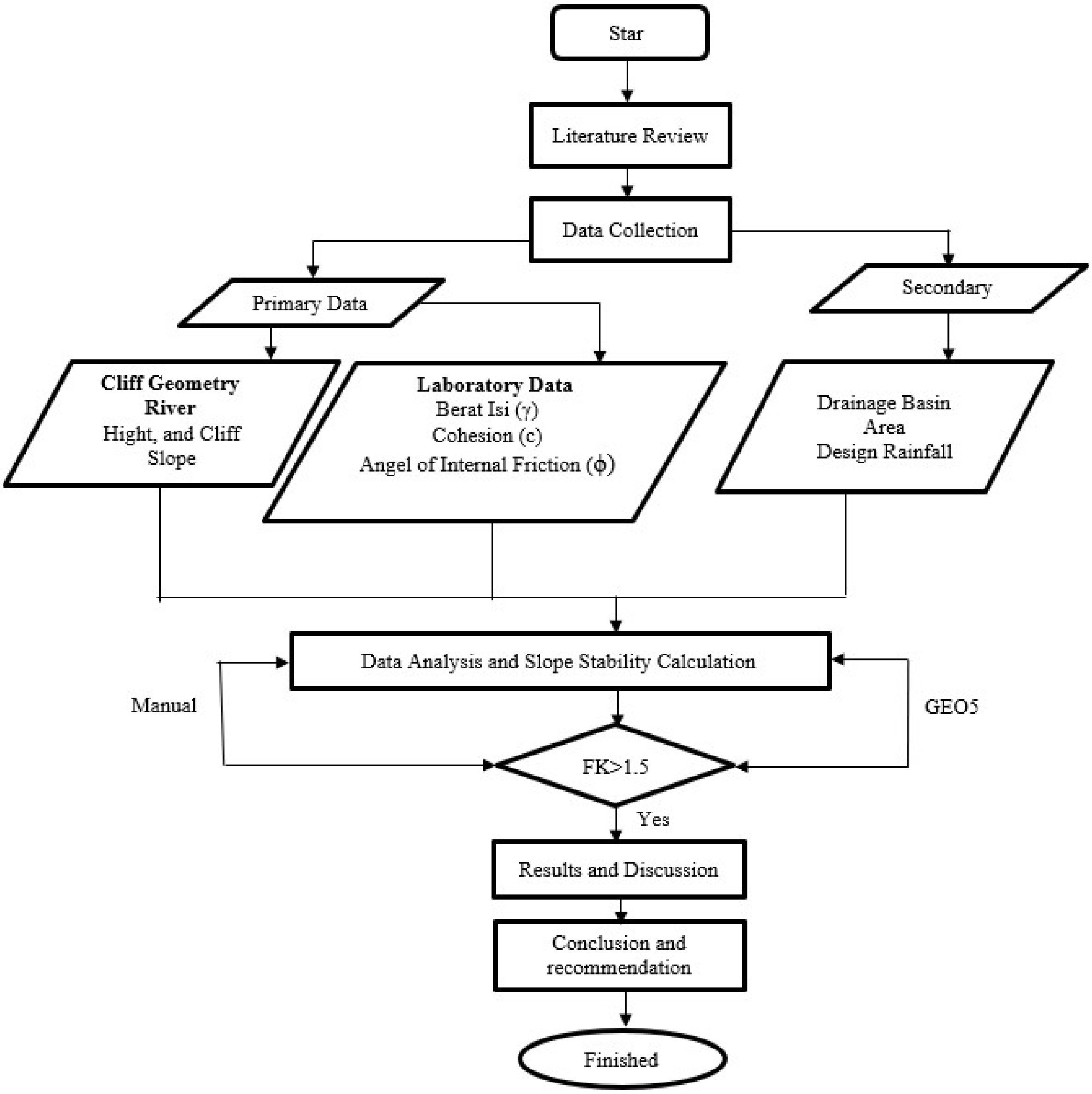
Research Location

This research was conducted in the Tolokibit Village River, South Banggai District, Banggai Laut Regency, Central Sulawesi Province, at several river intersection points: Hulu, P01, P02, P03, and Hilir.

Figure 1: Research Location: Tolokobit Village.

Data Used

Crucial data for slope stability analysis, particularly in riverine areas, include maximum daily rainfall data, which influences infiltration and pore water pressure buildup, and river geometry data, which defines the shape and slope of the slope. Laboratory soil test results are also required, such as unit weight (γ), friction angle (ø), and cohesion (c), which determine the shear strength of the soil, as well as water content (w); this information is complemented by groundwater table data to calculate the pore pressure acting on the potential shear plane. Finally, traffic load data should be considered if there are external loads from above the slope, as these loads can increase the driving forces that can trigger slope failure.



RESULTS AND DISCUSSION

Hydrological Analysis

Maximum rainfall was analyzed using the Log Pearson III method, resulting in a design rainfall that was then used to calculate intensity. The time of concentration was calculated using the Kirpich formula and used to obtain the average rainfall intensity at P02.The results of the hydraulic analysis show that the peak flood discharge with a 10-year return period (Q_{10}) reached 54.5282 m^3/s at all monitoring points in P02. This discharge produces varying hydraulic conditions at each marker, indicated by a water level (h) ranging from 1.233 m to 1.528 m and a flow velocity (V) ranging from 3.882 m/s to 4.478 m/s, as shown in Table 1.

Table 1: Results of River Hydraulic Calculations P02

Period Repeat	Flood Discharge Plan (Q_n)	S	b	h	A	P	R	n	V	Q
(Year)	(m^3/sec)		(m)	(m)	(m^2)	(m)	(m)		(with that)	(m3 / day)
2	383,604	0.025	6	2,924	55,573	24,082	2,308	0.040	6,903	383,604
5	483,219	0.025	6	3,188	66,078	26,260	2.516	0,040	7.313	483.219
10	545.282	0,025	6	3.336	72.346	27.477	2.633	0,040	7.537	545.282
25	623.621	0,025	6	3.508	80.009	28.896	2.769	0,040	7.794	623.621
50	679.556	0,025	6	3.623	85.333	29,842	2,860	0.040	7,964	679,556

Bishop Method Stability Analysis

Table 2: Summary of FS Values for the Simple Bishop Method

NO	Patok	FS
1	Hulu	1,76
2	P01	1,43
3	P02	2,03
4	P03	1,61
5	Hilir	2,05

Point P01 has the lowest FS value, namely 1.43, which, although still above the safe threshold (FS > 1.3), requires more attention because it has the potential to become a critical point if conditions change, such as increased rainfall, additional loads from construction, or vegetation disturbance.

Geo5 Modeling Results

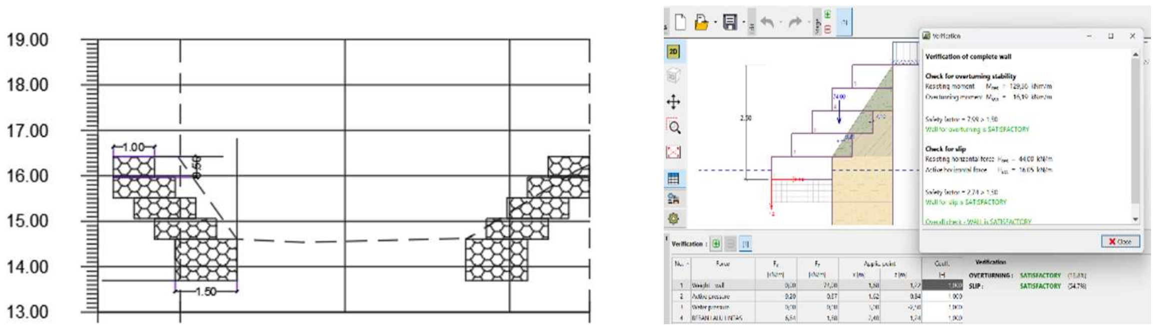


Figure 2: Planning and Modeling of Gabions.

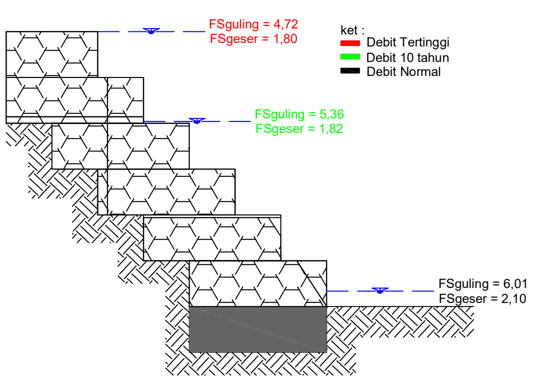


Figure 3: Fluctuation Results Water Level in the Upstream

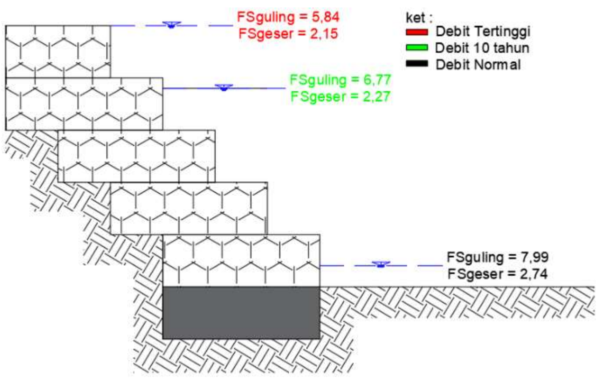


Figure 4: Fluctuation Results Water Level at P01

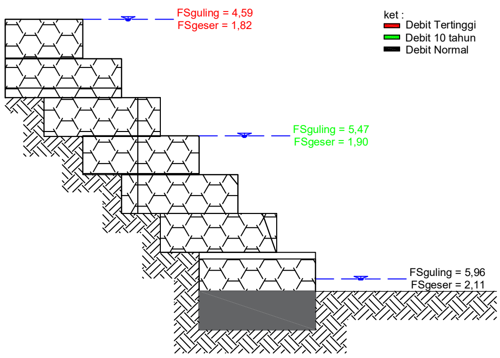


Figure 5: Fluctuation Results Water Level at P02

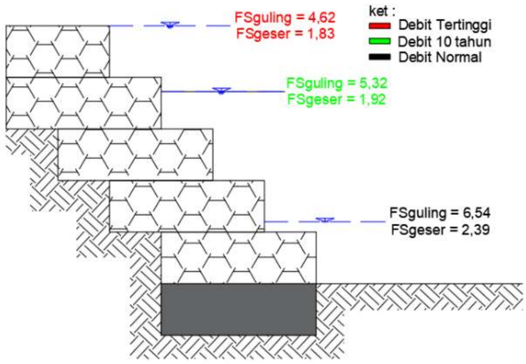


Figure 6: Fluctuation Results Water Level at P03

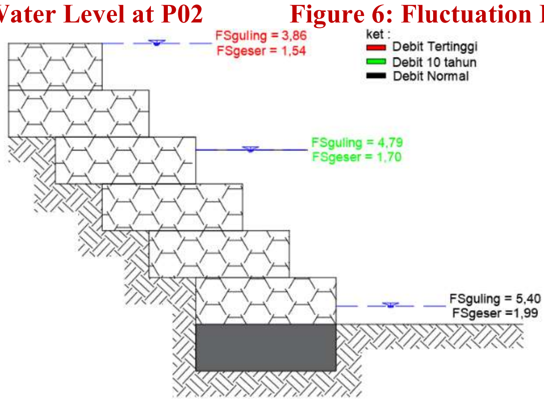


Figure 7: Fluctuation Results Water Level in the Lower Reaches.

Table 3: Recapitulation of FS_{roll} and FS_{slide}

FS_{roll}					
Water Level	**UPSTREAM**	**P01**	**P02**	**P03**	**DOWNSTREAM**
1. Normal	6.01	5.96	7.99	5.4	6.54
2. 10 Years	5.36	5.47	6.77	4.79	5.32
3. Peak	4.72	4.59	5.84	3.86	4.62
FS_{slide}					
Water Level	**UPSTREAM**	**P01**	**P02**	**P03**	**DOWNSTREAM**
1. Normal	2.1	2.11	2.74	1.99	2.36
2. 10 Years	1.82	1.9	2.27	1.7	1.92
3. Peak	1.8	1.82	2.15	1.54	1.83

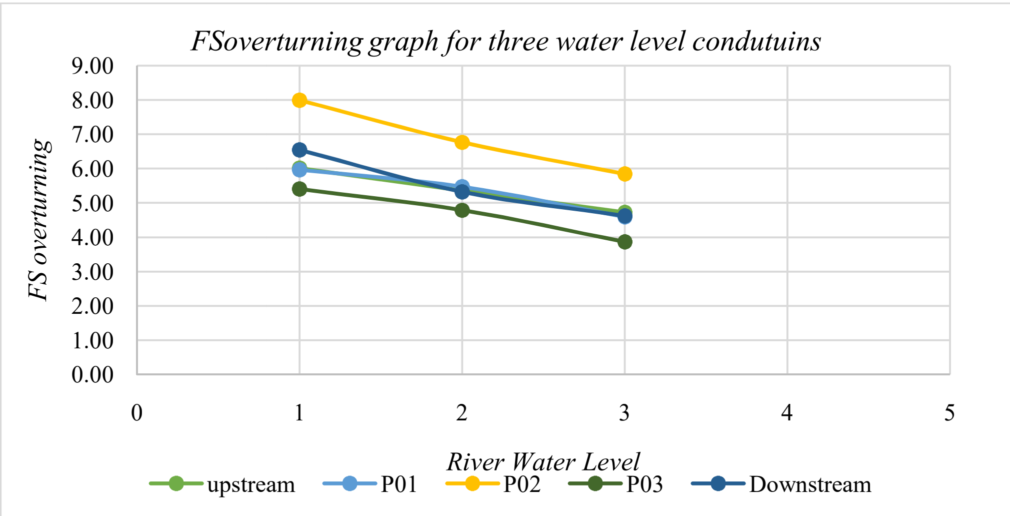


Figure 8: Recapitulation of $FS_{rolling}$

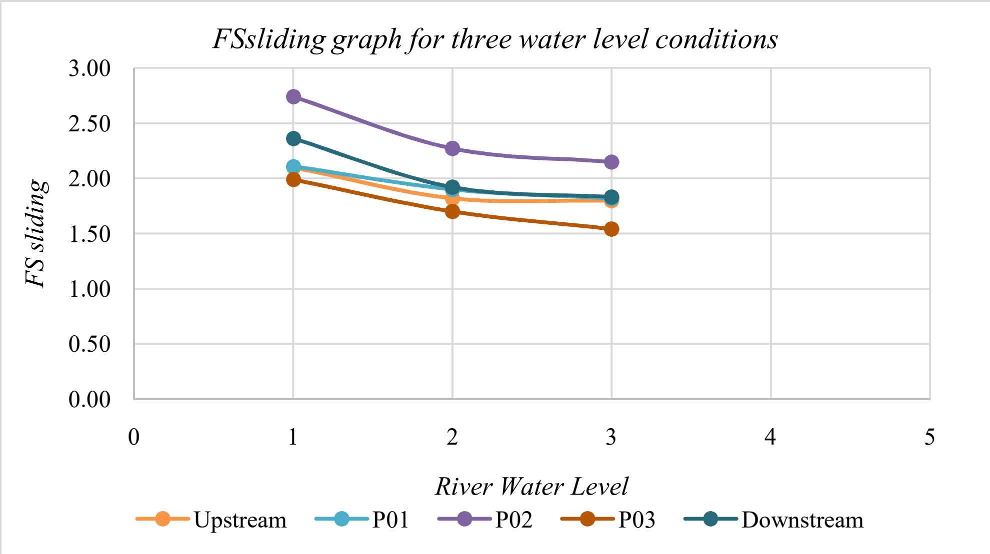


Figure 9: Recapitulation of $_{sliding}$ FS.

Figures 8 and 9 show that the FS values decrease consistently as the water discharge increases, indicating that larger hydraulic loads reduce the structural safety margin. The most striking difference is that the Overthrow FS values are always significantly higher (reaching almost 8.00) compared to the Shear FS values (which have a maximum of only 2.74), indicating that shear stability is the most critical criterion and the main focus in the design of this structure.

Gabion Installation Configuration

Table 4: Recapitulation of FS $_{overturning}$ and FS $_{sliding}$ in the Gabion Model Configuration

10 Years		
Configuration	**Fs $_{overturning}$**	**Fs $_{sliding}$**
Model 1	6.04	2.19
Model 2	6.77	2.27

The Model 2 gabion configuration was chosen because it has a higher overturning and shear safety factor value than Model 1, with all Geo5 analysis results still meeting the safety limits (overturning FS > 2 and shear FS > 1.5). In addition to good stability, Model 2 is more efficient in terms of material volume and cost because its shape is more upright, so it does not require a large horizontal space. This condition is very advantageous in locations with limited land, such as narrow cliffs near rivers or areas adjacent to roads and buildings. Its implementation is also faster and simpler because it does not require widening downstream, so excavation work can be minimized. This configuration provides an optimal balance between stability and technical and economic efficiency.

CONCLUSION

- The peak flood discharge with a 10-year return period calculated using the Rational method was obtained at 54.5282 m^3/sec with a 10-year water level ranging from 1.407-1.512 m. This discharge produces significant hydrostatic and erosion forces on the river slope. According to the results of Geo5 modeling, the designed gabion groyne structure is able to withstand this pressure, producing a safety factor (Fs) of 1.81-4.77, which exceeds 1.5, indicating it is safe in resisting landslides due to water and soil loads.

- Based on the results of calculations and modeling of river wall reinforcement stability using GEO5, it can be seen that groundwater level fluctuations have a significant influence on river wall stability, which is reflected in changes in the overturning and sliding Factor of Safety (FS) values at various water level conditions. The greater the water level fluctuation, the smaller the overturning and sliding FS values.
- The Model 2 gabion configuration was chosen as the optimal slope reinforcement solution because it successfully achieved the ideal balance between superior structural safety and high project efficiency. Model 2 proved to be better than Model 1 with the Safety Factor (FS) values for overturning (> 2) and shear (> 1.5) exceeding the minimum limits required by Geo5 simulation, confirming a very stable and safe slope condition. This technical superiority is supported by the efficiency aspect, where its more upright shape saves material volume, reduces construction costs, and minimizes the need for horizontal land, making it a practical and fast choice for implementation in the field with limited space, especially in vulnerable areas such as the Tolokibit Village River.

SUGGESTION

- Based on the study next, it is recommended to carry out an analysis to further investigate the stability cliff river by comparing two or more methods for stability analysis. This is aimed at getting more secure and accurate results. In addition, the study should also cover analysis of movement land as well as influence factors environmental, such as rainfall, water flow, and local geology conditions, in order to provide evaluation more stable and comprehensive
- Agency related, in this matter, this is the Public Works and Spatial Planning Department, Water Resources (SDA), and Disaster Management Agency, Regional Disaster Management Agency (BPBD) of the Regency Banggai Laut, can make dimensions planned gabions in the study. This serves as a reference in planning reinforcement of the river cliff in Tolokibit Village,District South Banggai.

BIBLIOGRAPHY

1. *Apriyono, A. (2018). Application of used tire woven gabion walls as slope reinforcement to prevent landslides in the laboratory. IOP Conference Series: Materials Science and Engineering, 288 (1), 012030. https://doi.org/10.1088/1757-899X/288/1/012030*
2. *Ahmad, Zulfikar Ali, Muh. Nathan and Syamsul Arifin Lias. 2019. "Correlation Between Flow Discharge and Suspended Sediment (Supended Load) in the Data River, Pinrang Regency." Ecosolum Journal 8 (1): 21. https://doi.org/10. 20956/ecosolum.v8i1.6894.*
3. *Asadpour, H., & Akhlaghi, T. (2017). Stability analysis of gabion walls with tiebacks in seismic areas. Geotechnical and Engineering Geology, 35 (4), 1541–1554. https://doi.org/10.1007/s10706-017-0174-7*
4. *Barliyan, B., et al. (2022). River bank stability analysis using limit equilibrium and finite element methods (Semitn 2019). Civil Engineering Journal.*
5. *Bowles, Joseph E. 1989. Physical & Geotechnical Properties of Soil.*

6. *Chairullah, B., Pratama, RA, & Suparma, LB (2024). The investigation of stability on slopes using reinforcing gabion walls and concrete piles for mitigating landslide disasters. IOP Conference Series: Earth and Environmental Science, 1285 (1), 012013. https://doi.org/10.1088/1755-1315/1285/1/012013*
7. *Das, Braja M. 1995a. "Soil Mechanics Volume 1 (Principles of Geotechnical Engineering." Erlangga Publisher, 1–300.*
8. *Das BM 2014. "Principles Of Geotechnical Engineering." Cengage Lerning 8th.*
9. *Das, Braja M. nd "'Principles of Geotechnical Engineering.'" Institute of Technology 10 November, 239.*
10. *Das BM 1995. Soil Mechanics (Principles of Geotechnical Engineering). Volume 2. Jakarta: Erlangga.*
11. *ESDM. 2007. Introduction to Landslides.*
12. *Hardiyatmo. 2002. "Soil Mechanics I." Gadjah Mada University Press 4 (1): 1–23.*
13. *Hardiyatmo, Hary Christady. 2003. "Soil Mechanics II." Gadjah Mada University Press 91 (5): 1–398.*
14. *Hardiyatmo, Hary Christady. 2007. Soil Mechanics 2 Third Edition. 3rd ed. Yogyakarta: GADJAH MADA UNIVERSITY PRESS.*
15. *Hoek, E. 1991. "When is Design in Rock Engineering Acceptable." Aachen: Proceedings of the 7th International Congress of Rock Mechanics 3 : 1485–97.*
16. *Jordy, D., Amalia, DR, & Amarta, R. (2024). The effect of scour phenomena on slope stability in the substructure construction of the Cipeles Bridge. Journal of Physics: Conference Series, 2716 (1), 012017. https://doi.org/10.1088/1742-6596/2716/1/012017*
17. *Junaidi F Fathona. 2017. "Analysis of Musi River Flow Velocity Distribution (Ampera Bridge Section to Kemaro Island)." Journal of Civil and Environmental Engineering 2 (3): 603–9.*
18. *Kangkong, Andi Muh. Alam, Sulha Sulha, and Umran Sarita. 2020. "ANALYSIS OF GABION STABILITY CALCULATION AND RAB (Case Study: Jl. Budi Utomo Baru - Simpang Tiga Dangga, Kendari City, Southeast Sulawesi)." STABILITY || Scientific Journal of Civil Engineering 8 (3): 159. https://doi.org/10.55679/jts.v8i3.16193.*
19. *Karim, ISA, et al. (2023). Study of landslide management on the Pedes River cliff in Brebes Regency.Journal of Civil Engineering, Diponegoro University.*
20. *Liswati, A. 2009. "Slope Stability Analysis in the Palu City Industrial Area." Tadulako University.*
21. *Murri, MM, et al. (2014). Slope stability analysis with gabion installation (Case study in Gajah Putih River, Surakarta). Civil Engineering Journal, Muhammadiyah University of Surakarta.*
22. *Murti, Angga Wisnu, Henny Pratiwi Adi, and M. Faiqun Niam. 2023. "Comparative analysis of slope stability reinforcement alternatives at the Semarang – Solo toll road rest area (Case Study of Rest Area Km. 456)." Rang Teknik Journal 6 (2): 231–41. https://doi.org/10.31869/rtj.v6i2.4207.*

23. *Nguyen, Q.T., Dias, D., & Le, V.D. (2022). Effect of dimension variables on the behavior of slopes stabilized by an integrated method combining gabion-faced geogrid-reinforced retaining wall with embedded piles. Soils and Foundations, 62 (3), 1005–1022. https://doi.org/10.1016/j.sandf.2022.04.003*

24. *Ruhiat, Dadang. 2022. "Implementation of Gumbel Probability Distribution for Analysis of Planned Rainfall Data." Teorema: Mathematical Theory and Research 7 (1): 213. https://doi.org/10.25157/teorema.v7i1.7137.*

25. *Sianturi, NM (2022). Analysis of the Bah Bolon River bank protection in North Sumatra using segmental concrete blocks with geosynthetic reinforcement. Final Project, University of North Sumatra.*

26. *Soegiyarto, I. (2019). Analysis of river bank reinforcement with gabions in Senganten Village, Gondang District, Bojonegoro Regency. Civil Engineering Journal.*

27. *Triatmodjo. 2008a. "APPLICATION OF Bambang Triatmodjo Beta Offset."*

28. *Triatmodjo, Bambang. 2008b. "Applied Hydrology." Beta Offset Yogyakarta, 0–358.*