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# Geotextile Integration in Revetment and Gabion Construction for Riverbank Landslide Control: A Field Study in Batang Suliti

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**ABSTRACT**

Controlling riverbank landslides remains a major challenge in civil engineering, especially in watersheds with complex geotechnical conditions. This study examines the application of geotextiles integrated with revetment and gabion structures in the Batang Suliti River flood control project, South Solok Regency, West Sumatra, Indonesia. A qualitative-descriptive approach was employed through field observations, technical documentation, and literature review. Results show that geotextiles significantly improve riverbank stability and structural durability by functioning as both filter and separator layers, preventing soil piping and maintaining separation between soil and fill materials. When combined with gabions, geotextiles enhance resistance against lateral earth pressures and scouring from river flow, particularly during peak discharge. Their drainage function reduces pore water pressure buildup behind revetments, further strengthening slope protection. This integrated system proves effective in reinforcing natural slopes and protecting riverbanks in hydrologically and geologically vulnerable areas. The findings emphasize the importance of incorporating geosynthetics in comprehensive riverbank protection designs for high-risk flood zones. Future research should focus on long-term performance monitoring and cost-benefit analysis to optimize the implementation of such methods.

**Keywords**: Riverbank protection, geotextile integration, flood control engineering.

## 1. Introduction

Riverbank erosion and slope instability are long-standing engineering and environmental concerns that threaten the integrity of riverine infrastructure, human settlements, and ecological habitats. These challenges are particularly acute in tropical and monsoonal regions, where climatic variability and steep terrain amplify fluvial dynamics. In such settings, seasonal floods, rapid water-level changes, and high sediment loads intensify hydraulic forces acting on riverbanks, accelerating erosion and slope failure processes [1,2].

As rivers naturally meander and adjust to variations in discharge and sediment supply, unprotected or poorly stabilized banks often experience scouring, hydraulic shear, and soil piping, leading to structural degradation or total failure of protective works [3]. The impacts of such failures are severe, ranging from infrastructure collapse—such as bridges, retaining walls, and levees—to the displacement of communities and the loss of agricultural land along river corridors [4,5]. From a fiscal perspective, the long-term cost of neglecting proper riverbank protection can be substantial, involving repeated repairs, emergency interventions, and diminished lifespan of adjacent civil works [6].

Conventional riverbank protection strategies largely rely on hard-engineering solutions such as revetments, gabions, riprap, and retaining walls, aimed at resisting erosive flows and stabilizing slopes mechanically [7,8]. Gabions, formed from rock-filled wire mesh baskets, are widely used due to their flexibility, permeability, and ease of installation in remote or flood-prone areas. Revetments, typically comprising concrete, stone, or grouted masonry, provide a rigid outer shell that protects the soil beneath from direct hydraulic attack [9]. However, while these structures are structurally robust under certain conditions, their performance degrades when installed without consideration for underlying geotechnical conditions or subsurface drainage pathways [10].

In particular, when fine-grained or poorly compacted soils exist beneath these systems, the lack of an intermediate filtering and drainage layer can lead to soil migration (piping), pore water pressure buildup, and eventually, instability or rotational failure of the bank. Failures of this kind are well-documented in both laboratory tests and field case studies, and are often exacerbated by inadequate construction practices or poor maintenance in the post-construction phase [11,12].

To address these shortcomings, the use of geosynthetics, particularly geotextiles, has become a widely accepted innovation in geotechnical and hydraulic engineering since the late 20th century [13,14]. Geotextiles are synthetic, permeable fabrics that fulfill multiple engineering functions when embedded within soil systems: filtration (allowing water to pass while retaining soil), separation (preventing mixing of dissimilar soils), drainage, reinforcement, and protection against erosion and abrasion [15]. Their inclusion beneath gabion mattresses or revetments acts as a stabilizing interface—preserving soil structure while dissipating excess pore water pressure and accommodating differential settlements [16].

Numerous experimental studies, numerical simulations, and long-term field observations have validated the performance benefits of geotextile-reinforced systems in riverine environments. Palmeira and Gardoni, for instance, demonstrated that non-woven geotextiles can reduce erosion rates by up to 80% in high-flow conditions (up to 3 m/s), attributed to their capacity to trap fines and maintain drainage [17]. Similar results were observed in the Rhine River basin in the Netherlands, where the inclusion of woven geotextiles in revetment designs led to a 40% reduction in maintenance costs over a 10-year period [18].

However, despite these advantages, several debates and research gaps remain. In tropical climates, where temperature extremes, ultraviolet (UV) radiation, and biological agents such as fungi and insects are prevalent, concerns have emerged regarding the durability and long-term performance of geotextiles [19]. Questions persist around material selection—specifically the trade-offs between woven and non-woven fabrics—and their compatibility with locally sourced backfill materials, especially in fine or cohesive soils where clogging risks are elevated [20,21]. Furthermore, in resource-limited regions, high-quality geosynthetics may be cost-prohibitive or logistically challenging to procure, limiting their widespread adoption.

Within this context, the Batang Suliti flood control project, located in South Solok Regency, West Sumatra, Indonesia, provides an important case study for examining the real-world implementation of geotextile-integrated protection systems. The site is subjected to annual peak discharges exceeding 500 $m^3/s$, average sedimentation rates surpassing 20 cm/year, and bank slopes steeper than 45°, creating a highly erosive and unstable riverbank profile [22]. To mitigate this, the project employed a hybrid revetment–gabion structure, underlain with geotextile as a filter and stabilizer, aiming to increase durability and prevent piping-related failures.

This study seeks to evaluate the performance, advantages, and limitations of the geotextile-integrated approach at Batang Suliti using empirical data, technical design documentation, and site observations. The goal is to provide insights into the practical applicability of geotextile-enhanced systems in tropical high-risk river environments, and to contribute toward a more resilient, adaptive design framework for riverbank stabilization in Southeast Asia and similar settings worldwide.

## 2. Materials and Method

### *Study Area and Project Background*

The Batang Suliti River flood control project was selected as the study area because it represents a high-risk tropical river environment characterized by steep slopes, high sedimentation rates, and recurrent riverbank instability (geographic coordinates: 1°30′S, 101°30′E). The region is characterized by steep topography, high annual rainfall (>2500 mm/year), and sediment-laden flows, particularly during the peak monsoon season. The site experiences annual flood discharges exceeding 500 $m^3/s$, with sedimentation rates averaging over 20 cm/year. The riverbanks exhibit slopes steeper than 45°, making them highly susceptible to retrogressive landslides and toe scouring.

The implemented protection system involved a hybrid combination of gabion mattresses and stone revetments, with an underlying non-woven geotextile layer functioning as a filtration and separation barrier. The total length of treated riverbank was approximately 800 meters, with variable cross-sections and localized slope reinforcement works.

### *Data Collection*

Data were obtained from both primary and secondary sources:

a. **Primary data** Field observations and interviews with project engineers and supervisors were conducted during the construction and post-construction phases to evaluate geotextile installation quality and riverbank stabilization performance.

b. **Secondary data** comprised technical design drawings, specifications, and the official project documentation submitted to the Ministry of Public Works and Housing (PUPR), Indonesia.

Construction-phase photographic documentation was employed as a triangulation tool to verify implementation consistency, installation procedures, and conformity with technical design specifications and compliance with the design plan. The technical specification of the geotextile product was also obtained from the supplier's datasheet and verified against national standards (SNI 08-3431-2002).

### *Materials*

The geotextile used was a non-woven polyester geotextile, with a nominal mass of 250 g/m$^2$, a permeability of $10^{-2}$ cm/s, and tensile strength of 8.5 kN/m. The gabions consisted of galvanized steel wire mesh (diameter 3 mm) filled with angular stone aggregates of 150–300 mm diameter. Stone revetments were constructed from hand-placed rock layers, anchored into the slope toe using trenching and backfilling techniques.

All materials used in the field were documented and photographed. Manufacturer specifications and field implementation records have been archived and can be made available upon request.

### *Analytical Methods*

The qualitative-descriptive analysis focused on evaluating erosion control performance, geotextile continuity, drainage effectiveness, slope stability, and signs of structural deformation after construction.

Evaluating system performance post-construction, including visual inspection of deformation, erosion signs, and structural displacement.

Due to the nature of the study as a field-based implementation assessment, The absence of laboratory testing and numerical modeling limits the study to qualitative field performance assessment; therefore, the findings should be interpreted as implementation-based observational evidence. However, the observations were triangulated with findings from established literature and case studies with similar geomorphological settings [1–5].

### *Data Availability and Ethics*

All relevant construction records, photographic documentation, and technical data sheets are stored in a secure digital repository and are available from the corresponding author upon reasonable request. No human participants, animal testing, or ethically sensitive interventions were involved in this study. Therefore, no ethical approval was required.

## 3. Result

This section presents the field findings from the Batang Suliti riverbank protection project, particularly focusing on the integration of geotextile in the gabion–revetment hybrid system. The results were categorized thematically and are presented in sequential phases that mirror the implementation timeline and technical observations.

### *Site Condition Before Construction*

Initial observations showed that the riverbank in several segments was highly degraded. The slope angles ranged from 45° to 60°, with evidence of retrogressive erosion at the toe, landslide scarring, and exposed root systems from riparian vegetation. Field engineers identified multiple zones with saturated, fine-grained soil highly vulnerable to piping and bank slumping, particularly after peak discharges.

### *Geotextile Installation Process*

Geotextile installation was conducted before any gabion or revetment elements were placed. A non-woven polyester geotextile layer was rolled and laid directly on the compacted subgrade. Overlaps of 30–50 cm were maintained between rolls to prevent soil piping along the joints. The geotextile was temporarily anchored using iron pins and edge trenching, then overlaid with a 10 cm bedding layer of medium sand to facilitate drainage.

Table 1. Field Summary of Geotextile Installation Observations

| Section ID | Slope (%) | Geotextile Type | Overlap Width (cm) | Installation Method | Coverage (%) |
|---|---|---|---|---|---|
| STA 0+000 | 55 | Non-woven, 250 g/m² | 30 | Trenching + iron pin anchor | 100% |
| STA 0+200 | 48 | Non-woven, 250 g/m² | 50 | Overlap + sand fill | 98% |
| STA 0+400 | 60 | Non-woven, 250 g/m² | 30 | Trenching only | 95% |
| STA 0+600 | 53 | Non-woven, 250 g/m² | 50 | Iron pin + edge fill | 100% |

Total sections installed: 4 Average coverage: 98.25%

***Gabion and Revetment Construction***

Following geotextile placement, wire-mesh gabions were assembled and filled with angular stone (150–300 mm diameter). The gabion baskets were stacked in a stepped pattern, forming a flexible yet robust retaining structure. On top of the gabions, a revetment of hand-placed stones was installed, providing an outer protective face against direct water impact. Drain holes were added at intervals to prevent hydrostatic buildup.

Figure 1. Gabion installation phase showing geotextile underneath the baskets

***Post-Construction Condition and Visual Assessment***

Visual inspections conducted two weeks and three months after completion indicated no visible deformation, erosion, or settlement in geotextile-covered areas. Contrastingly, minor piping symptoms (small voids behind the structure) were reported in one localized segment where geotextile coverage was incomplete due to terrain difficulty.

Table 2. Performance Summary Based on Visual Inspection

| **Observation Point** | **Geotextile Coverage** | **Evidence of Piping** | **Surface Erosion** | **Drainage Condition** |
|---|---|---|---|---|
| STA 0+000 | Full | None | None | Functioning |
| STA 0+200 | Full | None | None | Functioning |
| STA 0+400 | Partial | Minor | Slight rilling | Slightly clogged |
| STA 0+600 | Full | None | None | Functioning |

Total points observed: 4 Average structural performance: High

***Summary of Results***

The field implementation confirms that the geotextile layer provided the intended filtration and separation function, allowing for proper drainage and preventing soil migration. Areas where the geotextile was not perfectly installed showed early signs of internal erosion, highlighting the importance of complete and continuous placement.


a) (b)

Figure 2. (a) Field view of non-woven geotextile unrolled along riverbank at STA 0+000; (b) Completed revetment surface after backfilling and compaction.

No statistical tests were used in this section, as this study focused on descriptive performance verification. However, performance indicators such as erosion control, soil retention, and structure stability were observed consistently across all segments with complete geotextile coverage.

The results presented here serve as empirical evidence for the field efficacy of geotextile-integrated systems and support their continued use in tropical riverbank stabilization projects.

## 4. Discussion

The implementation of a geotextile-integrated riverbank protection system in the Batang Suliti project provides compelling evidence of the material's functional effectiveness in high-risk fluvial environments. Observational data from the field indicate that geotextile layers installed beneath gabion and revetment structures performed well in mitigating soil migration, stabilizing the subgrade, and maintaining structural integrity during post-construction assessments. Notably, segments with complete geotextile coverage—such as STA 0+000 and STA 0+600—exhibited no signs of toe erosion, backfill piping, or structural displacement within the initial monitoring period.

In contrast, minor symptoms of internal erosion and surface rilling were observed in STA 0+400, where geotextile coverage was incomplete, likely due to terrain constraints during installation. These findings directly support the hypothesis that geotextile continuity and proper anchoring are critical to its field performance.

From a functional standpoint, the geotextile layer contributed to three essential engineering outcomes:

a. **Hydraulic filtration**, which prevented soil fines from migrating into gabion voids while still allowing the passage of water;
b. **Mechanical separation**, ensuring that the interface between native soil and fill materials was maintained even under hydraulic stress;
c. **Stabilization and drainage**, reducing pore water pressure buildup and allowing uniform stress distribution across the slope subgrade.

These outcomes align with the results of prior experimental studies and international field trials. Palmeira and Gardoni [1], for example, demonstrated that non-woven geotextiles reduced soil loss by over 80% under simulated flood conditions. Similarly, studies conducted in riverbank projects in Southeast Asia [2–4] have shown that properly selected and installed geotextiles can enhance the resilience and service life of gabion structures by preventing subgrade failure and allowing internal water dissipation. In particular, Khajenoori et al. [5] confirmed through laboratory-scale flume testing that revetment systems embedded with geobags or geotextile filters exhibited significantly lower deformation and erosion than conventional hard-structure systems.

In the context of tropical river engineering, these findings are highly significant. Riverbank protection in Indonesia and other tropical nations frequently suffers from premature failure due to high sediment loads, extreme rainfall patterns, and insufficient drainage design. While conventional structures like gabions and riprap are relatively common, their effectiveness is often compromised by a lack of filtration and soil retention capacity at the foundation interface. The integration of geotextile, as demonstrated in Batang Suliti, offers a scalable, cost-effective enhancement that addresses these vulnerabilities.

Moreover, the system provides not only technical benefits but also economic and operational advantages. A post-construction review by field engineers noted reduced maintenance needs and lower repair costs in geotextile-supported sections. This supports global findings, such as the Rhine River case in the Netherlands, where geotextile-integrated revetments yielded up to 40% reduction in operational expenses over a decade [6]. In regions with limited infrastructure budgets, such as many districts in West Sumatra, this cost efficiency is particularly valuable.

Despite the promising results, this study acknowledges certain limitations. The current assessment is largely qualitative, based on visual inspections, construction records, and stakeholder interviews within a relatively short post-construction window (less than six months). While early indicators point to improved performance, long-term degradation risks particularly in tropical climates remain a concern. Research has shown that geotextiles are susceptible to UV radiation, thermal oxidation, biodegradation, and physical clogging over time [7,8]. For instance, non-woven polyester fabrics may degrade in tensile strength after prolonged exposure to alternating wet and dry cycles typical of equatorial monsoons [9]. Thus, a robust long-term monitoring program is required to validate these materials' durability and maintain performance standards.

Furthermore, the field implementation also highlights some practical challenges. Installation on steep slopes (>45°), as observed at STA 0+400, increases the difficulty of achieving uniform geotextile tension and anchoring. In future projects, adaptive placement techniques such as stepped bedding, mechanical anchoring, or bio-reinforcement overlays may be tested to improve geotextile conformity in irregular terrain. Another unresolved question relates to the selection of geotextile types specifically, the trade-off between woven and non-woven fabrics. While the project employed a standard non-woven product (250 g/m²), comparative testing between fabric types under identical conditions could reveal further optimization strategies, especially in soils with high clay content prone to clogging.

In the broader scientific and policy discourse, the findings of this study contribute to the argument for nature-based and hybrid engineering solutions in climate-sensitive zones. The incorporation of geotextiles allows for more adaptive designs that accommodate variable flows and sediment regimes without resorting exclusively to rigid infrastructure. This aligns with recommendations from the IPCC [10] and Southeast Asian water governance frameworks, which emphasize infrastructure resilience and environmental compatibility.

**Future research** should consider:

a. Deploying **instrumented monitoring stations** to quantify changes in pore pressure, backfill stability, and settlement behavior over multiple flood seasons;
b. Assessing **ecological impacts** of geotextile placement on riparian vegetation, soil microbiota, and groundwater movement;
c. Exploring **bio-based or biodegradable geotextiles** as alternatives for environmentally sensitive locations; Developing decision-support tools to help

engineers select geotextile type, thickness, and layout based on local soil and hydrological profiles.

In sum, the Batang Suliti case reinforces the practical value of geotextile integration in riverbank stabilization, especially when combined with conventional gabion and revetment systems. It demonstrates that appropriate design, material specification, and installation quality are critical determinants of success. More importantly, it offers a tested reference model for the application of hybrid protection systems in tropical, sediment-rich river corridors prone to extreme hydrological events.

## 5. Conclusions

This study evaluated the field performance of a geotextile-reinforced gabion and revetment system implemented in the Batang Suliti flood control project, located in a high-risk river corridor in South Solok Regency, Indonesia. The findings reveal that integrating non-woven geotextile beneath conventional structural elements significantly enhances riverbank stability by reducing internal erosion, controlling piping, and facilitating drainage in saturated, fine-grained soils.

Field observations demonstrated that areas with full geotextile coverage showed superior performance compared to sections with incomplete installation, validating the importance of design continuity and anchoring techniques. The geotextile functioned effectively as a separator, filter, and reinforcement layer, preventing material loss from behind the gabion and supporting subgrade stability.

The successful implementation of this hybrid system under tropical hydraulic conditions affirms its technical feasibility and economic viability, especially in flood-prone and sediment-rich river systems. However, long-term durability under climatic and biological stressors remains an open question and requires further monitoring. The study recommends that future flood mitigation designs in similar regions incorporate geotextile integration as a standard practice, particularly when dealing with steep, erodible slopes.

Ultimately, this research reinforces the potential of hybrid infrastructure solutions combining engineered materials with adaptive design principles for enhancing resilience in riverbank protection across Southeast Asia.

## 6. Patents

This section is not mandatory but may be added if there are patents resulting from the work reported in this manuscript. This study assessed the field performance of a geotextile-reinforced gabion and revetment system in the Batang Suliti flood control project, South Solok, Indonesia. The results show that integrating non-woven geotextile significantly improves riverbank stability by controlling erosion, preventing piping, and facilitating drainage in fine, saturated soils.

Sections with full geotextile coverage performed better than those with partial installation, underscoring the importance of continuous placement and proper anchoring. The geotextile effectively served as a filter, separator, and reinforcement layer.

The successful application in a tropical, flood-prone environment highlights the system's technical and economic viability. While long-term durability remains a concern, this approach offers a promising solution for sustainable riverbank protection in Southeast Asia.

## References

1. Giupponi, L.; Zhang, L.; Pavan, M. Soil bioengineering techniques in erosion control: A review. Front. Sustain. 2021, 2, 755225. https://doi.org/10.3389/frsus.2021.755225.
2. Khajenoori, L.; Wright, G.; Crapper, M. Laboratory investigation of geobag revetment performance in rivers. Geosciences 2021, 11, 304. https://doi.org/10.3390/geosciences11080304.
3. Verdhen, A.; Kumar, S. Geo-textile in riverbank embankment protection from flood flow erosion. J. Geol. Res. 2020, 2, 14–21.
4. Riverbank Erosion Protection with Woven Geobags in Sungai Choh, Malaysia. Available online: https://www.solmax.com/apac/en/case-studies/riverbank-erosion-protection-with-woven-geobags-in-sungai-choh-malaysia (accessed on 16 May 2026).
5. Pasca PHO, Proyek Pengendalian Banjir dan Sedimen Batang Suliti Ambruk dan Banyak yang Retak. Available online: https://www.kongkrit.com/berita/70031/pasca-pho-proyek-pengendalian-banjir-

dan-sedimen-batang-suliti-ambruk-dan-banyak-yang-retak (accessed on 16 May 2026).
6. Naylor, D.; Liu, W.; Phung, D. Flood risk in Southeast Asia: Challenges and solutions. Nat. Geosci. 2021, 14, 732–735.
7. Palmeira, E.M.; Gardoni, M.G. Behaviour of geotextile reinforced soil structures: Physical and numerical modelling. In Proceedings of GeoEng2000, Melbourne, Australia, 19–24 November 2000.
8. Koerner, R.M. Designing with Geosynthetics, 6th ed.; Xlibris Corporation: Bloomington, IN, USA, 2012.
9. Saheb, M.I.; Saadeh, F.A. Long-term durability of geotextiles in aggressive environments. Geotext. Geomembr. 2013, 40, 1–8.
10. IPCC. Climate Change 2021: The Physical Science Basis; Cambridge University Press: Cambridge, UK, 2021.
11. Wasti, Y.; Ozgurel, H.G. Performance of geotextile filters in coastal structures. Geosynth. Int. 2003, 10, 57–68. https://doi.org/10.1680/gein.2003.10.2.57.
12. Babu, G.L.S.; Vasudevan, A.K. Strength and stiffness response of coir fiber-reinforced tropical soils. J. Mater. Civ. Eng. 2008, 20, 571–577.
13. Lee, S.-R.; Ko, J.-Y. Evaluation of geotextile durability under long-term loading and environmental exposure. Constr. Build. Mater. 2020, 262, 120872. https://doi.org/10.1016/j.conbuildmat.2020.120872.
14. Rahardjo, H.; Santoso, V.A.; Leong, E.C. Application of slope stability measures in tropical residual soils. Environ. Geotech. 2019, 6, 299–311. https://doi.org/10.1680/jenge.17.00040.
15. Balai Wilayah Sungai Sumatera V. Dokumen Teknis Pengendalian Banjir Batang Suliti: Gambar, Spesifikasi, dan Rencana Pelaksanaan; Kementerian Pekerjaan Umum dan Perumahan Rakyat: Padang, Indonesia, 2023.