

# Fin Gabions: A Solution for River Bend Stability

Mas Mera, Yolanda Wulandari, Junaidi, Februarman\*

Department of Civil Engineering, Universitas Andalas, Indonesia

Received December 19, 2024; Revised February 5, 2025; Accepted March 17, 2025

## Cite This Paper in the Following Citation Styles

(a): [1] Mas Mera, Yolanda Wulandari, Junaidi, Februarman, "Fin Gabions: A Solution for River Bend Stability," *Civil Engineering and Architecture*, Vol. 13, No. 3, pp. 1668 - 1676, 2025. DOI: 10.13189/cea.2025.130317.

(b): Mas Mera, Yolanda Wulandari, Junaidi, Februarman (2025). *Fin Gabions: A Solution for River Bend Stability*. *Civil Engineering and Architecture*, 13(3), 1668 - 1676. DOI: 10.13189/cea.2025.130317.

Copyright©2025 by authors, all rights reserved. Authors agree that this article remains permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

**Abstract** River bends are susceptible to sedimentation near the inner bend and erosion near the outer bend due to uneven velocity distribution. This study investigates the effectiveness of fin gabions in mitigating these issues through physical modeling. Five experimental setups were conducted in a laboratory flume: (1) Baseline: A leveled sand bed with regular gabions placed on the outer bend; (2) Lower Fin Gabion: A fin gabion embedded at the lower part of the bend. This setup addresses topography issues encountered in post-simulation of setup 1; (3) Mid-Bend Fin Gabion: An additional fin gabion embedded at the middle of the bend. Topography challenges in post-simulation of setup 2 necessitated this configuration; (4) Reinstalled Gabions: Reinstallation of all gabions from setup 3. This setup is implemented to ensure that the gabion configuration in setup 3 can maintain the baseline without changing significantly; and (5) Surface-Placed Gabions: All gabions placed on the surface without embedding. This setup aims to ensure that the fin gabions are firmly embedded. Results demonstrate that the fin gabion configurations, especially setup 3, significantly reduced sedimentation near the inner bend by up to 72%. This reduction led to a more uniform flow distribution, mitigating erosion at the outer bend. The findings highlight the potential of fin gabions as an effective solution for enhancing river bend stability.

**Keywords** Fin Gabion, Erosion, Sedimentation, Inner Bend, Outer Bend

---

## 1. Introduction

River bends are prone to sedimentation near the inner

bend and erosion near the outer bend due to uneven velocity distribution [1]. The higher velocity near the outer bend leads to erosion and potential bank collapse [2]. Similar issues can arise around bridge pillars [3].

While rainfall can exacerbate erosion, especially during extreme events, the most severe erosion often occurs at the ends of the bend [4]. Bank protection structures like gabions are particularly vulnerable at these locations, with the lower end experiencing more rapid damage [5]. Gabions are often chosen due to their economic efficiency and effectiveness [6, 7]. In addition to their role in bank protection, gabions are also employed as weir structures [8].

Conversely, the lower velocity near the inner bend promotes sedimentation. The severity of both sedimentation and erosion is influenced by the bend angle, with sharper bends leading to more pronounced effects. In sloping areas, factors like rainfall, topography, land use, and soil type also contribute to sedimentation [9-11].

The combined impact of these factors can lead to the failure of gabion structures [2]. While gabions are commonly used for bank protection, Hasan and Toda explored the use of groins in meandering rivers [12]. Numerical simulations indicated that cross-bar groins, extending from the bank to the river's mid-channel, can inadvertently increase erosion risk.

This research objective is to control sedimentation near the inner bend of a flume bend by utilizing fin gabions attached to regular gabions on the outer bend. While both types of gabions have identical dimensions, their distinct placements within the flume result in different functions. The hypothesis is that fin gabions can effectively alter the flow velocity distribution, shifting it from the outer bend towards the inner bend. This present research employs physical modeling to simulate sedimentation and erosion

processes at the inner and outer bends of a flume bend and evaluate the effectiveness of fin gabions as a mitigation strategy. This outcome is consistent with the SDGs (Sustainable Development Goals), emphasizing the need for robust water infrastructure.

Figure 1 shows a river bend reinforced with gabions on both embankments. However, the absence of gabion fins results in uneven velocity distribution, leading to visible erosion near the outer bend and sedimentation near the inner bend after the flood (Figure 1B).

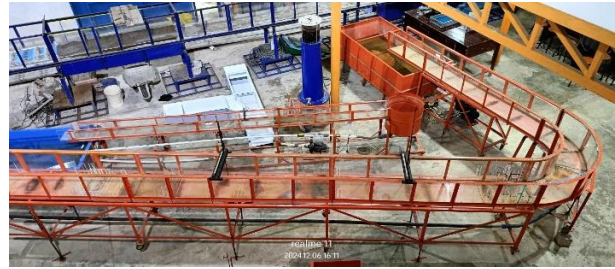


**Figure 1.** River bend conditions during (top) and after (bottom) the flood

## 2. Materials and Methods

### 2.1. Experimental Setup

A laboratory flume with a gross width of 40 cm and a height of 40 cm was used for the experiments. The net channel width was 38 cm after accounting for the 1 cm thick flume walls. The curved section of the flume had an outer wall radius of 98 cm and an inner wall radius of 60 cm. The outer and inner bend lengths were 206 cm and 125 cm, respectively. Straight channel sections of 217 cm and 80 cm preceded and followed the bend, respectively. The flume can be seen in Figure 2. The curved section was divided into three equal parts: upper, middle, and lower, as illustrated in Figure 3.



**Figure 2.** The flume used in this study

### 2.2. Materials

Sand sourced from the Batang Kuranji riverbed in Padang, West Sumatra, was used as the bed material. Gravel with a diameter range of 1.5 to 2 cm, also from the Batang Kuranji riverbed, was used as the filler material for the gabions. The gravel size exceeded the wire mesh hole diameter [13, 14]. This approach differs from previous studies that utilized geo-polymer materials [15] and soft materials [16] as gabion fillers, or geogrids for gabion wall construction [17].

### 2.3. Gabion Installation

Regular gabions, measuring 10 cm × 5 cm × 5 cm, were installed along the 206 cm outer bend. These gabions were constructed using 1.6 mm diameter concrete steel wire with a 1.25 cm × 1.25 cm mesh size. A conventional stack-and-pair configuration was employed to resist lateral forces, diverging from the interlocking configuration [18].

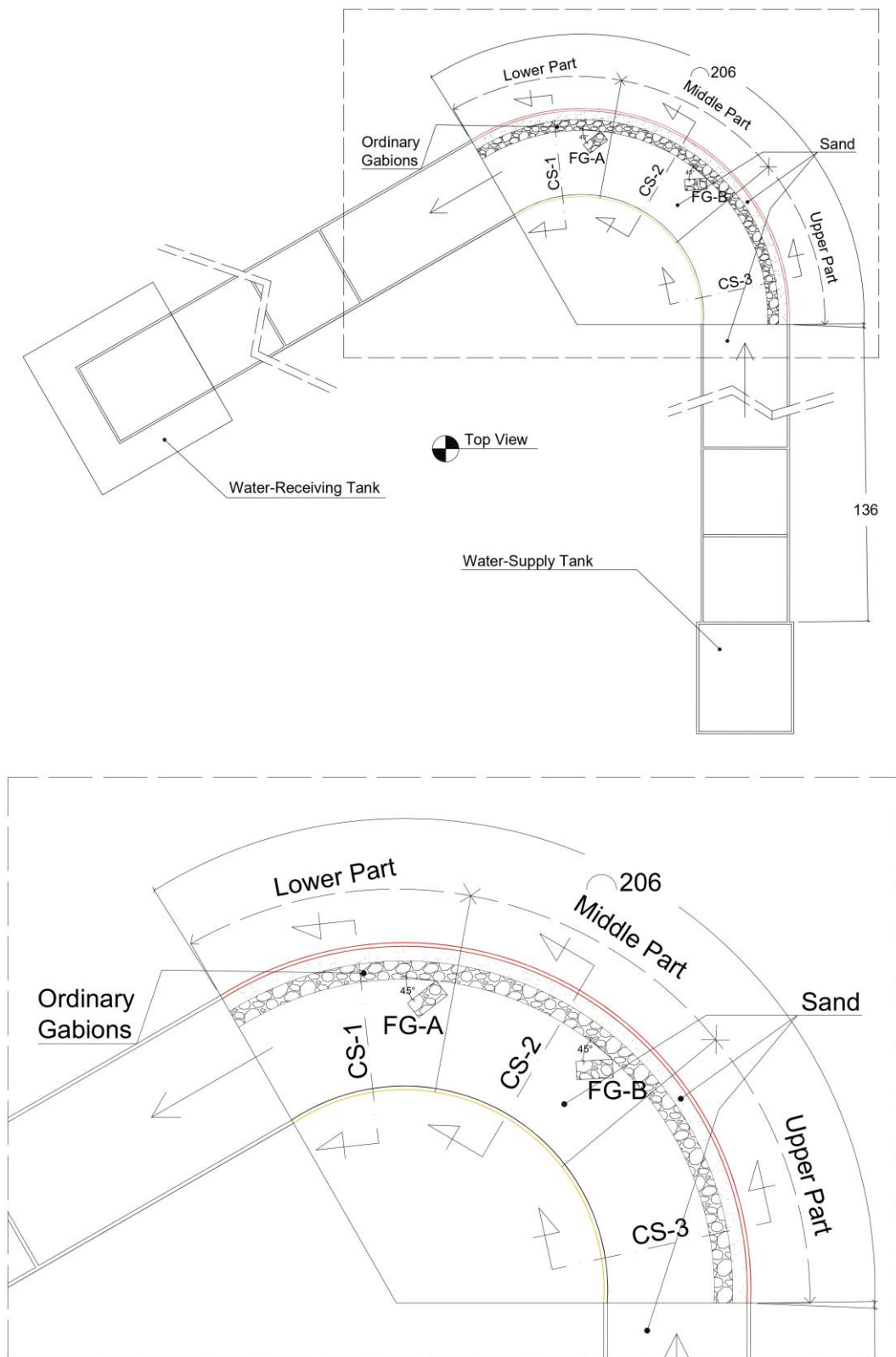
### 2.4. Experimental Procedure

Five experimental setups were conducted:

1. **Baseline:** A 10 cm thick sand bed was leveled, and regular gabions were placed on the outer bend.
2. **Lower Fin Gabion:** A fin gabion (FG-A) was embedded 2 cm into the sand bed at a distance of 63 cm from the downstream end of the bend.
3. **Mid-Bend Fin Gabion:** An additional fin gabion (FG-B) was embedded 122 cm from the lower end of the outer bend.
4. **Reinstalled Gabions:** The gabions from Setup 3 were reinstalled on a leveled sand bed.
5. **Surface-Placed Gabions:** The gabions from Setup 4 were placed on the sand surface without embedding.

In all setups, the gabions were placed 5 cm from the flume wall, and the gap was filled with sand, reducing the effective channel width to 28 cm. The flow depth was maintained at a constant level.

The bed topography was measured before and after each experiment to assess the extent of sedimentation and erosion. The effectiveness of the fin gabions in controlling sedimentation and modifying flow patterns was evaluated by comparing the results from the different setups. A brief explanation of the model setups can be seen in Table 1.



**Figure 3.** Top view sketch of the experimental flume, highlighting the upper, middle, and lower sections. The locations of ordinary gabions, Fin-Gabion A (FG-A), and Fin-Gabion B (FG-B) are indicated. Cross-sections 1 (CS-1), 2 (CS-2), and 3 (CS-3) represent the lower, middle, and upper parts of the bend, respectively

**Table 1.** Specific data of Column/Row

Setup	Bed surface	Regular Gabions	Fin Gabions
1	Leveled	Place simply on the bed surface in the outer bend	-
2	As in the final state of setup 1	As in the final state of setup 1	Immerse its base next to the regular gabion in the lower part of the bend.
3	As in the final state of setup 2	As in the final state of setup 2	Add another one and immerse its base next to the regular gabion in the middle part of the bend
4	Leveled	Place simply on the bed surface in the outer bend	Immerse their base next to the regular gabion. One is in the lower part of the bend, and the other in the middle.
5	Leveled	Place simply on the bed surface in the outer bend	Place simply on the bed surface next to the regular gabion. One is in the lower part of the bend, and the other in the middle.

## 2.5. Dynamic Similitude

To ensure a model accurately represents its real-world counterpart (the prototype), dynamic similitude between the two is essential. This requires both geometric and kinematic similarity [19].

Geometric similarity is established by comparing the dimensions of the prototype and the model. A prototype gabion measures 200 cm in length, 100 cm in width, and 100 cm in height. At a 1:20 scale, the corresponding model gabion measures 10 cm long, 5 cm wide, and 5 cm high. Our laboratory's flume, which includes a bend, has fixed dimensions, including width and radius. Only the prototype dimensions can be adjusted. For instance, if the effective width of the model channel is 28 cm, the effective width of the prototype becomes  $28 \text{ cm} \times 20 = 560 \text{ cm}$ . Consequently, investigating the effects of scaling on erosion and sedimentation is currently challenging in our laboratory.

Kinematic similarity is achieved by equating the Froude number between the prototype and the model. This leads to the following relationships: the ratio of flow velocity in the prototype ( $v_p$ ) to that in the model [19],

$$v_p = v_m \sqrt{20} \quad (1)$$

the ratio of flow rate in the prototype ( $Q_p$ ) to that in the model ( $Q_m$ ) [19],

$$Q_p = Q_m (20)^{2.5} \quad (2)$$

and the ratio of flow time in the prototype ( $t_p$ ) to that in the model ( $t_m$ ) [19],

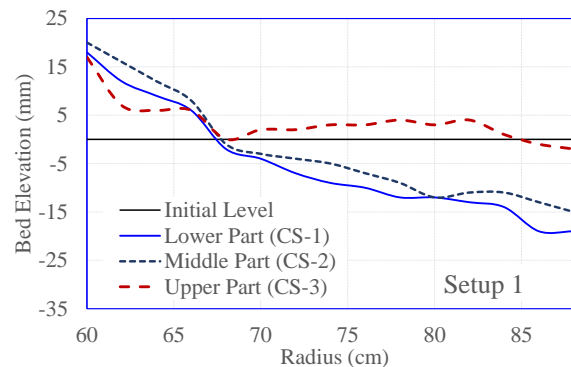
$$t_p = t_m \sqrt{20} \quad (3)$$

## 3. Results and Discussion

### 3.1. Setup 1: Baseline Condition

This study focuses on a single, normal discharge of 2.17 L/s, constrained by laboratory equipment limitations. The simulation was terminated when the first signs of gabion instability were observed in Setup-1, which occurred after 15 minutes and 50 seconds. This duration was subsequently used as the simulation time for subsequent setups. If the simulation time in the subsequent setup is exceeded and the gabion performance in this subsequent setup still surpasses that of setup 1, then the subsequent setup is considered superior to setup 1, and vice versa.

The initial simulation, Setup 1, aimed to establish a baseline condition without any intervention. As expected, significant sedimentation occurred near the inner bend, while erosion prevailed near the outer bend. The sand surface elevation increased by 20 mm near the inner bend and decreased by 19 mm near the outer bend (Figure 4). This uneven sedimentation and erosion led to a reduction in the effective channel width and the eventual failure of the regular gabions (Figure 5).



**Figure 4.** Bed elevation profile after the initial simulation (Setup 1), showing sedimentation near the inner bend and erosion near the outer bend in all three sections of the bend



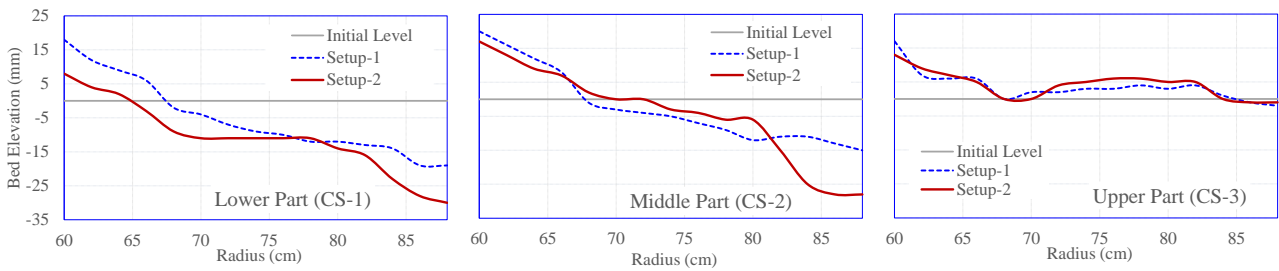
**Figure 5.** Flume bed topography after the initial simulation (Setup 1), showing the development of a sediment deposit near the inner bend and erosion near the outer bend in all three sections of the bend

### 3.2. Setup 2: Lower Fin Gabion

To mitigate the observed issues, a fin gabion (FG-A) was installed at the lower part of the bend in Setup 2. While the fin gabion partially alleviated the erosion at the lower end, it did not fully prevent sedimentation and erosion in the middle and upper parts of the bend. Notably, significant erosion occurred at the downstream end of the fin gabion itself (Figures 6 and 7).

### 3.3. Setup 3: Mid-Bend Fin Gabion

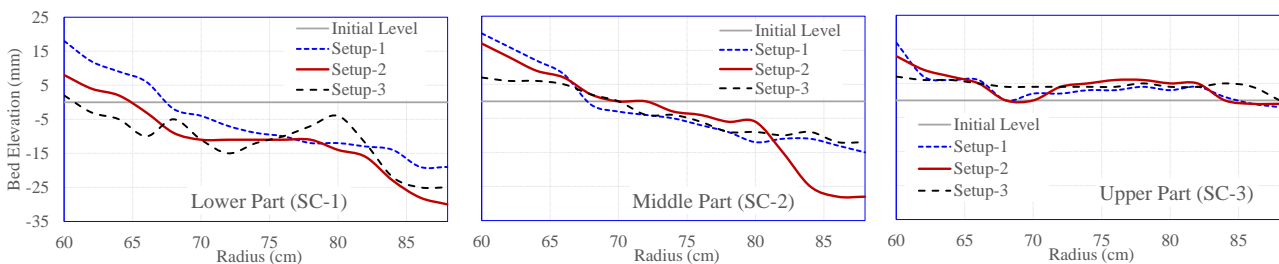
In Setup 3, an additional fin gabion (FG-B) was installed at the middle part of the bend. This configuration resulted in a more stable bed profile, with reduced sedimentation and erosion in all parts of the bend. However, erosion still persisted upstream of FG-A, indicating a need for further refinement (Figures 8 and 9).



**Figure 6.** Comparison of flume bed topography after Setup 1 (baseline) and Setup 2 (lower fin gabion), highlighting the impact of the fin gabion on sedimentation and erosion patterns



**Figure 7.** Post-simulation (Setup 2) condition of the regular gabions and fin gabion at the lower part of the bend, viewed from upstream and downstream



**Figure 8.** Comparison of flume bed topography after the baseline simulation (Setup 1), the lower fin gabion installation (Setup 2), and the additional mid-bend fin gabion installation (Setup 3)



**Figure 9.** Sedimentation patterns observed upstream and downstream of Fin Gabion A, highlighting the deposition of sediment downstream of the structure



**Figure 10.** Setup-4 before simulation (photo viewed from down-stream but sketch viewed from upstream)

### 3.4. Setup 4: Reinstalled Gabions with Embedded Fins

To further enhance the stability of the gabion structures, the fin gabions were embedded into the sand bed in Setup 4 (Figure 10). This configuration proved highly effective in controlling sedimentation and erosion. The sedimentation near the inner bend was reduced by 72% compared to the baseline condition. The flow velocity distribution was also significantly altered, leading to a more uniform flow pattern (Figures 11 and 12).

### 3.5. Setup 5: Surface-Placed Gabions

Finally, Setup 5 assessed the importance of embedding the fin gabions. When the fin gabions were simply placed on the sand surface without embedding, they experienced significant subsidence and shifting due to the underlying erosion. This highlights the crucial role of proper installation in ensuring the long-term stability of the gabion structures (Figures 13 and 14).

Overall, the results demonstrate the effectiveness of fin gabions in mitigating sedimentation and erosion at river bends. By carefully designing and installing fin gabions, it is possible to achieve significant improvements in river

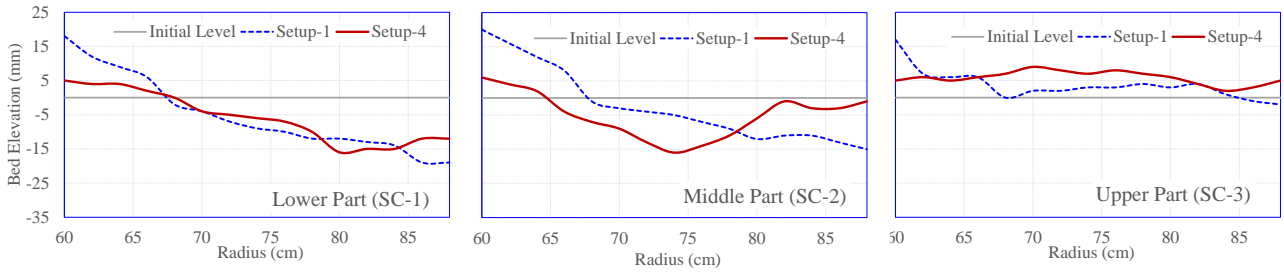
stability and reduce the need for frequent maintenance.

### 3.6. Dynamic Similitude

Due to the current limitations of our laboratory's pump, we are unable to vary the discharge. The existing discharge, considered a normal discharge, is 2.17 L/s for the model, which corresponds to a prototype discharge of 3,882 m<sup>3</sup>/s. With a flow depth of 1 cm before the bend, the wetted area is 1 cm × 28 cm = 28 cm<sup>2</sup>. Dividing the model discharge (2.17 L/s) by the wetted area yields a model velocity of 0.78 m/s. This velocity is sufficient to transport fine gravel, as velocities at or above 0.76 m/s have been shown to do so [20]. This model velocity corresponds to a prototype velocity of 3.47 m/s. Given a water depth of 1 cm above the downstream spillway, the Froude number ( $Fr$ ) is calculated to be

$$Fr = \frac{v}{\sqrt{gh}} = \frac{0.78 \text{ m/s}}{\sqrt{9.807 \text{ m/s}^2 \times 1 \text{ cm}}} = 2.47 \quad (4)$$

This Froude number applies to both the model and the prototype.



**Figure 11.** Comparison of the topography formed at the flume bed after the simulations are complete in setup-1 and 4 at the lower, middle and upper parts of the bend



**Figure 12.** Post-simulation topography in Setup 4: Upstream (left) and downstream (right) perspectives



**Figure 13.** Setup-5 before simulation (photo and sketch viewed from upstream)



**Figure 14.** Post-simulation topography in Setup 4: Upstream (left) and downstream (right) perspectives

## 4. Conclusions

The physical model experiments demonstrated that regular gabions, when employed as bank reinforcement on the outer bend, are susceptible to subsidence. This vulnerability stems from sedimentation near the inner bend, which results in increased flow velocity and erosion near the outer bend. To mitigate these issues, the integration of fin gabions, anchored to regular gabions in the downstream and middle sections of the bend, was proposed. Simulation results indicate that fin gabions can effectively reduce sedimentation near the inner bend by up to 72%, thereby dispersing flow velocity and minimizing erosion near the outer bend.

## Acknowledgements

Acknowledgments are given to the Civil Engineering Department, Faculty of Engineering, Universitas Andalas for providing facilities for this research.

## REFERENCES

- [1] Z. Akbar, G. A. Pasha, N. Tanaka, U. Ghani, H. Hamidifar. "Reducing bed scour in meandering channel bends using spur dikes", *International Journal of Sediment Research*, Vol.39, No.2, 243-256. 2024, doi: 10.1016/j.ijsrc.2024.01.001
- [2] Z. Badpa, Z. Heidari, M. Fazli. "Experimental study of the effect of the length of gabion spur dike on flow pattern and topography of bed in a channel with moveable bed". *Iranian Journal of Soil and Water Research*, Vol.49, No.4, 891-905, 2018, doi: 10.22059/ijswr.2017.243897.667775
- [3] M. T. Shukri, J. K. Ahmed, O. Muhie. "Experimental study of local scour downstream of cylindrical bridge piers". *Jordan Journal of Civil Engineering (JJCE)*, Vol.11, No.3, 363-372, 2017, <https://jjce.just.edu.jo/Download.ashx?f=FTPstmvL3%2bYgmt9RWbuEDQDiS9UeQCD2zjH5%2f5CMqms%3d>
- [4] R. L. Anderson, K. M. Rowntree, J. L. Le Roux. "An interrogation of research on the influence of rainfall on gully erosion", *Catena*, Vol.206, No.2, 105482, 2021, doi: 10.1016/j.catena.2021.105482
- [5] R. Cajka, K. Burkovic, Z. Neuwirthova, P. Mynarcik, D. Bujdos. "Experimental measuring of the load-bearing capacity of wire hooks and bends used in gabion retaining walls", *International Journal of Geomate*, Vol.25, No.111, 170-176, 2023, doi: 10.21660/2023.111.s8672
- [6] G. C. Chikute, I. P. Sonar. "Techno-economical analysis of gabion retaining wall against conventional retaining walls", *International Research Journal of Engineering and Technology (IRJET)*, Vol.6, No.8, 1161-1167, 2019. <https://www.irjet.net/archives/V6/i8/IRJET-V6I8217.pdf>
- [7] T. Craswell, S. Akib. "Reducing bridge pier scour using gabion mattresses filled with recycled and alternative materials", *Advances in Engineering*, Vol.1, No.2, 188-210, 2020, doi: 10.3390/eng1020013
- [8] A. Khamid, S. I. Wahyudi, Soedarsono. "Analysis of stability safety factors of gabion weir models against the wall and water level variation", *Civil Engineering and Architecture*, Vol.11, No.3, 1107-1124, 2023, doi: 10.13189/cea.2023.110301
- [9] G. Battista, F. Schlunegger, P. Burlando, P. Molnar. "Sediment supply effects in hydrology-sediment modeling of an Alpine Basin", *Water Resources Research*, Vol.58, No.7, 1-20, 2022, doi: 10.1029/2020WR029408
- [10] N. Bekin, Y. Prois, J. B. Laronne, R. Egozi. "The fuzzy effect of soil conservation practices on runoff and sediment yield from agricultural lands at the catchment scale", *Catena*, Vol.207, 105710, 2021, doi: 10.1016/j.catena.2021.105710
- [11] C. Beveridge, E. Istanbuluoglu, C. Bandaragoda, A. M. Pfeiffer. "A channel network model for sediment dynamics over watershed management time scales", *Journal of Advances in Modeling Earth System (JAMES)*, Vol.12, No.6, 1-29, 2020, doi: 10.1029/2019MS001852
- [12] M. Z. Hasan, Y. Toda. "Evaluation of groynes installation at the vulnerable bank of a braided river", *Journal of JSCE*, Vol.12, No.2, 23-16021, 2024, doi: 10.2208/journalofjsce.23-16021
- [13] G-L. Yang, Z-Z. Liu, G-L. Xu, X-J. Huang. "Protection technology and applications of gabion", *Proceeding of International Symposium on Geoenvironmental Engineering*, Hangzhou, China, Sep. 8-10, 2009, [https://link.springer.com/chapter/10.1007/978-3-642-04460-1\\_120](https://link.springer.com/chapter/10.1007/978-3-642-04460-1_120)
- [14] D. Chaychuk. "The use of gabions and reno mattresses in river and stream rehabilitation", *Stormwater Industry Association 2005 Regional Conference*, Port Macquarie, NSW, Apr. 1-19, 2005. <https://www.scribd.com/document/228710837/Maccafferri-the-Use-of-Gabions>
- [15] S. Marathe, S. Akhila, I. R. Mithanthaya, N. B. S. Rao. "Geo-polymer sea sand cubes filled gabions", *Materialstoday: Proceeding*, Vol.18, No.1, 14-18, 2023, doi: 10.1016/j.matpr.2023.04.372
- [16] P. K. Jayasree. *Performance of Gabion Faced Reinforced Earth Retaining Walls*. PhD Thesis, Cochin University of Science and Technology, India, 294p, 2008, <https://dyuthi.cusat.ac.in/jspui/bitstream/purl/2821/1/Dyuthi-T0841.pdf>
- [17] S. Saravanapriya. "Experimental investigation on improvement in strength characteristics of gabion wall", *International Journal of Civil Engineering and Technology (IJCIET)*, Vol.9, No.9, 628-641, 2018, [https://iaeme.com/MasterAdmin/Journal\\_uploads/IJCIET/VOLUME\\_9\\_ISSUE\\_9/IJCIET\\_09\\_09\\_061.pdf](https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_9_ISSUE_9/IJCIET_09_09_061.pdf)
- [18] M. Ramli, T. J. R. Karasu, E. T. Dawood. "The stability of gabion walls for earth retaining structures", *Alexandria Engineering Journal*, Vol.52, No.4, 705-710, 2013, doi: 10.1016/j.aej.2013.07.005
- [19] M. Mera. *Mekanika Fluida Rekayasa Sipil, Edisi Kedua (Fluid Mechanics in Civil Engineering, Second Edition)*, Andalas University Press, 236p, Padang, 2020, ISBN: 978-623-7763-47-5.

- [20] M. Mera. *Hidrolika Saluran-Terbuka (Open-Channel Hydraulics)*, CV. Ferila, Padang, 210p, 2010, ISBN: 978-602-9081-03-9