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Analysis Stability of Gabion Weir Design for Raw Water (A Case Study of Tidal Floods in Kawunganten Central Java)

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ABSTRACK

Global warming followed by climate change has become a new disaster in the world. One of the impacts of climate change that can be clearly seen is the rise of sea water to the land surface causing tidal floods in Cilacap Regency, Central Java Province. Research on Bronjong Dams as an appropriate alternative technology is the first step to overcome the problem of tidal flood mitigation and as a raw water filter. Research into planning the design of this Gabion Dam to handle tidal floods and as a filter to be used for raw water located at the mouth of the Parit River. The method used is a quantitative method by carrying out prototype testing to justify field conditions by handling close results. The research analysis technique begins with collecting primary data and secondary data. The design of the Gabion weir models as a filter included three types of weir testing models namely type 1 trapezoidal model, type 2 beam model, and type 3 combination model. The material, geometry and dimensions of the experimental prototype are a reduction of the real problem conditions in the field. The results of the observation analysis of the Gabion weirs have obtained the average elevation of the water, MAR = 100 cm, MAB 600 cm, MAN = 450 cm, the elevation of the MAB upstream of the weir =650 cm, the elevation of the center of the weir = 445 cm, the downstream weir MAB = 410 cm, the measured flow velocity upstream of the weir 7.5 l/s, center 7.5 l/s, downstream 6.0 l/s and upstream temperature 31°C, center 30.3°C, 30°C, clean downstream water conditions. The results of the study represent a function of the elevation of the flood water level both upstream and downstream which are through the Gabion Weirs with several thicknesses as raw water filters.

Keywords: Stability Safety Factors, Gabion Weir Models, Water Level variation.

INTRODUCTION

There has been a noticeable rise in the number of reported flooding events worldwide in recent years. In dam spillways, gabion structures provide one method of flood prevention. The computer modeler faces an additional hurdle with these kinds of structures since flow through the porous gabions needs to be simulated (Reeve et al., 2019). The latest global catastrophe is caused by climate change and global warming. The rise in sea level, which causes floods and tidal floods, is one of the effects of climate change that is readily apparent (Zainuri et al., 2022);(Wahyudi et al., 2019). The flood discharge, water channel hydraulics, water reservoir volume, and the suitable pump capacity must all be determined through analysis (Wahyudi et al., 2017).

Based on the above facts, one alternative to do is how to build a weir as a flood control reservoir in the rainy season and additionally can be efficiently used in the dry season (Huang et al., 2018). The availability of the gabion weirs is expected to reduce flood disasters in coastal areas and will indirectly improve the standard of living of the local community.

In order for the weir, one of the key elements in the design planning project for the gabion weir, to be able to survive for a long time, it must be designed and constructed as much as feasible. One crucial need for ensuring the longevity of the weir and its capacity to increase the water level that flows during floods is that the weir created must comply with the stability standards. A gabion weir's permeability allows substances and aquatic life to pass through it, making it more environmentally friendly than an impermeable weir. Additionally, gabion weirs provide a low-afflux alternative design that could be used to reduce flash floods (Shariq et al., 2020). Weir stability is a phrase used to describe a weir's capacity to withstand internal and external stresses, including overturning, shifting, collapse, and external forces brought on by earthquakes. It indicates that the weir is in great working order and may be utilized as a weir.

Research on the Gabion weirs as a reasonable alternative to appropriate technology constitutes the first appropriate step to address the problem of tidal-flood mitigation and as a raw water filter. For many different objectives, including diversion works, river training, soil stabilization, and water delivery schemes, gabions are used to build weirs (Brunet et al., 2005). The use of Gabion weirs in the modern era for irrigation on agricultural land during the dry season, floods, tidal-waves and filters is the first step to address the problem of controlling estuary river water to irrigate rice fields and raw water to contribute as a parameter of the planning of the Gabion weirs as a device for addressing the problem of tidal-floods (Rahma et al., 2019); (Rudiarto et al., 2020). Structures like gabion weirs, which can be designed as broad crested weirs, are suitable for reducing flash floods with little harm to the aquatic ecosystem (Mohammadpour et al., 2013).

This study looks at the water elevation in four different Gabion weir model scenarios as a weir to raise the water level and filter. In testing the prototype utilizing an open circuit channel at the Sultan Agung Islamic University's hydraulics lab in Semarang, research on the proper and appropriate form of the cocktail model was typically needed. This was performed by simulating 3 types of Gabion weirs, namely by testing the filter level, elevation and safety against vertical and horizontal forces (Salmasi & Sattari, 2017).

METHOD

This study uses a quantitative method with a weir, the test is in the form of a prototype. The research analysis technique begins with primary data collection including field observation data and hydraulics data. While secondary data was obtained from the results of previous analysis and literature review. The research flowchart can be seen in Figure 1.

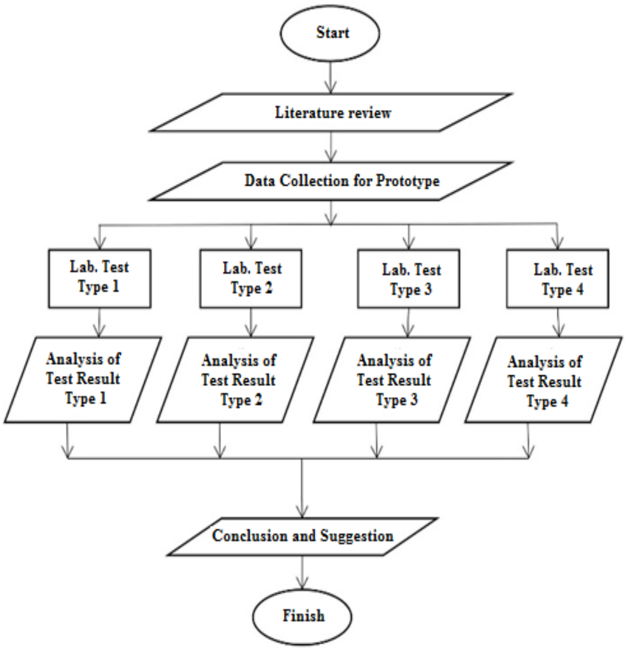


Figure 1. Research Methodology Flow Chart

The experimental material was chosen because it is easy to obtain in the field. The geometric shapes were selected in 3 scenarios according to the guidelines for water structures in Indonesia. While the dimensions of the prototype are made based on non-dimensional analysis with a half dimension reduction of the real construction. The design of the gabion weir model as a filter is 3 types of weir testing model, namely type I Beam model, type 2 Beam with inclined upstream, type 3 Trapezoidal model and model type 4 Trapezoid and Geotextile. A gabion weir made of 4-5 cm long pieces of sandstone and 1-2 cm thick gabion wire is used as a filter. Using a flow velocity monitoring equipment, the gabion weir was tested as a filter. Utilizing a diver and a piezometer, a current meter is used to measure the water's elevation.

RESULT AND DISCUSION

The design of the Gabion weirs as a filter and to regulate water elevation, with four test scenario models, namely type 1 Gabion Weir in the form of Beams, with gravel material, type 2 Gabion Weir in the form of inclined upstream beams with gravel, type 3 Gabion Weir in a trapezoidal shape with gravel, and type 4 Gabion Weir with trapezoidal shape with gravel + geotextile material. / In testing the gabion weir as a filter, the current meter was used to adjust the elevation, while the diver and piezometer were used to monitor the elevation.

The analysis was carried out based on laboratory test observation data and hydraulic review.

Model 1: the Gabion Beam Weir Model, can be seen in Figure 3

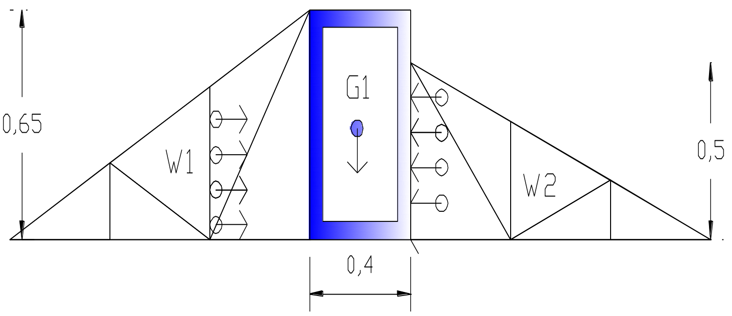


Figure 2 Model 1 Beam Gabion Weir

Overturning stability= $\frac{\Sigma MT}{\Sigma MG}$ Shear Stability= $\frac{fx\Sigma V}{\Sigma h}$
Overturning Stability and Shear Stability Model 1 Beam Gabion Weir, can be seen in table 1

Table 1
Overturning Stability and Shear Stability Model 1 Beam Gabion Weir

h (cm)	Stability against overturning	h (cm)	Stability against shearing
1	18.784	10	34.046
5	17.610	50	31.698
10	16.436	100	29.350
15	15.262	150	27.002
20	15.262	200	25.828
25	14.088	250	23.480
30	12.914	300	22.306
35	11.740	350	19.958
40	10.566	400	18.784
45	9.392	450	17.610
50	8.218	500	16.436
55	7.044	550	14.088
60	5.870	600	12.914
65	4.696	650	10.566
70	3.522	700	8.218
75	2.348	750	5.870

Output SF (Safety Factor) Manual Calculation of Reverse Stability and Shear Stability can be seen in Figure 4.

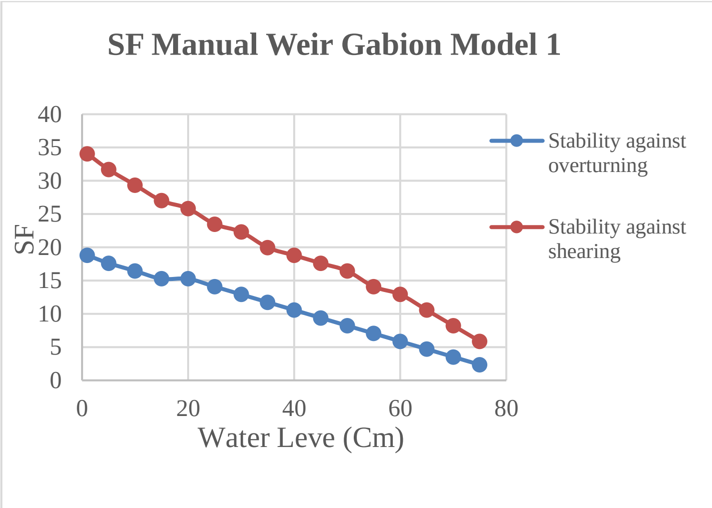


Figure 3
Graph of Output SF Manual Overturning and Shear Stability Calculations

Plaxis Software Output Total Displacement HWL, can be seen in Figure 4.

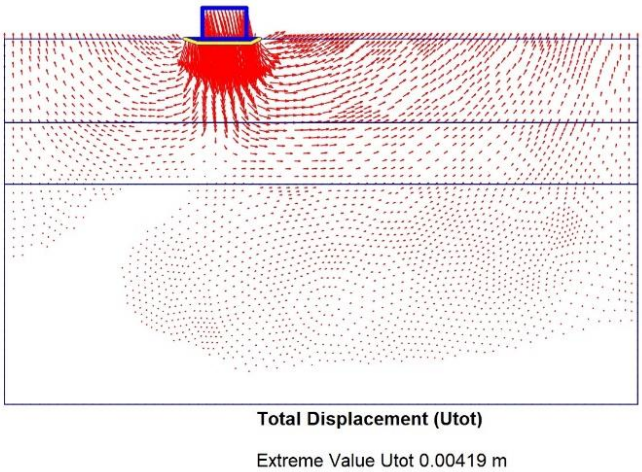


Figure 4 Plaxis Software Output Total Displacement HWL

Plaxis Software Output Average Voltage HWL, can be seen in Figure 5

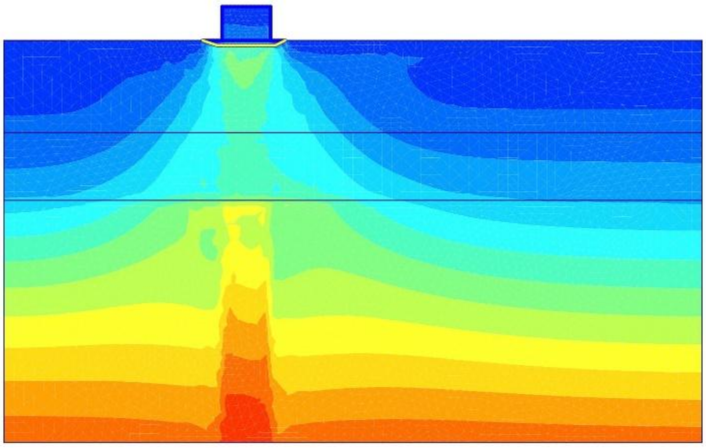


Figure 5 Average Voltage of the Plaxis Software Output HWL

Water Level Analysis for Weir Test. Water Level Elevation for Weir Gabion Model 1, can be seen in Figure 6.

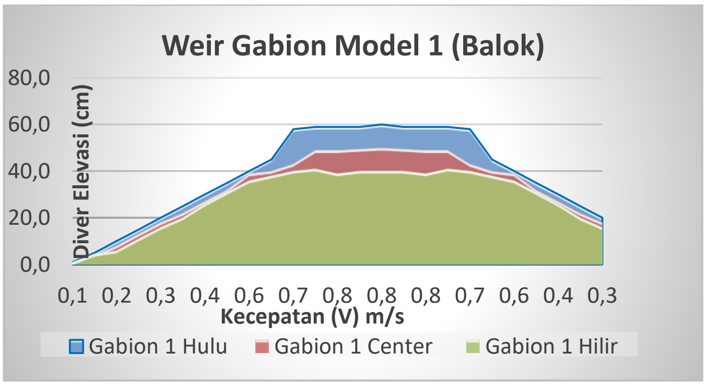


Figure 6 Water Level Elevation for Weir Gabion Model 1

1. Weir model 1 shows observations of the Diver device with the weir elevation value remaining stable. In the trial, it was found that the elevation of LWL20= cm, MWL= 400 cm and HWL = 600 cm.
2. Weir model 1 remains stable against shear and overturning forces when the water reaches High water level =600 cm.
3. Test values were determined for the upstream Gabion weir at 1.6 cm/s and 20 °C, the center at 0.9 cm/s and 15 °C, and the downstream weir at 0.6 cm/s and 14 °C using observations made using a current meter.
4. In simulation using plaxis software, the value of factor of LWL= 1.201, MWL= 1.198, HWL= 1.174 with the value of total deformation $393.94\text{x}10^{-3}$, efective stress -245,79 KN/m2

Model 2: Weir Gabion Beam with Sloping Upstream, can be seen in Figure 7.

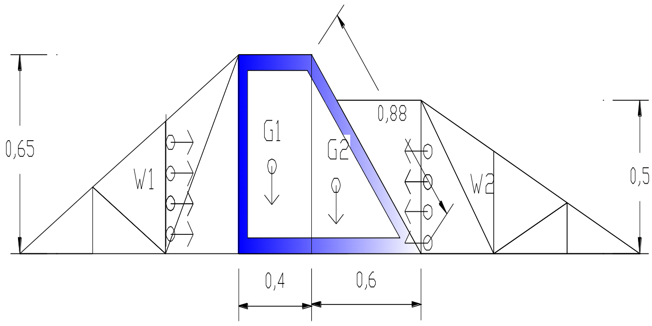


Figure 7 Model 2 weir Gabion beam with Sloping Upstream

Overturning stability= $\frac{\Sigma MT}{\Sigma MG}$ Shear Stability= $\frac{f x \Sigma V}{\Sigma h}$

Overturning stability and Shear Stability Model 2.
Weir Gabion Beam, can be seen in table 2

Table 2
Overturning stability and Shear Stability Model 2 Weir Gabion Beam

h (cm)	Stability against overturning	h (cm)	Stability against shearing
1	52.308	10	96.770
5	47.949	50	76.718
10	43.590	100	62.334
15	39.231	150	58.847
20	34.872	200	55.359
25	30.513	250	48.821
30	26.154	300	43.154
35	21.795	350	37.052
40	17.436	400	31.821
45	13.077	450	22.667
50	8.718	500	15.257
55	7.628	550	13.949
60	6.539	600	13.077
65	5.449	650	11.769
70	4.359	700	10.462
75	2.180	750	9.590

SF (Safety Factor) Output Graph for Manual Calculation of Overturning Stability and Shear Stability, can be seen in Figure 8.

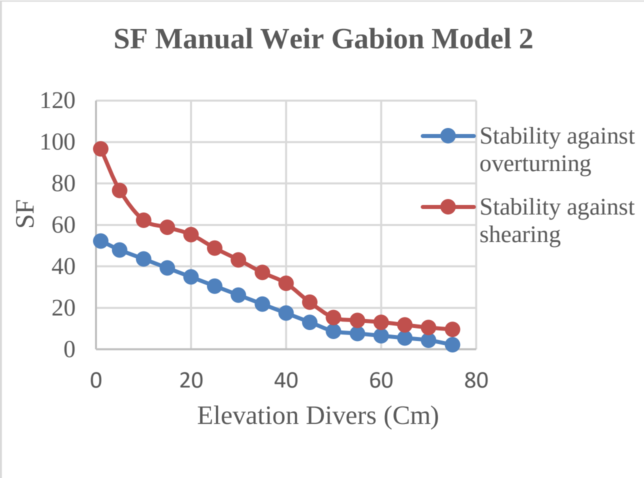
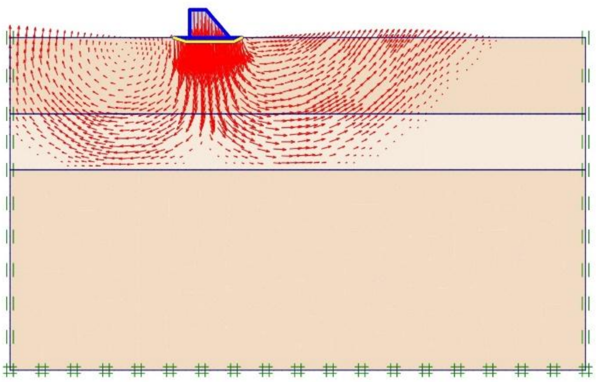


Figure 8
SF Output Graph for Manual Calculation of Overturning Stability and Shear Stability

Plaxis Software Output Total Displacement HWL (High Water Level), can be seen in Figure 9.



Total Displacement (Utot)
Extreme Value Utot 7.00* 10^3

Figure 9. Plaxis Software Output Total Displacement HWL

Plaxis Software Output Average Voltage HWL, can be seen in Figure 10

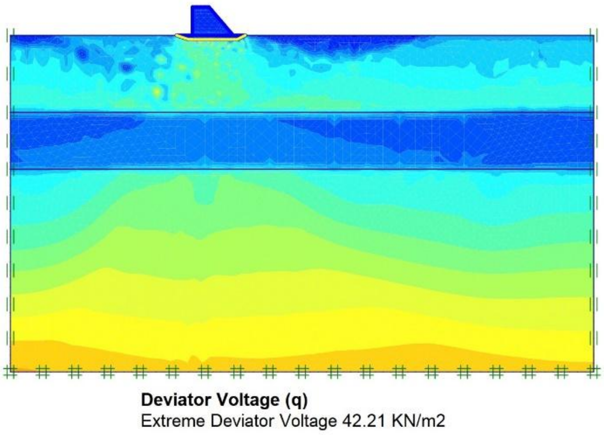


Figure 10. Average Voltage HWL of the Plaxis Software Output

Water Level Analysis for Weir Test
Elevation Water Level Weir Gabion Model 2, can be seen in Figure 11.

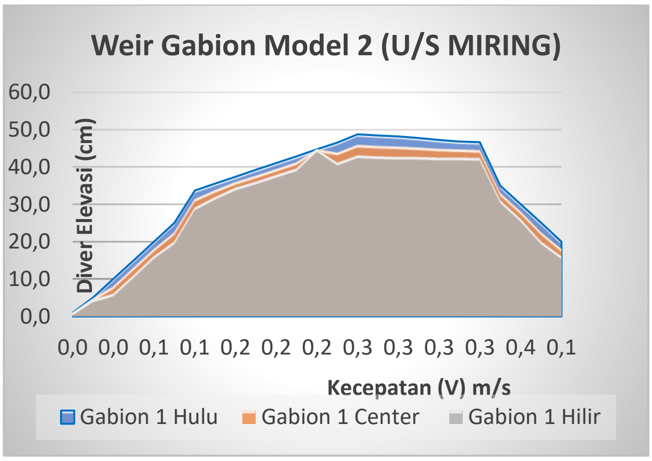


Figure 11
Elevation Water Level Weir Gabion Model 2

1. The diver device is observed using Weir Model 2, with the weir elevation value maintaining constant. It was discovered throughout the experiment that the elevation of LWL was 200 cm, MWL was 400 cm, and HWL was 600 cm.
2. When the water reaches, Weir model 1 maintains stability against shear and overturning g forces. Height of water = 600 cm.
3. The results of observations using the Current meter device on the flow velocity and temperature of the highest water temperature found the value of the Gabion weir upstream = 1.6 cm/s and 20°C, center = 0.9 cm/s and 15°C, downstream = 0.6 cm/s and 14 °C.
4. In the simulation results using Plaxis software, it was found that the value of Safety factor LWL=4.652, MWL= 4.340, HWL = 4.359 with a total deformation value of 393.94x10^{-3}, effective stress -245,79 KN/m2.

Model 3 : Trapezoidal Gabion Weir, can be seen in Figure 13

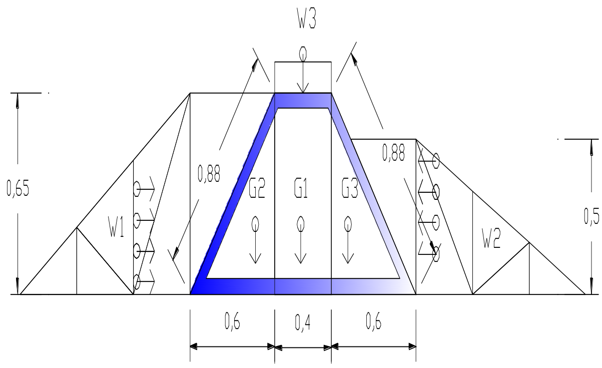


Figure 12 Model 3 Trapezoidal Gabion Weir

Overturning stability= $\frac{\Sigma MT}{\Sigma MG}$ Shear stability= $\frac{fx\Sigma V}{\Sigma h}$
Overturning Stability and Shear Stability Model 3 Trapezoidal Gabion Weir, can be seen in table 3.

Table 3
Overturning Stability and Shear Stability Model 3 Trapezoidal Gabion Weir

h (cm)	Stability against overturning	h (cm)	Stability against shearing
1	49.533	10	81.955
5	45.030	50	59.890
10	40.527	100	50.884
15	36.024	150	41.428
20	31.521	200	36.024
25	27.018	250	31.071
30	22.515	300	28.819
35	18.012	350	27.018
40	13.509	400	24.767
45	9.006	450	22.065
50	5.404	500	20.714
55	4.953	550	17.562
60	4.503	600	14.860
65	4.053	650	9.907
70	3.602	700	6.755
75	3.152	750	4.503

SF Output Graph for Manual Calculation of Overturning Stability and Shear Stability, can be seen in Figure 14

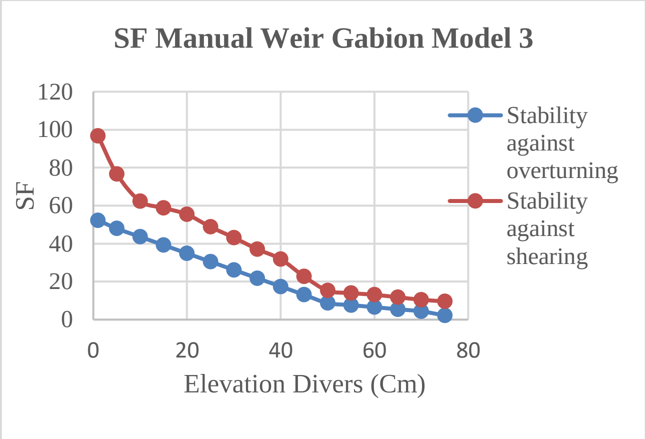


Figure 13 SF Output Graph for Manual Calculation of Overturning Stability and Shear Stability

Software Output Total Displacement from Plaxis HWL, can be seen in Figure 14.

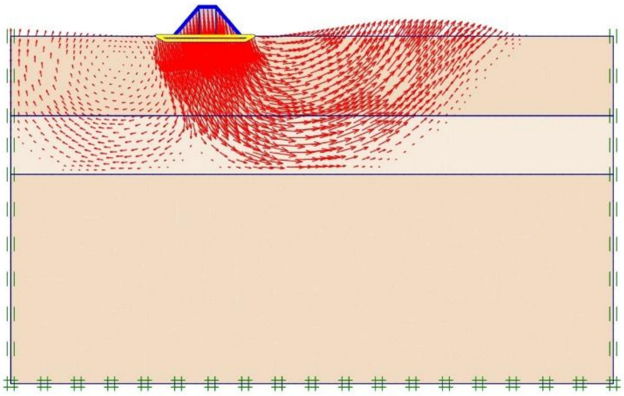


Figure 14 Software Output Total Displacement from Plaxis HWL

Average Voltage of the Plaxis Software Output, can be seen in Figure 15.

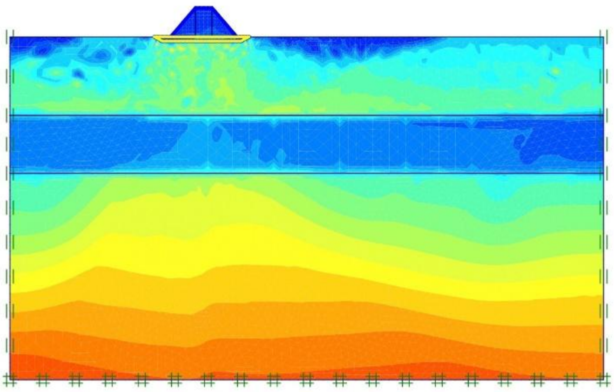


Figure 15 Average Voltage of the Plaxis Software Output

Water Level Analysis for Weir Test
Elevation Water Level Weir Gabion Model 3, can be seen in Figure 16

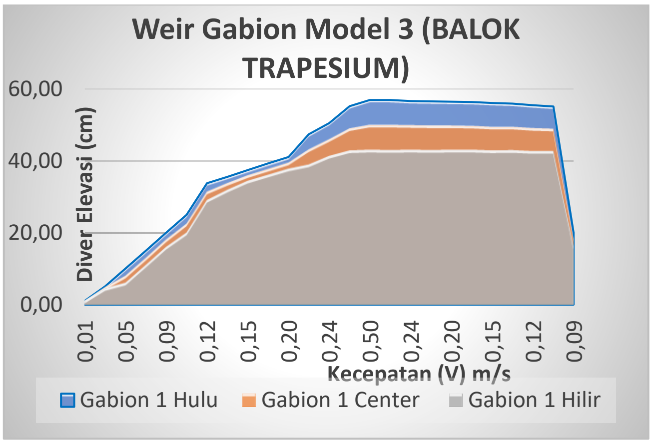


Figure 16. Weir Weir Water Level Model 3 Gabion

1. Weir model 3 shows the observation of the Diver device with the weir elevation value remaining stable. The trial obtained elevation of LWL = 200 cm, MWL= 500 cm and HWL =650 cm.
2. Weir model 3 remains stable against shear and overturning forces when the water reaches High water level = 650 cm.
3. The results of observations using a Current meter device on the flow velocity and temperature of the highest water temperature found the value of the Gabion weir upstream= 1.6 cm/s and 20°C, center = 0.9 cm/s and 15°C, downstream = 0.6 cm/s and 14 °C.
4. In the simulation results using Plaxis software, the safety factor value, it was found that LWL= 4.511 MWL = 4.578, HWL= 4.503 with a total deformation value of $393.94 x 10^{-3}$, effective stress -245,79 KN/m2.

Model 4 Trapezoidal Gabion Weir + Geotextile
Model 4 Trapezoidal Gabion Weir + Geotex, can be seen in Figure 17

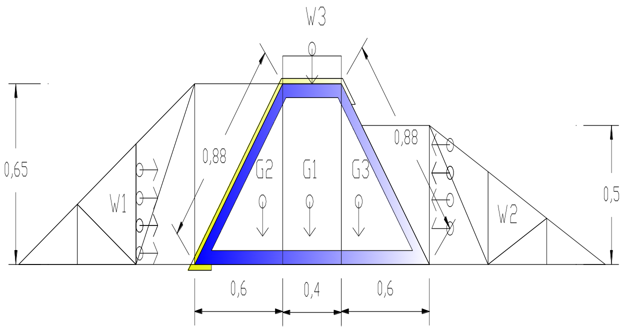


Figure 17 Model 4 Trapezoidal Gabion Weir + Geotex

Overturning stability= $\frac{\Sigma MT}{\Sigma MG}$ Shear Stability= $\frac{f x \Sigma V}{\Sigma h}$
Overturning Stability and Shear Stability Model 4 Trapezoidal Gabion Weir + Geotex, can be seen in Table 4.

Table 4
Overturning Stability and Shear Stability Model 4 Trapezoidal Gabion Weir + Geotex

h (cm)	Stability against overturning	h (cm)	Stability against shearing
1	94.761	10	116.297
5	55.995	50	68.486
10	51.688	100	64.610
15	47.380	150	58.579
20	43.073	200	55.133
25	38.766	250	51.688
30	34.458	300	45.227
35	30.151	350	43.073
40	25.844	400	42.642
45	25.413	450	38.766
50	22.398	500	37.474
55	21.537	550	30.151
60	17.229	600	19.383
65	12.922	650	16.798
70	5.169	700	13.783
75	4.307	750	9.476

SF Output Graph for Manual Overturning and Shear Stability Calculations, can be seen in Figure 18. Overturning stability & Shear stability

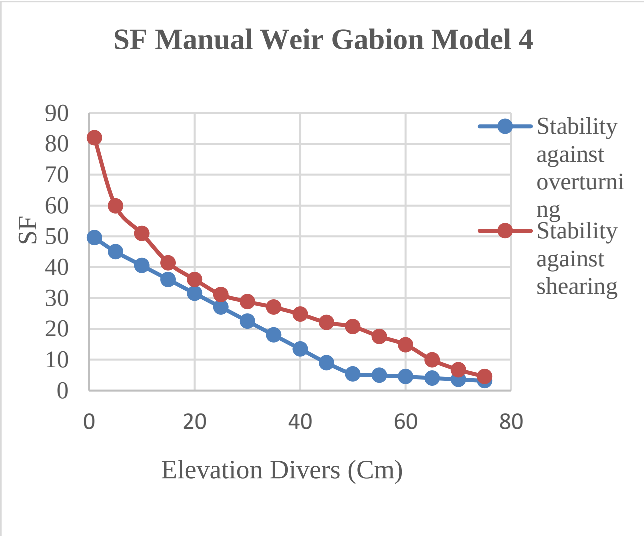


Figure 18 SF Output Graph for Manual Overturning and Shear Stability Calculations

Plaxis Software Output Total Displacement HWL(High Water Level), can be seen in Figure 19

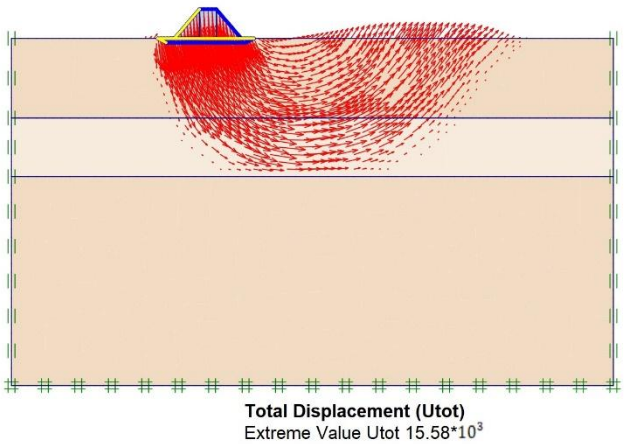


Figure 19. Plaxis Software Output Total Displacement HWL

Average Voltage HWL of the Plaxis Software Output, can be seen in Figure 20.

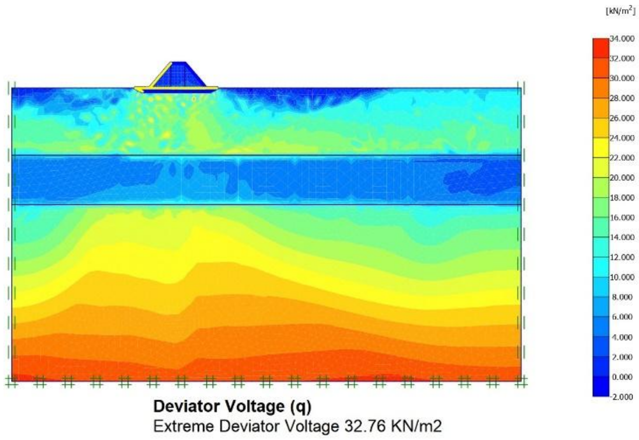


Figure 20. Average Voltage HWL of the Plaxis Software Output

Water Level Analysis for Weir Test

Elevation Water Level Gabion Weir Model 4, can be seen in Figure 21.

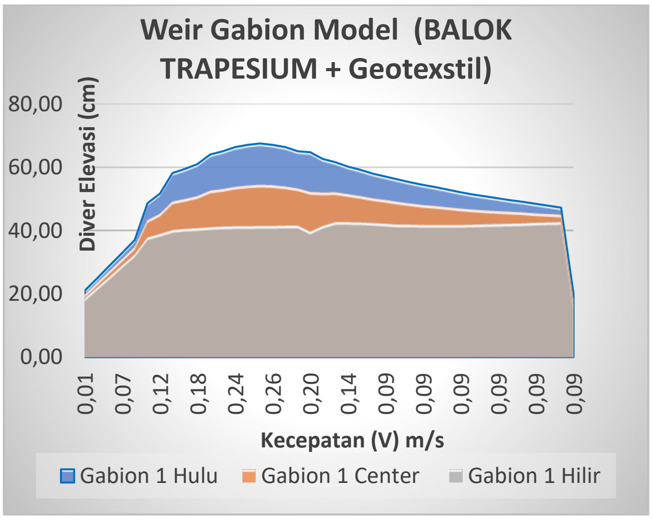


Figure 21. Elevation Water Level Gabion Weir Model 4

1. Weir model 4 shows observations of the Diver device with the weir elevation value remaining stable. In the trial, it was found that the elevation of LWL= 200 cm, MWL= 500 cm and HWL= 700 cm.
2. Weir model 4 remains stable against shear and overturning forces when the water reaches High water level= 700 cm.
3. The results of observations using a Current meter device on the flow velocity and temperature of the highest water temperature found the value of the Gabion weir upstream= 1.6 cm/s and 20°C, center = 0.9 cm/s and 15°C, downstream = 0.6 cm/s and 14 °C.
4. In the simulation results using Plaxis software, the safety factor value, it was foun that

LWL =4.472, MWL=4.242, HWL= 4.07 with a total deformation value of 393.94x10^{-3}, effective stress -245,79 KN/m2. Recapitulation of Weir Stability Calculation, can be seen in Tabel 5.

Table 5
Recapitulation of Weir Stability Calculation

Condition	Value of Safety Factor (SF) Plaxis			
	Model 1	Model 2	Model 3	Model4 (Geotex)
Construction	1.2942	4.3151	4.7986	4.5076
HWL	1.1740	4.3594	4.5030	4.3071
MWL	1.1986	4.3401	4.5789	4.2418
LWL	1.2011	4.6529	4.5112	4.4722

Table 5 shows that the best weir stability in HWL and MWL is obtained in Model 3 with a value of 4.5030 and 4.5789, while the best weir stability in LWL is Model 2 with a value of 4.6529.

CONCLUSION

Research on the Gabion weir as an appropriate technology alternative to successfully overcome the problem of tidal flood mitigation or as a raw water filter. The design of the Gabion weir model as a filter includes three types of weir testing models, namely the trapezoidal type 1 model, the type 2 beam model, and the type 3 combination model. The results of the analysis of the Gabion weir observation obtained that an average water level elevation, MAR = 100 cm, MAB 600 cm , MAN = 450 cm, elevation of MAB upstream of weir = 650 cm, elevation of center of weir = 445 cm, weir downstream of MAB = 410 cm, the water elevation upstream, inside and downstream of the experimental porous weir is in accordance with the initial hypothesis. The water measured flow velocitiesy are in upstream of weir 7.5 l/s, center of 7.5 l/s, downstream 6.0 l/s. and upstream temperature 31°C, center 30.3°C, 30°C, downstream water conditions are clean. The best weir stability at HWL and MWL was obtained in Model 3 with a value of 4.5030 and 4.58789, while the best weir stability at LWL was Model 2 with a value of 4.6529.

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