Study Of Effectiveness By Using Seawalls With Slopes Of 1:3 And 1:5 On Run Up, Wave Reflection And Overtopping At Selatbaru Beach Of Bengkalis

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Abstract. Selatbaru Beach is one of the mainstay tourist attractions in Bengkalis Regency after North Rhu Rupat Bay Beach. This beach area is located in the waters of the Melaka Strait, Malaysia. This beach has been built with coastal protection such as Breakwater, Groin and Seawall. The seawall that has been built by the Regional Government is 450 m long to protect the beach from coastal erosion. The current situation is that sea water is overflowing due to high tides, so restaurants along the seawall are affected. So there is a need for a study of this problem to find a solution. Now slope of the seawall is 1:3 with geobag material and geotextile mattress as the outer structure cover of the seawall.

This research wants to carry out experiments on changing the slope of the seawall because this effort is expected to reduce the height of waves that hit the seawall structure, and can reduce wave energy when it hits the structure, and uses data from field measurements and a prototype is made according to the field in the laboratory so that from the test data an analysis is carried out on the effectiveness of changes in seawall slope in reducing wave height.

The wave run up value that occurs at a seawall slope of 1:3 is 0.675, while for a seawall slope of 1:5 it is 0.475. With the freeboard condition of the seawall structure being 0.45, the overtopping at a slope of 1:3 occurs as high as 0.225 m and at a slope of 1:5 the overtopping is only 0.025 so the seawall structure is very safe from overtopping at a slope of 1:5. If there is a rise in sea level due to global warming, the freeboard of the structure will be smaller, namely 0.25 m, with the same run up, the overtopping that occurs at a slope of 1:3 is 0.475 and a slope of 1:5 is 0.275. From the results of the analysis, it is necessary to build seawall slope 1:5 and embankments The recommended embankment height is 0.5 m, so that the land area which is the restorant area is safe from flooding due to overtopping sea water. From the wave test results data, the reflection coefficient value for a slope of 1:3 at 0.45 m freeboard conditions is 0.65, and 0.25 m freeboard conditions is 0.61. Meanwhile, the reflection coefficient value for a slope of 1:5 in the 0.45 m freeboard condition is 0.49, and in the 0.25 m freeboard condition is 0.46. The steeper the slope of the structure, the greater the reflection value, indicating that the structure is able to reduce incoming waves that hit the structure. The results of this research conclude that a safe slope is 1:5 and the addition of embankments 0,5 m at the top of the structure in the restaurant to prevent flooding in the area.

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Keywords: Seawall slope;waves run up; wave reflection; overtopping.

1. Introduction

Selatbaru Indah Beach is one of the mainstay tourist attractions in Bengkalis Regency after North Rhu Rupat Bay Beach. This beach area is located in the waters of the Melaka Strait, Malaysia. This beach has been built with coastal protection such as Breakwater, Groin and Seawall. The seawall that has been built by the Regional Government is 450 m long to protect the beach from coastal erosion. The current situation is that sea water is overflowing due to high tides, so food stalls along the seawall are affected. So there is a need for a review of the seawall building structure. The current slope of the seawall is 1:3 with geobag material and geotextile mattress as the outer structural cover of the seawall. Efforts to reduce the impact of waves on seawall buildings cannot be done by installing breakwaters because this will obstruct visitors' view of the sea and reduce visitors' comfort in enjoying the beauty of the beach at low tide.

The impact of this wave not only caused overtopping but also damaged the structure of the seawall. Most of the seawall walls made of geotextile mattresses broke and caused the geobags inside to roll over and fall off the structure.

Fig. 1. Actual condition

This research does not discuss the safety of the seawall structure but rather anticipates run up or overtopping of waves hitting the seawall so that flooding does not occur in the seaside café area which is 2 meters from the seawall structure.

This research wants to carry out experiments on changing the slope of the seawall from 1:3 to 1:5 because this effort is expected to reduce the height of waves that hit the seawall structure, and can reduce wave energy when it hits the seawall structure. This research uses data from field measurements and a prototype is made according to the field in the laboratory so that from the test data an analysis is carried out on the effectiveness of changes in seawall slope in reducing wave height.

Fig. 2. Research site

2. Literature Review

2.1 Wave

Sea waves are the result of changes in forces acting on the surface of sea water caused by wind and the movement of changes in sea level or tides can also be caused by the movement of objects on the surface of sea water. Waves are a form of energy that can form beaches, cause currents and sediment transport in a perpendicular direction and along the beach, and cause forces that act on coastal buildings. [1].

Table 1. The Wave In Several Condition

Explanation	**Wave**		
	In shallow seas	***In the transitional sea***	***In the deep sea***
d/L	d/L ≥ ½	1/20 < d/L < ½	d/L ≤ 1/20
Tanh (2πd/L)	≓ 2πd/L	Tanh (2πd/L)	≓ 1
Wave Propagation	$C = \frac{L}{T} = \sqrt{gd}$	$C = \frac{L}{T} = \frac{gT}{2\pi} \tanh\left[\frac{2\pi d}{L}\right]$	$C = C_0 = \frac{L}{T} = \frac{gT}{2\pi}$
Wave length	$L = T\sqrt{gd}$	$L = \frac{gT^2}{2\pi} \tanh\left[\frac{2\pi d}{L}\right]$	$L = L_0 = \frac{gT^2}{2\pi} = 1{,}56\,T^2$

Yuwono, 2004

2.2 Seawall

The sea wall functions as a structure to protect the coast against wave attacks and to prevent wave runoff onto the land behind it. Usually seawalls are used to protect residential areas and/or public facilities that are very close to the coastline. This building can be sloping, upright, curved or with stairs, made of stone masonry, concrete walls [2]

In the Bengkalis area, the seawall used is the sloping side type, which is chosen in accordance with the soft soil structure and muddy beaches so that the sloping structure is able to support its own weight with wave heights of less than 2 meters, making it possible to make it with sloping sides.

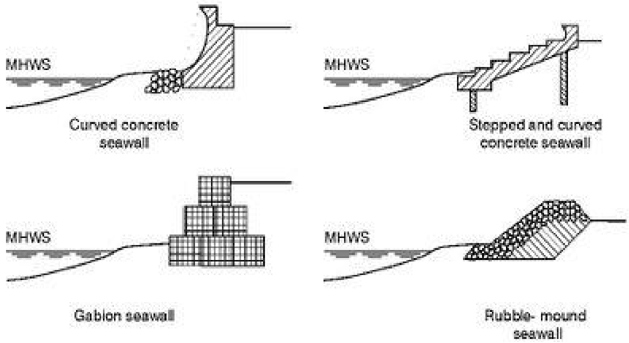

Fig. 3. Seawall Types

2.3 Wave reflection

Waves that hit/hit the structure of a beach building will be partially or completely reflected. A building that has sloping sides and is made from piles of stones will be able to absorb more wave energy than an upright and massive building [3].

$$X = \frac{H_r}{H_i} \quad (1)$$

By means of :

X = Reflection coefficient value
Hr = Reflection waves
Hi = Incident waves

Table. 2. Reflection Coefficient

No	Structure type	X Value
1	Vertical wall with peak above the water	0,7 – 1,0
2	Vertical walls with submerged tops	0,5 – 0,7

No	Structure type	X Value
3	Stone arrangement with sloping sides	0,3 – 0,6
4	Arrangement of concrete blocks	0,3 – 0,5
5	Vertical buildings with energy absorbers (with holes)	0,05 – 0,2

Triatmodjo, 2012

2.4 Wave Run up

Wave run up is defined as the highest reaching level of sea waves on a structure that has a sloping surface, measured vertically from the still water level (Still Water Level, SWL). Meanwhile, wave rundown is the lowest level reached by sea waves on a structure that has a sloping surface, also measured vertically from the still water surface [4].

$$\mathrm{Ir} = \frac{\tan\theta}{\left(\frac{H}{L_0}\right)^{1/2}} \tag{2}$$

By means of :
Ir = Irribaren Numbers
Θ = Slope structure
H = Wave height at the structure site
L0 = Wavelength in the deep sea

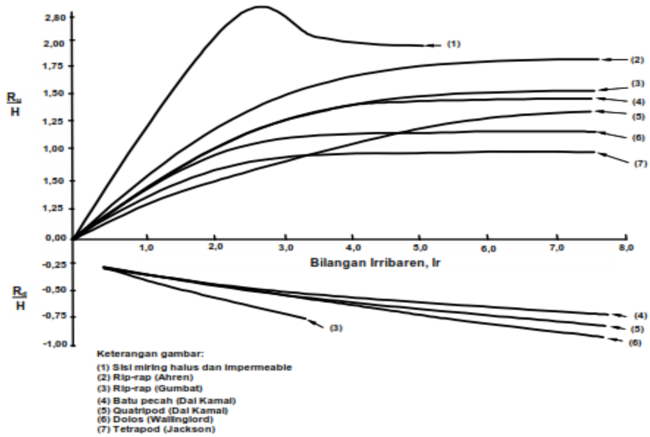

Fig. 4. Graph of the relationship between Run up and Run down with irribaren numbers

3. Method

This research uses data from field measurements and data obtained from digital sources. Data taken directly by measurement are data on seawall dimensions, seawall slope, water level height at maximum tide in the seawall structure. Other data taken from the website is data on significant wave heights, while data on sea level rise due to global warming is from graphs. After the field data was obtained, a seawall prototype was made with a slope of 1:3 and 1:5 for testing in the laboratory with a scale of 1:10 on the dimensions and wave height parameters. Then analyze the test results and approach the run up, over topping and wave reflection coefficient values. Wave testing was carried out at the Hydraulics Laboratory of the Civil Engineering Department of Bengkalis State Polytechnic. The flume was 5 m long, 0.5 m wide and 0.8 m high, equipped with a flape type wave maker.

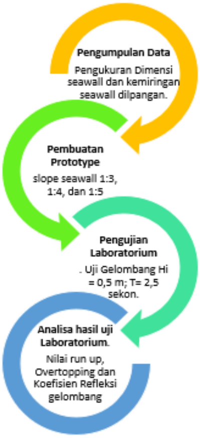

Fig. 5. Research plan

3.1 Field survey

This seawall dimension survey is needed to create a laboratory model with field dimensions. This survey uses measuring equipment consisting of::

1. Thedolite
2. Measuring signs
3. Tripod

Fig. 6. Seawall slope measurement

3.2 Other data

Significant wave data was obtained from the Tide Times and Tide Chart for Melaka website (tide-forecast.com), from height data on the Melaka Strait water map ranging from 0 m – 0.5 m. Significant wave data in the research area is not yet available so this data can be representative for use because the research location is in the waters of the Malacca Strait so this data can be used.

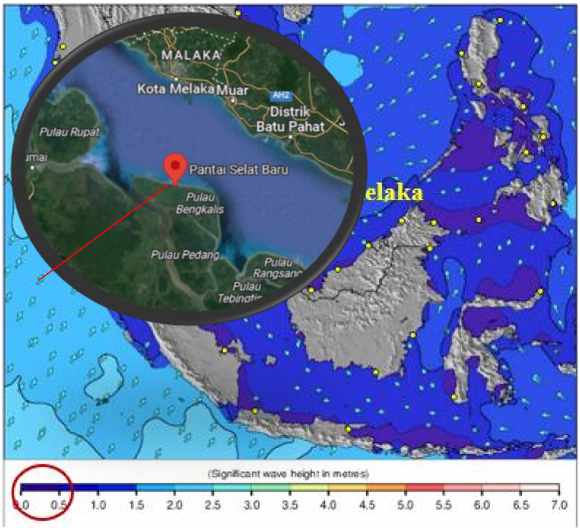

Fig. 7. Significant Wave Height Data

3.3 Prototyping

The seawall prototype used is with a slope of 1:3 and 1:5, with a structure made of steel material. The seawall height is 2.25 m, with a water depth based on field survey results of 1.8 m at the highest water level at high tide, and the water depth is due to global warming with a sea level rise of 0.2 m from the current highest water level. So the water depth used in this study was 1.8 m and 2.0 m. prototype made with a scale ratio of 1:10.

Table 3. Prototype Dimensions In The Laboratory

No	Description	Dimension (m)	
		Actual	*Prototype*
1	Seawall structure height	2,25	0,225
2	Water level height		
	- Current highest tide	1,80	0,18
	- Due to global warming	2,00	0,20
3	Significant wave height	0,50	0,05
4	Seawall width		
	- Slope 1:3	6,75	0,675
	- Slope 1:5	11,25	1,125

The wave test given to the structure is an irregular wave, with a laboratory scale wave height of 5 cm, and a wave period of 1.5 seconds. Tests were carried out on structures with slopes of 1:3 and 1:5. Two sensors are installed in the direction of the incoming wave and at the position of the wave hitting the structure, this is to determine the increase or decrease in wave height due to the slope of the seawall structure relative to the water depth in the seawall structure area.

Fig. 8. Wave test flume and seawall prototype

3.4 Wave Test on the prototype in the Laboratory

Wave testing is carried out on the prototype after conducting wave experiments to obtain the desired wave height and period. Prepare a wave test pool with water according to the desired depth, and ensure that the wave fan drive motor is functioning and place the seawall structure prototype into the wave test pool. Wave testing is carried out repeatedly at each slope and depth of the water surface. A sketch of the seawall structure prototype test in the wave test pool can be seen in Figure 8 below.

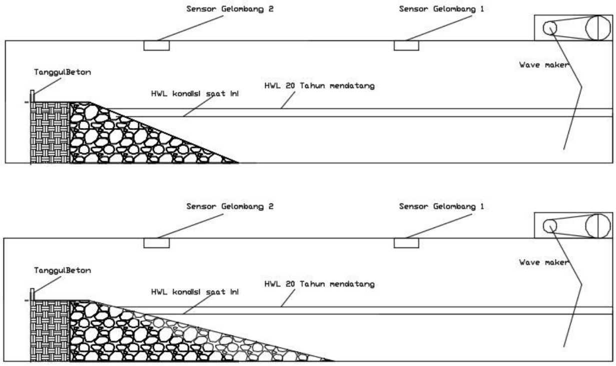

Fig. 9. Sketch of seawall prototype testing in a wave flume

Once the test equipment is set up, it can be continued with wave testing. To record wave height data via the Arduino application and USS sensor connected to a PC/Laptop for monitoring and displaying wave readings and graphs that occur in the wave test pool. The input to the Arduino is the height of the pool, the height of the water.

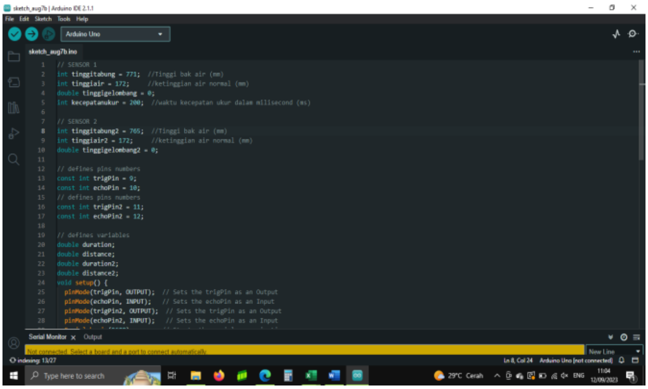

Fig. 10. Wave reading software via USS Data

Figure 10 below is the wave testing process on the seawall prototype at the Bengalis State Polytechnic Civil Engineering Department Laboratory.

Fig. 11. Seawall structure testing in the Laboratory

4. Result and analysis

From the results of field measurements, the seawall slope is 1:3 with the dimensions of the seawall being a structure height of 2.25 m and a width of 6.75 m. The distance between the top of the seawall and the food stall is only 2.1 m, as can be seen in Figure 11.

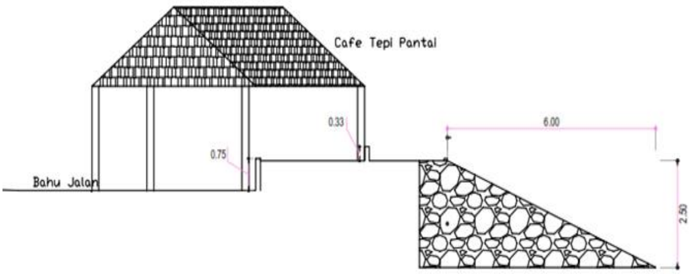

Fig. 12. Actual conditions

Analysis was carried out to find the run up, overtopping and wave reflection coefficient values for the seawall structure with slope variations of 1:3 and 1:5. For run up calculations obtained from data, the significant wave height in the waters of the Melaka Strait is 0.5 m with a wave period of 2.1 seconds. Calculation of wavelengths in the deep sea (L_0) and wave speed in the deep sea (C_0).

$$C_0 = \frac{gT}{2\pi} = 1{,}56\,T$$

$$C_0 = \frac{9{,}81\, {}^{m}/_{dt^2}\ x\ 2{,}1\ dt}{2\ x\ 3{,}14}$$

$$C_0 = 3{,}34\,{}^{m}/_{dt}$$

$$L_0 = \frac{g\,T^2}{2\pi} = 1{,}56\,T^2$$

$$L_0 = \frac{9{,}81\,{}^{m}/_{dt^2}\ x\ 2{,}1\ dt^2}{2\ x\ 3{,}14}$$

$$L_0 = 6{,}88\ m$$

From the calculations, the value C_0 = 3.27 m/sec and L_0 = 6.88 m is obtained, so the irribaren value can be calculated. The following is a calculation of the irribaren value with a structural slope of 1:3 and 1:5.

$$Ir = \frac{tan\ \theta}{\left(\frac{H}{L_0}\right)^{1/2}}$$

$$Ir = \frac{0{,}3333}{\left(\frac{0{,}5}{6{,}88}\right)^{1/2}}$$

$$Ir = 1{,}24$$

$$Ir = \frac{0{,}2}{\left(\frac{0{,}5}{6{,}88}\right)^{1/2}}$$

$$Ir = 0{,}74$$

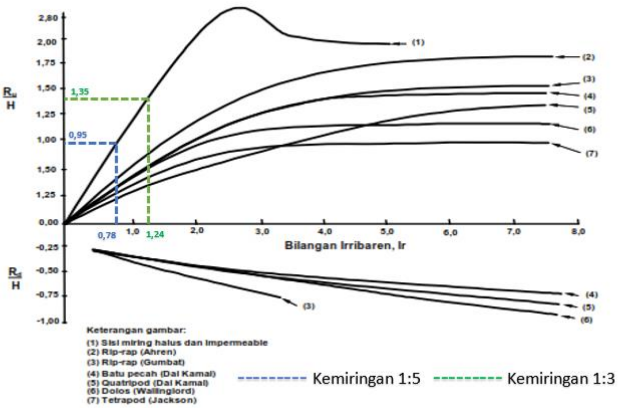

Fig. 13. Calculation results of the irribaren value to the Ru/H value

From the graph above on Figure 13 with a structural slope of 1:3, the Irribaren value is 1.24 and Ru/H is 1.35, so the Ru value or wave run up can be obtained.

Ru/H =1.35

Ru =1.35 x H

Ru =1.35 x 0,5 = 0,675 m

Meanwhile, for a slope of 1:5, the irribaren value is 0.78 and Ru/H is 0.95, so the Ru value or wave run up can be obtained

Ru/H =0.95

Ru =0.95 x H

Ru =0.95 x 0,5 = 0,475 m

The wave run up value that occurs at a seawall slope of 1:3 is 0.675, while for a seawall slope of 1:5 it is 0.475. With the freeboard condition of the seawall structure being 0.45, the overtopping at a slope of 1:3 occurs as high as 0.225 m and at a slope of 1:5 the overtopping is only 0.025 so the seawall structure is very safe from overtopping at a slope of 1:5. If there is a rise in sea level due to global warming, the freeboard of the structure will be smaller, namely 0.25 m, with the same run up, the overtopping that occurs at a slope of 1:3 is 0.475 and a slope of 1:5 is 0.275.

Data from wave testing on the seawall prototype with an incoming wave height of 0.5 m with a laboratory scale of 5 cm or 50 mm reading data on the sensor in mm, as in figure 15. This data is obtained from readings by sensors installed on the wave flume.

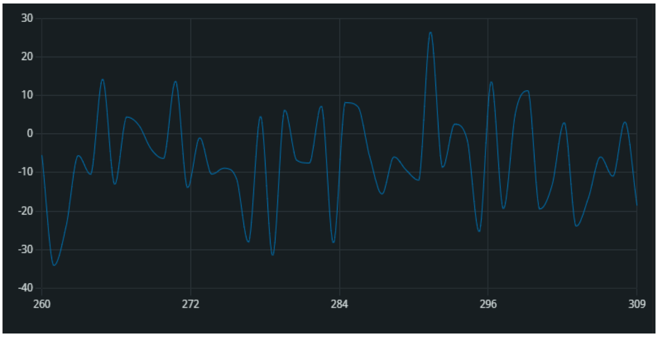

Fig. 14. Incident wave graph

This is a photo of a wave test Wave flume on a seawall structure with a slope of 1:3 and 1:5 at the highest tide level conditions and when sea levels rise due to global warming in Hydro Laboratory of Civil Engineering Department.

Fig. 15. Wave testing on seawall slope 1:3

From the figure 16 shows that the run up height of 60 mm on a laboratory scale is equal to 0.6 m real, this is in accordance with the results calculated using the irribaren value approach in Figure 13 which is 0.675 m.

Fig. 16. Wave testing on seawall slope 1:5

From the figure 17 shows that the run up height of 40 mm on a laboratory scale is equal to 0.4 m real, this is in accordance with the results calculated using the irribaren value approach in Figure 13 which is 0.475 m.

Wave testing with an incoming wave height of 5 cm was carried out at water levels of 18 cm and 20 cm for slopes of 1:3 and 1:5, according to table 4.

Table 4. Wave Test Results On Seawalls With Different Slopes And Freeboard

No	Description	Freeboard 0,45 m		X Value	Freeboard 0,25 m		X Value
		Hi	***Hr***		***Hi***	***Hr***	
1	Slope 1:3						
	Testing 1	5	3,25	0,65	5	3,15	0,63
	Testing 2	5	3,42	0,68	5	3,05	0,61
	Testing 3	5	3,17	0,63	5	2,95	0,59

No	Description	Freeboard 0,45 m		X Value	Freeboard 0,25 m		X Value
		Hi	*Hr*		*Hi*	*Hr*	
	Average			0,65			0,61
2	Slope 1:5						
	Testing 1	5	2,60	0,52	5	2,53	0,51
	Testing 2	5	2,23	0,45	5	2,16	0,43
	Testing 3	5	2,55	0,51	5	2,27	0,45
	Average			0,49			0,46

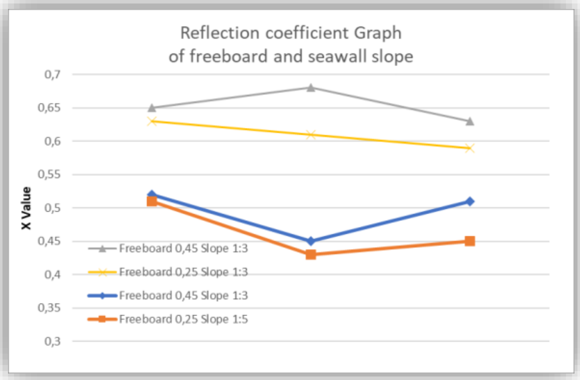

Fig. 17. Reflection Coefficient Graph

From the wave test results data, the reflection coefficient value for a slope of 1:3 at 0.45 m freeboard conditions is 0.65, and 0.25 m freeboard conditions is 0.61. Meanwhile, the reflection coefficient value for a slope of 1:5 in the 0.45 m freeboard condition is 0.49, and in the 0.25 m freeboard condition is 0.46. The steeper the slope of the structure, the greater the reflection value, indicating that the structure is able to reduce incoming waves that hit the structure.

Table 5. Overtopping Analysis

Seawall slope	Irribaren value (Ir)	Ru/H	Water level (d)	Ru	Freeboard	Valuation
1:3	1,24	1,35	1,80	0,675	0,45	Overtopping
			2,05	0,675	0,25	Overtopping
1:5	0,74	0,95	1,80	0,475	0,45	No
			2,05	0,475	0,25	No

From the table 5 TABLE 5 shows that overtopping occurs at a seawall slope of 1:3 of 0.225 m, whereas at a seawall slope of 1:5 there is only overtopping of 0.025, so it can be concluded that a seawall slope of 1:5 is more effective in reducing the occurrence of overtopping at the top of the seawall.

The results of this research conclude that a safe slope is 1:5 and the addition of embankments at the top of the structure in the restaurant to prevent flooding in the area. From the calculation results, it is necessary to build embankments so that the land area which is the food stall area is safe from flooding due to overflowing sea water. The recommended embankment height is 0.5 m, with the height of the structure is 2.25 m and the width is 11.25 m.

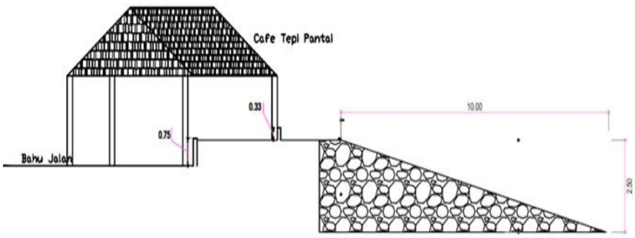

Fig. 18. Slope of 1:5 recommended for seawall and embankment height of 0.5 m

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