The Effect of Using Embankments and Modifying of Stepped Seawall Slope as Alternatives to Reduce over Topping at Selatbaru Beach Bengkalis

Zulkarnain[1,a)], Oni Febriani[2,b)], Lizar[3,c)]

[1,2,3]*Department of Civil Engineering, Bengkalis State Polytechnic, Riau, Indonesia*

a)Corresponding author: zulkarnaen@polbeng.ac.id
b)oni@polbeng.ac.id
c)lizar@polbeng.ac.id

Abstract. Located in Selatbaru Village, about 25 km from the centre of Bengkalis City, Selatbaru beach has become a favourite destination for tourists who want to enjoy the beauty of nature while engaging in outdoor activities. At that beach, a stepped-type seawall has been constructed to prevent erosion and make it easier for visitors to enjoy the beach, such as going down to and coming up from the beach. The current situation is during high tide and strong winds, waves run up the top of the seawall, causing seawater to surge onto the land. This research will conduct experiments by creating a prototype based on field survey data and laboratory scale, including the seawall dimensions, water level, and wave height, with a scale ratio of 1:10. The experimental scenarios to be conducted in the laboratory a. Existing seawall slope of 1:3 with embankment, b. Changing the seawall slope to 1:5, and c. Changing the seawall slope to 1:5 with embankment. The irregular wave height to be simulated in the laboratory is 0.8 meters. The experiment will be conducted to observe the response of the seawall structure to incoming waves and the over topping occurring on the seawall structure. The results shows that the alternative of adding an embankment and using a 1:3 seawall slope, has already been able to reduce over topping volume 40,74 %. For the second scenario, the over topping volume decreased by 77.78 %, while the third scenario reduced over topping by 100 %. The best scenario is the third with slope to 1:5 and added of embankment that will decrease volume overtopping up to 100 %.

Keywords: Seawall slope, Stepped seawall, Embankment, Over topping.

INTRODUCTION

Located in Selatbaru Village, about 25 km from the centre of Bengkalis City, Selatbaru beach has become a favourite destination for tourists who want to enjoy the beauty of nature while engaging in outdoor activities. At that beach, a stepped-type seawall has been constructed to prevent erosion and make it easier for visitors to enjoy the beach, such as going down to and coming up from the beach. The current situation is during high tide and strong winds, waves run up the top of the seawall, causing seawater to surge onto the land.

Therefore, it is necessary to conduct an analysis and simulation of the actual conditions using a prototype in the laboratory to determine whether adding embankment would be sufficient to the issue or whether an alternative, such modify the slope of the seawall with stepped concrete type and adding an embankment. This way, the most effective method can be identified among these three alternatives.

This research experiments by creating a prototype based on field survey data and laboratory scale, including the seawall dimensions, water level, and wave height, with a scale ratio of 1:10. The experimental scenarios to be conducted in the laboratory a. Existing seawall slope of 1:3 with the addition of embankment, b. Changing the seawall slope to 1:5, and c. Changing the seawall slope to 1:5 with the addition of embankment. The irregular wave height to be simulated in the laboratory is 0.8 meters. The experiment will be conducted for 3 minutes to observe the response of the seawall structure to incoming waves and the overtopping occurring on the seawall structure.

FIGURE 1. Research site

A. *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. Waves

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	$C = \frac{L}{T} = \sqrt{g}$	$C = \frac{L}{T} = \frac{gT}{2\pi}\tanh\left[\frac{2\pi d}{L}\right]$	$C = C_0 = \frac{L}{T} = \frac{gT}{2\pi}$
Wave length	$L = T\sqrt{gd}$	$L = \frac{gT^2}{2\pi}\tanh\left[\frac{2\pi d}{L}\right]$	$L = L_0 = \frac{gT^2}{2\pi} = 1{,}56\,T^2$

B. *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 sea walls 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]

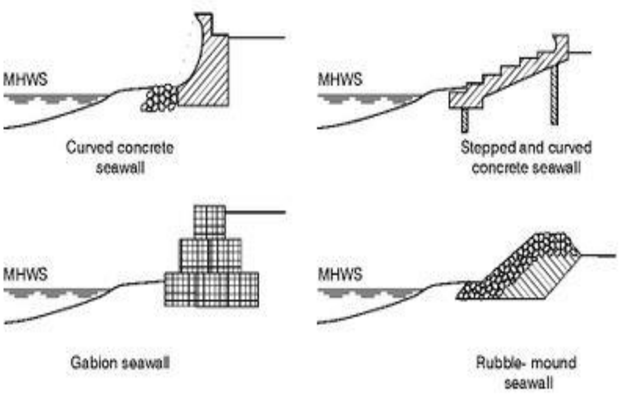

FIGURE 2. Seawall Types

C. *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].

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

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

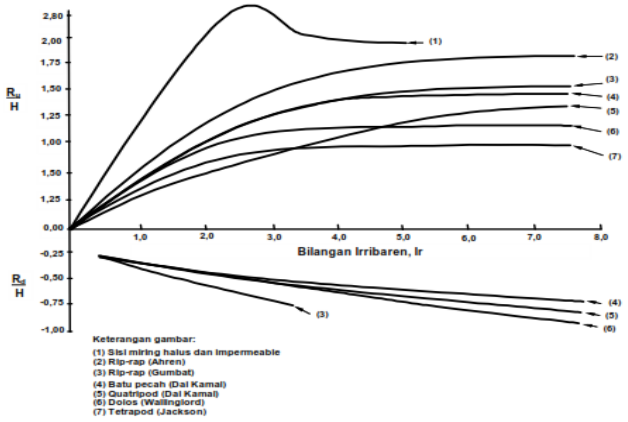

FIGURE 3. Graph of the relationship between Run up and Run down with irribaren numbers

D. *Physical Modeling*

The basis of physical modeling is that the model to be tested must be adapted to the prototype, so that the model's behavior will be similar to the prototype state. Even though applications in the laboratory may not be exactly the same as conditions in the field, efforts are made to pay attention to scaling effects and minimize laboratory effects. Similarity between the prototype and the physical model can be obtained if all the factors that influence the reaction are in the appropriate portion between the actual conditions and the model.

Geometric similarity can be achieved if the ratio of all linear dimensions of the model and prototype is the same. This relationship only shows similarities in form, not in terms of movement. Geometrically similar models are also called geometrically undistorted models, because they have the same scale both vertically and horizontally. [5]

$$nL = \frac{l_P}{l_m}$$

By mean of
nL = model scale
lp = prototype dimension
lm = model dimension

METHODS

(2)

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 wave flume was 5 m long, 0.5 m wide and 0.8 m high, equipped with a flape type wave maker.

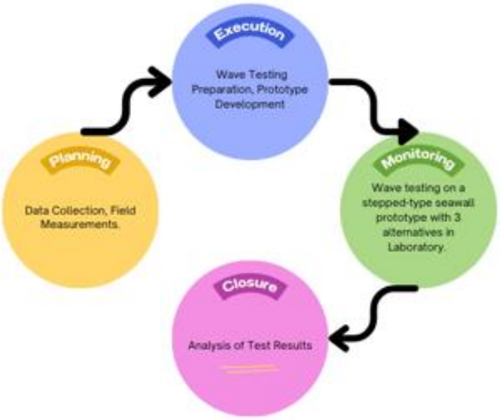

FIGURE 4. Research plan

A. Field survey

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

1. Auto level
2. Measuring signs
3. Tripod
4. Roll meter

Figure 5. Seawall slope measurement

B. Prototyping

The seawall prototype used is with a slope of 1:3 and 1:5, with a structure made by concrete 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, the water depth used in this study was 1.8 m. prototype made with a scale ratio of 1:10.

TABLE. 2 Prototype dimensions scale 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
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
5	Embankment	0,5	0,05

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 2.3 seconds. Tests were carried out on stepped seawall structures with slopes of 1:3 and 1:5.

Figure 6. Stepped seawall prototype

In the wave flume has been 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.

Figure 7. Wave test flume and Stepped seawall prototype

C. Wave Test 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 flume. 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.

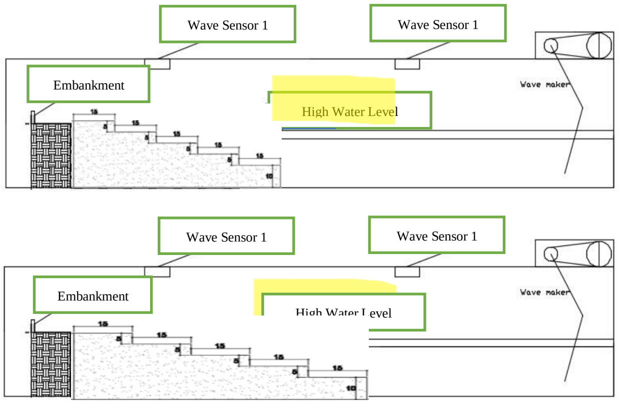

Figure 8. Simulation of Seawall prototype testing in a wave flume

Test equipment is set up and ready 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 flume. The input to the Arduino is the height of the flume and the height of the water.

Figure 9. below is the wave testing process on the seawall prototype at the Bengkalis State Polytechnic Civil Engineering Department Laboratory.

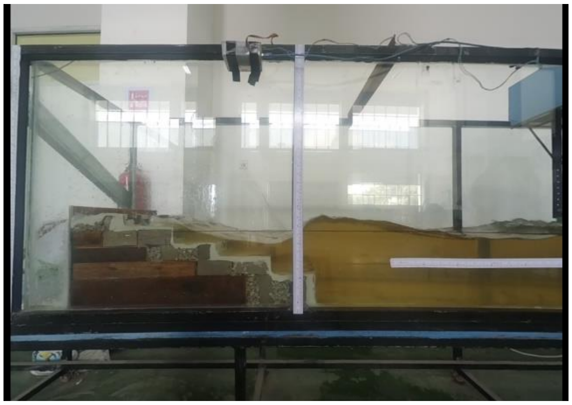

Figure 9. Seawall prototype testing in a wave flume

RESULTS AND DISCUSSION

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.

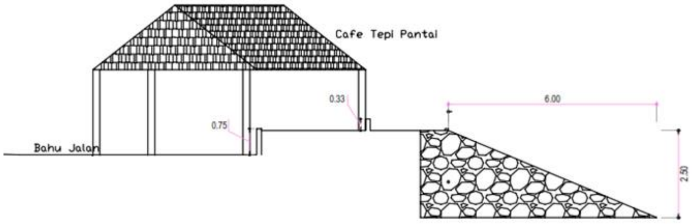

Figure 10. Actual conditions

From the wave simulation results, the incident wave height was 5 cm. After testing with the first model, which represents the existing condition with a 1:3 slope, the wave height increased to 8.5 cm. Meanwhile, with a 1:5 slope, the wave height was 6.5 cm. From these results, it can be concluded that a gentler slope will reduce the wave height due to the damping effect from a longer wave propagation structure.

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 2.3 seconds. Calculation of wave lengths in the deep sea (L_0) and wave speed in the deep sea (C_0).

$$Co = \frac{gT}{2\pi}$$

$$Co = \frac{9.81\,\frac{m}{dt^2}\ x\ 2.3\ dt}{2\ x\ 3.14}$$

$$Co = 3.59 \text{ m/dt}$$

$$Lo = \frac{gT}{2\pi}$$

$$Lo = \frac{9.81\,\frac{m}{dt^2}\ x\ 2.3\ dt^2}{2\ x\ 3.14}$$

Lo = 8.26 m

From the calculations, the value C_0 = 3.59 m/sec and L_0 = 8.26 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.

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

$$Ir = \frac{0{,}3333}{\left(\frac{0{,}85}{8{,}26}\right)^{1/2}}$$

$$Ir = \ 1{,}04$$

$$Ir = \frac{0{,}2}{\left(\frac{0{,}65}{8{,}26}\right)^{1/2}}$$

$$Ir = \ 0{,}71$$

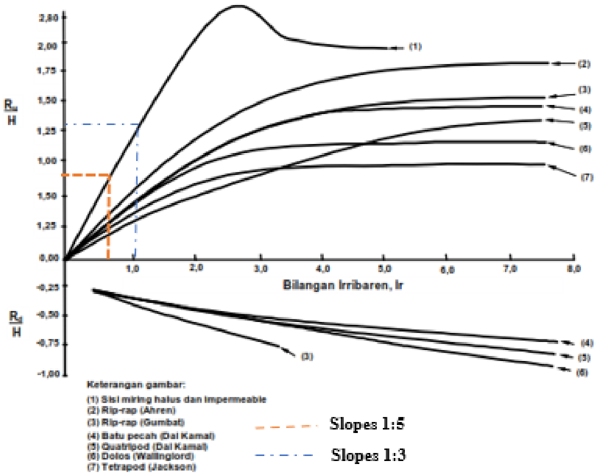

Figure 11. Calculation results of the irribaren value to the Ru/H value

From the graph above on Figure 12 with a structural slope of 1:3, the Irribaren value is 1.04 and Ru/H is 1.30, so the Ru value or wave run up can be obtained.

Ru/H = 1.30

Ru = 1.30 x H

Ru = 1.30 x 0,85 = 0,105 m

Meanwhile, for a slope of 1:5, the irribaren value is 0.71 and Ru/H is 0.8, so the Ru value or wave run up can be obtained

Ru/H = 0.8

Ru = 0.8 x H

Ru = 0.8 x 0,65 = 0,52 m

The data indicates that a safe distance to prevent overtopping of the structure is already achieved with the first alternative, which is to add a levee without changing the slope of the structure to 1:3. This suggests that overtopping can be addressed by adding a levee as a measure to reduce the impact of overtopping on the seawall structure. n the long term, the second and third alternatives are highly recommended to address global warming, as it will raise sea levels, which will affect the clearance of the structure. Further studies are needed to assess the impact of long-term global climate change.

TABLE 4. Overtopping volume on seawalls

Model	P (m)	L (m)	T (m)	Overtopping Lab Scale (m³)	Overtopping Real (m³)	Overtopping Real (ml)
Slope 1:3	0.485	0.115	0.049	0.0027	0,027	27
Slope 1:3 + Embankment	0.485	0.115	0.029	0.0016	0,016	16
Slope 1:5	0.485	0.115	0.01	0.0006	0,006	6
Slope1:5 + Embankment	0.485	0.115	0	0	0	0

The graph above shows that the alternative of adding an embankment using a 1:3 seawall slope, as per field conditions, has already been able to reduce overtopping. Therefore, the second and third alternatives do not need to be implemented, as the first alternative has already reduced overtopping by 40 percent. Thus, the first alternative, which involves adding a levee without changing the slope of the structure, is already sufficient to mitigate the impact of overtopping.

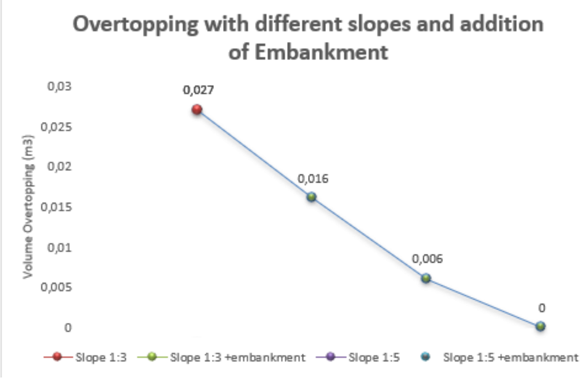

Figure 12. Volume Overtopping

CONCLUSIONS

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 stepped seawall with 1:5 slope and embankment height is 0.5 m.

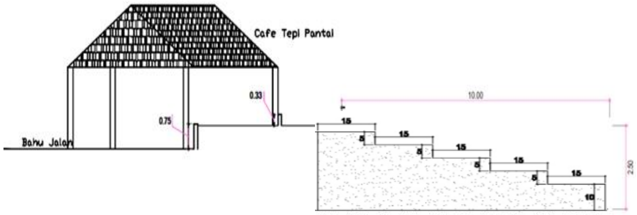

Figure 13. Slope of 1:5 recommended for seawall and embankment height of 0.5 m

REFERENCES

[1] CERC, 1984. Shore Protection Manual, Departement of the Army Waterway Experiment Station, Corps of Engineers, Coastal Engineering Research Center, Fourth Editioan, U.S. Government Printing Office, Washington, Hampshire, London.

[2] Triatmodjo, B. (2012). Teknik Pantai. Beta Offset. Yogyakarta.

[3] Wicaksono, Pangestu Ari, Pemodelan Numerik Run Up dan Overtopping Struktur Seawall Buis Beton, Jurnal Teknik ITS Vol 8 No 2, 2019

[4] Yuwono, Nur. 1982, “Teknik Pantai Volume I“, Biro Penerbit Keluarga Mahasiswa Teknik Sipil Fakultas, Teknik UGM. Yogyakarta.

[5] Abrori, 2009, Pengaruh Freeboard Terumbu buatan bentuk silinder berongga sebagai breakwater terbenam dalam mereduksi gelombang, Tesis Program Magister Teknik, Fakultas Teknik Kelautan ITS Surabaya.

[6] Akhwady, Rudhy. Mukhtasor. Armono, H.D. dan Mustain, Mahmud. (2008). Pengaruh Gelombang Reguler dan Irreguler Terhadap Koefesien Transmisi Peredam Gelombang Ambang Terbenam Tipe Silinder Berongga (Bottle Reef). Jurnal Kelautan Nasional, Balitbang KKP RI. Jakarta

[7] Armono, H.D. and Hall, K.R.(2003). “Wave Transmission on Submerged Breakwaters Made of Hollow Hemispherical Shape Artificial Reefs”. Canadian Coastal Conference at Queen University, Kingston, Canada.

[8] CERC, 1984, Shore Protection Manual Volume I, US Army Coastal Engineering Research Center, Washington.

[9] Durgappa, R.: Coastal protection works, Seventh International Con- ference of Coastal and Port Engineering in Developing Countries, COPEDEC VII, Dubai, 1–15 March 2008, 97, 2008.

[10] Fatnanta, 2009, Kajian Perilaku Transmisi dan Stabilitas Pemecah Gelombang Kantong Pasir Tenggelam, Disertasi Program Doktor Teknik dan Manajemen Pantai ITS Surabaya

[11] Harris, L.E. dan Marsha, P.W. (2001) Artificial Reefs for Submerged and Subaerial Habitat Protection, Mitigation and Restoration, Depatment of Marine and Environmental Systems, Flouride Institute of Technology, Melbourne.

[12] Hughes, S.A., 1993, Physical Models and Laboratory Techniques in Coastal Engineering, Coastal Engineering Research Center, USA.

[13] Kularatne, S. R., and C. Pattiaratchi (2008), Turbulent kinetic energy and sediment resuspension due to wave groups, Cont. Shelf Res., 28, 726–736, doi:10.1016/j.csr.2007.12.007.

[14] M. A. Beer and T. Srinceton, 1997, Plasma Physics Princeton Laboratory , New Jersey Princeton University Ahmed. Tarek, “*Reservoir Engineering Handbook*”, 3rd Edition, Elsevier Inc, 2006.