THE ROLE OF GEOTEXTILE TUBE AS LOW-CRESTED BREAKWATERS IN RESTORING SEVERE BEACH EROSION PROBLEM AT PEBUAHAN BEACH IN BALI ISLAND

Dede M. Sulaiman[1] and Hendra Hidayat[2]

Pebuahan Beach in Jembrana Regency, Bali has experienced severe beach erosion since the construction of the Nusantara Pengambengan fishing port, 10 km east of Pebuahan. Efforts to countermeasure the coastal problem has been carried out by many local residents, but failed due to strong longshore drift. Through a collaboration between the Research Center for Water Resources, the Bali Penida River Basin, and PT. Geotechnical Systemindo, the implementation of low-crested breakwaters (LCB) or PEGAR, made of Woven Geotextile Tubes was initiated. Four woven geotextile tubes C12.9 m with length varied from 20 m to 25 m were installed to form LCB with the length of 60 m, at distance to the coast of 50 m. The monitoring of shoreline changes was conducted over the 3 months after its installation, which shows the formation of a new shoreline with the amount of deposited sand of 185.8 m3. The breaking wave on LCB crest results in successfully controlling the longshore current, hence the longshore drift settles behind the LCB to form a new coastline. It is expected this field study can be treated as an additional input to improve LCB Guideline and to expand LCB effectiveness scope not only apply to shallow wave conditions and beaches such as on North coast of Java, but also can be applied more universally to a deeper coastal waters with high wave conditions.

Keywords : Low Crested Breakwaters, beach erosion, longshore drift, shoreline change, Geotextile Tube.

INTRODUCTION

Pebuahan Beach is located in Jembrana Regency, in the Northwest of Bali. The beach suffered from severe erosion which probably occurred due to the existence of a 1,100 m length of Jetty construction located about 10,000 m east of Pebuahan beach. The black sand beach with a moderate steep slope is a culinary tourism area with many visitors.

The impact of coastal erosion has resulted in a shoreline retreat that caused destruction of village houses and roads, resulting in the reduction of tourism. The level of damage to the coast caused by high waves of 0.5 to 4.95 m high, strong longshore current with velocity of 0.5 to 0.65 m / sec, and tidal range of almost 3 m. Community efforts to protect the shoreline from severe erosion were conducted, such as installing revetments made from gabions. However, due to rapid longshore current that caused erosion along the Pebuahan beach, these initiatives failed. (Bali Penida River Basin, 2015).

Figure 1. Location of Pebuahan Beach, Jembrana, Bali (Bali-Penida River Basin, 2015)

Pemecah Gelombang Ambang Rendah (PEGAR), technically known as Low crested breakwaters (LCB) is a coastal protection structure that is always overtopped by waves (RCWR, 2017). Armor on LCB is subject to wave action resulting in breaking waves (Pascual et al., 2007).

[1] Experimental Station for Hydraulics and Geotechnics,Jl. Ir.H.Juanda N0.193 Bandung 40135, Indonesia.
[2] PT.Geotechnical Systemindo, Menara MTH, Jl..MT.Haryono Kav.23, Jakarta 12820, Indonesia

LCB can be distinguished by the submerged breakwater in terms of freeboard, and can be grouped as reef breakwaters (Mead, 2009). The freeboard (Rc) for LCB can be either negative or positive, while Rc for submerged breakwater is always negative. Unlike LCB, in a conventional breakwater the diffraction around the structure is more dominant. Similarly, the reflection of the wave towards the sea is more dominant in the conventional structure. The main difference between Conventional breakwater and LCB lies in the amount of wave energy that can break above the structure. The conventional breakwater holds most of the wave energy, while LCB passes some wave energy over it to the shadow area behind the structure. LCB generates a convergent current that flows in the shadow region due to the set up of the water mass or piling up (Sulaiman, 2017). The hydrodynamic and morphodynamic properties of LCB are very different from the conventional breakwater, and have not been well understood. For example, there are several calculation formulas and procedures for predicting coastal response behind conventional breakwater (Burcharth et al., 2007).

The advantages of implementing LCB as a coastal protection method include 1) low visual impact on the surrounding environment; 2) LCB development costs are relatively low and proportional to the volume of materials used; 3) sedimentation effects behind structures; 4) wave overtopping LCB produces good water circulation behind the structure; 5) LCB is similar to coral reefs and attract fish and other coastal vegetation. However, LCB also has weaknesses and shortcomings, among these are: 1) danger to boat traffic; 2) wave overtopping and wave breakdown above LCB will cause an increase in water level, also known as piling-up, which will generate strong backflows around the gap; 3) LCB provides only partial wave attenuation; 4) LCB structure efficiency related to wave energy dissipation and sediment transport is much influenced by freeboard (Buccino and Calabresse, 2007; Sulaiman, 2017).

This paper shares field experience on LCB application using Woven Geotextile Tube installed at shoreline with a high wave, strong longshore current and tidal range nearly 3 m.

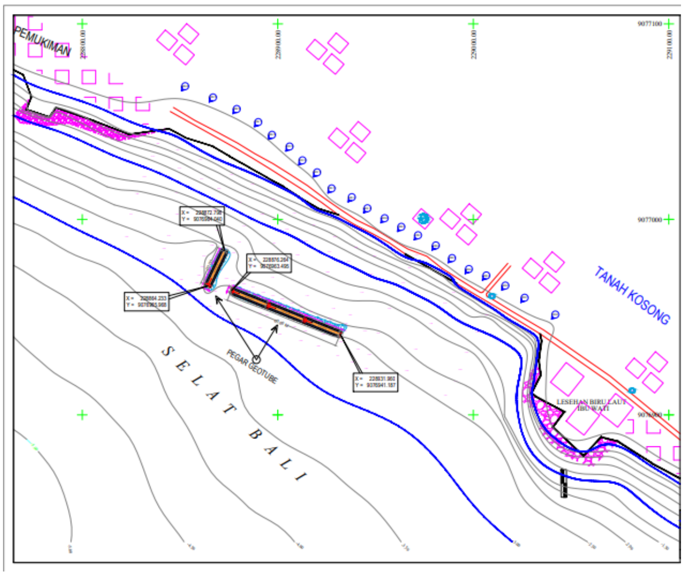

Figure 2. Plan view – Installation of LCB made from Woven Geotextile Tube at Pebuahan beach

METHODOLOGY

To find the best solution regarding Pebuahan beach erosion, in October 2018, through a collaboration between the Research Center for Water Resources, the Bali Penida River Basin Center and PT. Geotechnical Systemindo, a field experiment was conducted in the construction of low crested breakwaters structure (LCB). The LCB is an offshore breakwaters, a coastal protection structure with crest level between mean sea water level (MSL) and the highest water level (HWL), capable of restoring eroded coast. The LCB installed at Pebuahan beach is made of woven geotextile tube consists of 2 units with a length of 25 m (circumference of 12.9 m), and 2 units with a length of 20 m. They were installed at a distance to the coast of 50 m. To understand the performance of LCB structure in restoring eroded beaches, a shoreline change monitoring survey was carried out in January and April 2019. The measurement result of the cross-section and current profile give an approximation to the extent of LCB effectiveness in countermeasuring beach erosion.

RESULTS AND DISCUSSION

Low Crested Breakwaters As Wave and Current Rotator

The main function of the low crested breakwater is to reduce wave energy through the breaking of waves. Waves, when coming from the sea, will run-up and over the LCB crest, then it will break and produce vorticity behind the structure. The currents generated by these breaking waves weaken each other and lessening longshore currents which have an important role in causing beach erosion along Pebuahan beach. This current circulation phenomenon has resulted in the formation of salient and tombolo, which made the beach wider and restore areas that had previously eroded (Black and Andrew, 2001; Mead, 2009)

The results of monitoring in January and April 2019 show sedimentation behind the structure as much as 185.8 m^3. The sediment accumulation behind LCB consists of salient and tombolo formations, which are attached to the structure (Balai Pantai, 2019).

The LCB structure plays a role in changing the flow pattern behind the structure as shown in Figure 5. Before breaking and overtopping LCB, the direction of waves and the dominant currents are coming from the South. After breaking, on the left side of the LCB, the current leads to the Southwest, while behind the LCB the dominant current leads to the Northwest. The dominant current outside the influence of LCB, which is at the west side, leads to the Southwest (Figure 3)

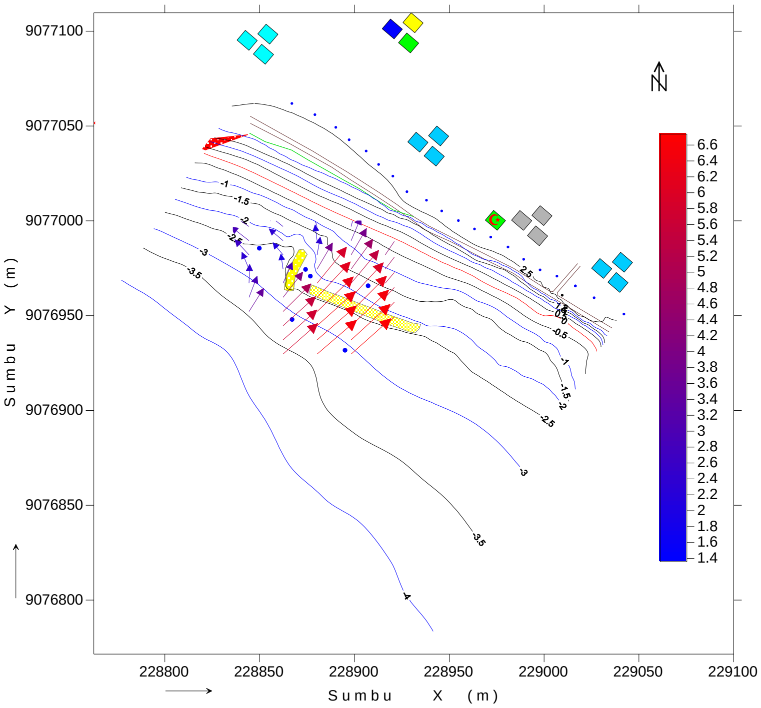

Figure 3. Current vector in 1m deep west side of the LCB location

Shoreline Changes

The profile of the shoreline cross-section measured on October 7, 2018 acts as the reference data for comparison to the future monitoring measurement. The monitoring results based on measurement taken on January 7, 2019, were then plotted to obtain a pattern of 3 months changes in the shoreline after installation.

The P1 profile of the Pebuahan, beach is under accretion condition or deposition of sediments, occurs as thick as 50 cm starting from a position of 10 m from the shoreline extending 25 m towards the sea. However, the eroded conditions, which were shown by the cross-section results of monitoring, were lower than the initial post-construction measurements. The segment that was eroded in the P1 profile occurs between the shoreline up to 10 m towards the sea and at position 35 m from the shoreline. In general, beach cross section at P1, demonstrate that accretion occurs.

P2 beach section which is similar to the profile P1. Erosion occurs on the shoreline as a result of the waves crashing during high tides which cannot be suppressed by the presence of LCB structure. Sedimentation occurs from a distance of 10 m up to 40 m from the shoreline. The pattern of changes in shoreline and thickness of accreted sediments is the same as in the P1 beach section. Moving to the west, the beach crossing at P3 coastal plain appears thicker and extends up to 50 m to the shoreline or about 5 m to the position of the LCB structure. At this beach section the sediment accretion is thicker than the profile of the beach at the east.

The P4 beach profile is a beach section behind the LCB structure. On the beach segment behind this LCB, the beach surface is higher, the accretion thickness is about 50 cm spread evenly, starting from the shoreline out to 45 m at a position 5 m behind the LCB. The greatest accretion or shallow siltation occurs just behind LCB, the sediment has been integrated with the LCB structure which is the Tombolo formation. Upon completion of LCB installation (7 October 2018) the water depth behind this structure is -2.5 m while the height of LCB after installation is 2.2 m. This P4 profile is at the left end (East) of LCB. The appearance of this P4 profile is shown in Figure 4 and net sedimentation along the beach is presented in Figure 5. Meanwhile the shoreline and tombolo formation are shown in Figurs 6,7 and 8.

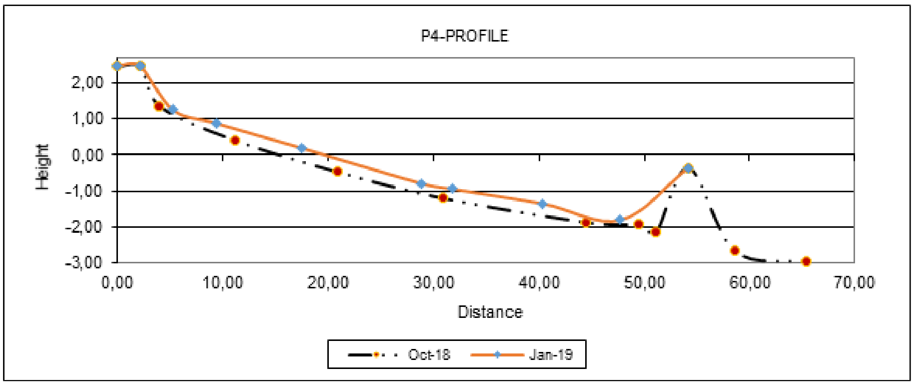

Figure 4. Cross section of P4 Profile

Tombolo formation extends to the west, as shown in P5 cross section. The surface of the beach looks more convex and the accretion is thicker than the cross section at the east side. Likewise, the coastal plain starts from the shoreline to the LCB structure sedimentary occurs evenly without decreasing depth. Abrasion or erosion condition occur at the cross-section of the beach P6, surface of the beach decrease again, lower than the condition of P6 during installation. The eroded part occurs up to a distance of 10 m from the shoreline, while accretion occurs from a distance of 10 m up to 35 m to the shoreline. Furthermore, up to the LCB, the contour remains the same as during installation in October 2018.

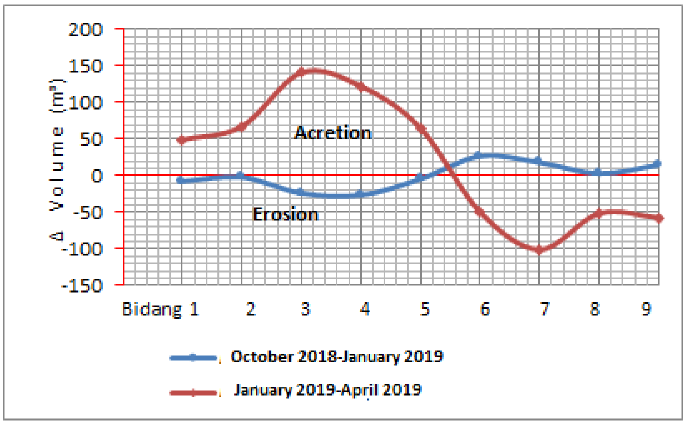

Figure 5. Erosion- accretion and net sedimentation behind LCB at Pebuahan Beach

Figure 6. Shoreline condition after installation 7 October 2018

Figure 7. Shoreline condition after monitoring 7 January 2019

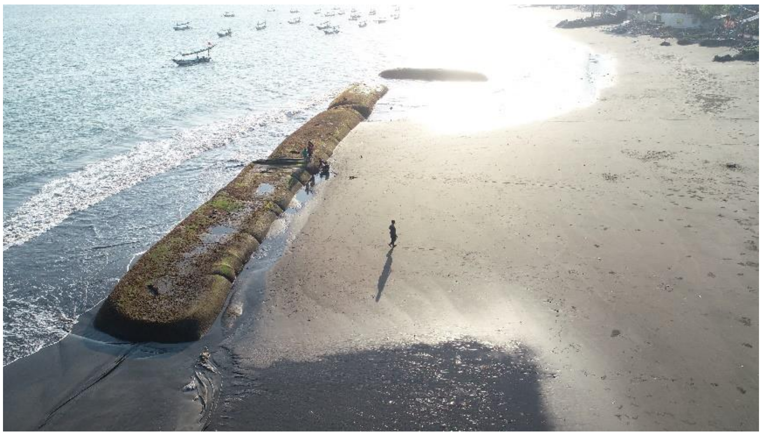

Figure 8. Shoreline condition of 1 August 2019

CONCLUSION

The rapid sedimentation process behind LCB made of woven Geotextile Tube, has shown how much the influence of low crest structure creates in the rotary current, which causes slow sediment velocity of longshore drift, so the sediment deposition occurs behind the LCB. Monitoring representing the west wind season, which was carried out on January 7, 2019, has produced 185.8 m3 of sand sediment deposited behind the LCB within 3 months after the installation on October 7, 2018. Although not all of the beach sediment behind the LCB reach the LCB body and formed Tombolo, the overall beach profile behind the low threshold structure has increased in the form of a new shoreline or Salient.

Changes in the coastline that experience a deficit that visually appears eroded, occur at both ends of the LCB, this is caused by the "flanking phenomenon", which is caused by the diffraction process at left and right edges of the LCB. Installation of low crest structure using woven geotextile materials at coastal area with high wave condition, strong coastal current, and steep slope are the challenges and also the solution to coastal erosion prevention initiative, which is relatively economical and affordable to the community. The science and technology study which is behind the experience of handling coastal erosion in this unique and extreme condition require more in-depth research, one aspect is the need for detailed measurement of the current with a long measurement period, to obtain a current pattern that can describe the process of sedimentation, especially in the area surrounding the low threshold structure.

ACKNOWLEDGEMENT

The authors would like to thank both individuals and institutions for the data, information, and materials allowing this paper to be prepared. My special thanks go to Director of Research Center for Water Resources; Chief of Experimental Station for Coastal Engineering; Chief of Bali-Penida River Basin, and Director of PT.Geotechnical Systemindo, Jakarta, for the opportunity and support to complete this paper.

REFERENCES

Bali-Penida River Basin, 2015. *Studi Kelayakan Pembangunan Breakwater Pantai di Kab. Gianyar, Kab. Jembrana, dan Kab. Buleleng*, Laporan Akir, Denpasar. 143 pp.

Bali Penida River Basin, 2019. *Drone photographs of Pebuahan beach in January and August Monitoring.* Laporan Dokumentasi. Denpasar.

Black, K.P. and Andrews, C.J., 2001. Sandy shoreline response to offshore obstacles, Part 1: Salient and tombolo geometry and shape. In: Black, K. P. (ed.), Natural and Artificial Reefs for Surfing and Coastal Protection. *Journal of Coastal Research*, Special Issue No. 29, pp. 82-93.

Buccino, M., dan Calabrese, M., 2007. Conceptual Approach for Prediction of Wave Transmission at Low Crested Breakwaters. *Journal of Waterway, Port, Coastal, and Ocean Engineering.ASCE*, pp. 213-224. Vol.133(3). Reston. Virginia.

Burcharth, H.F., Hawkins, S.J., Zanuttigh, B. and Lamberti, A., 2007. *Environmental Design Guidelines for Low Crested Structures*. pp. 213-231.Elsevier, Amsterdam.The Netherland.

Coastal Engineering Laboratory.2018. Installation of LCB Geotekstil Woven at Pebuahan Beach, Jembrana Bali. In: Istallation Report of LCB Geotekstil Woven.Buleleng. pp. 1–27.

Coastal Engineering Laboratory. 2019. *Monitoring Perubahan Garis Pantai Pebuahan Pasca Pemasangan LCB Geotekstil Woven. Jembrana*: Laporan Monitoring. Buleleng. pp1–31.

Mead. S.T. 2009. Wave Rotation for Coastal Protection. *Reef Journal*. Vol.1 (1). Raglan. New Zealand. pp.301-311.

Pascual CV, Mera FL, Rodriguez IL. 2007. Breakwaters Stability Analysis of Low Crested and Submerged Rubble Breakwaters: Relationship between Flow Characteristic. In: Proceedings of the 5th International Conference on Coastal Structures 2007. Venice-Italy. pp. 939–50.

Research Center for Water Resources, 2017 . Planning and Construction Manual of PEGAR Using Geotextile Tubes., Concensius Meeting, Bandung. 48 pp.

Sulaiman, Dede M., 2017. Segmented Low-Crested Breakwaters.. Deepublish, Yogyakarta. Ed-1, pp.28-72.