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STUDY ON THE DESIGN AND IMPLEMENTATION OF BPPT-LOCK ARMORED GROIN FOR SEDIMENT CONTROL STRUCTURE IN FRONT OF SEA WATER INTAKE

*Muhammad Zuhdan Jauzi, Dinar Catur Istiyanto, Aris Subarkah, Sungsang Urip Sujoko, Mardi Wibowo, Raka Firmansyah, Rizaldi Caesar Yuniardi
The National Research and Innovation Agency (BRIN)
*mzuh001@brin.go.id

Abstract

High-rate accumulation of sediment materials in front of the sea water intake (SWI) of a petrochemical factory cooling water system has caused high maintenance dredging costs. A study was conducted to identify the pattern and rate of sedimentation and to find an engineering solution that enables controlling sedimentation rate reduction. Based on numerical simulation, it is identified that the existing total rate of sedimentation around the channel in front of the SWI is 50 cm/year. Further numerical simulation series revealed an optimum mitigation scenario by the construction of a pair of groins along both sides of the channel in front of the SWI. Under this scenario, the average bed level change becomes 0.10 cm/year and the maximum value of the bed level change is around 24.96 cm/year. A BPPT-lock armored rubble mound-type structure was designed for this sediment control groin by considering its advantages. BPPT-lock is selected due to its high hydraulic stability (KD) of 17 for the trunk application and 13 for the head application. It is found that about twenty-five percent more armor unit numbers were required at the final stage of construction compared to the designed one. In this case, the calculation was designed for random placement, but the actual construction was in uniform placement. A calculation was made to compare the construction budget requirement between this constructed groin armored with BPPT-lock and if the same structure armored with tetrapod. The calculation result shows that BPPT-lock armor units required 64% less budget compared to the tetrapod.

Keyword: *BPPT-lock, Budget, Design, Groin, Sediment control*

1. INTRODUCTION

A petrochemical factory needs a cooling water system to keep the production process run normally. Under specific circumstances, the cooling water supply may be disrupted by any potential natural disturbance [1]. A case happened to a petrochemical factory in Indonesia where its Sea Water Intake’s front area was covered by currents and waves generated high-rate sedimentation. It is anticipated that this sedimentation will only get worse by which the supply of cooling water will become much limited and potentially stop the production [2]. Frequent maintenance dredging had been carried out, but it caused undesirable significant operation and maintenance costs [3].

An engineering solution is required in this regard to stop or at the very least to minimize the rate of sedimentation instead of dredging every year in front of sea water intake area [4]. A study to identify the pattern and rate of sedimentation, the possible alternative means to control the sedimentation and detailed engineering design of the selected sediment control’s structure were conducted [5]. Under several considerations, a rubble mound type groin is selected as the sediment control structure in the present case based on its performance, feasibility, ease of construction, and local availability of structure materials. In comparison to tetrapod, BPPT-lock was given the priority as the armor units due to its high coefficient of hydraulic stability (KD), which is 17 for the trunk application and 13 for the head application [6]. The sediment transport modeling, calculation design of BPPT-lock armored groin, and basic comparison between the possible use of BPPT-lock and tetrapod for the present case will be described in the following.

2. METHOD

Figure 1 shows the location of the study at a petrochemical factory in Tuban, East Java. Due to the currents and waves hydrodynamics around the area, sedimentation has occurred in front of sea water intake (SWI) area of its cooling water system. The amount of cold-water supply for the factory cooling system may decrease due to sedimentation that takes place in the sea water intake area. Additionally, the transfer of sedimentary material into pipes and equipment has the potential to impair the system performance of the petrochemical factory.

Figure 1. Sea Water Intake Area in Tuban, East Java [7]

The present study includes the activies of data collection and processing, data analysis for design, numerical simulation, detailed design of sediment control structure (groin) with BPPT-lock armored layer, detailed design of sediment control structure (groin) with tetrapod armored layer, and the budget comparison between the use of BPPT-lock and tetrapod for armor materials. Primary data were obtained through field data acquisition survey activities, including hydro-oceanography, bathymetry and topography, and sediment sample. The secondary data used in this study include wind/wave data, geotechnical data, and others. Primary and secondary data as well as numerical modeling were employed in the structural design process. The final output of the study is the design of groin as a sediment control structure.

The acquired primary and secondary data are then prepared and examined to be used as parameters in the groin design as a sediment control structure. Additionally, this data is also used in several numerical models such as sediment models and wave models. Iterations are required in the design process that needs numerical to acquire the most effective layout of the groin structure in minimizing or reducing the sedimentation rate in front of sea water intake (SWI) of the petrochemical factory cooling water system.

3. RESULT AND DISCUSSION

3.1. Survey Data

In this study, survey activities were carried out in 2018. In term of the survey, it was tide measurement, bathymetry, topography, currents, and sediment sample. Tide measurements were carried out using a Valeport Tide Master tool. The location of the tide measurements is made right in front of sea water intake on December 19, 2018, to January 9, 2019. The results show that the elevation of HHWL = 0.96 m and LLWL = -0.96 m, so the tidal range is 1.92 m. Furthermore, the Ceeducer Pro tools was used to measure the contours of the seabed.

Current measurement is carried out using the ADCP Bottom Mounted (ADCP BM) tools in front of sea water intake (SWI) [8]. With a maximum current velocity about 0.9 m/s and a dominant direction toward the southeast, the predominant current velocity in front of the SWI mouth at spring tide conditions is in the range of 0.1 to 0.3 m/s. Sediment characteristics, this study took 16 bottom sediments and suspended sediments that were evenly distributed [9]. Based on laboratory analysis, the bottom sediment has d50 between 0.05 - 1.6 mm (Figure 2), gradation coefficient 1.41-5.77, water content 30.6 – 206.3% and specific gravity 2.09 – 2.57 g/cm3. In the west, towards the open sea, the sediment size is getting coarser, this is because the current velocity in the high seas is relatively large. Meanwhile, around the anchorage pool, the distribution of grain size is irregular, possibly due to development activities in the vicinity. The concentration of suspended sediment in the waters of the study area ranges from 30 – 160 mg/L.

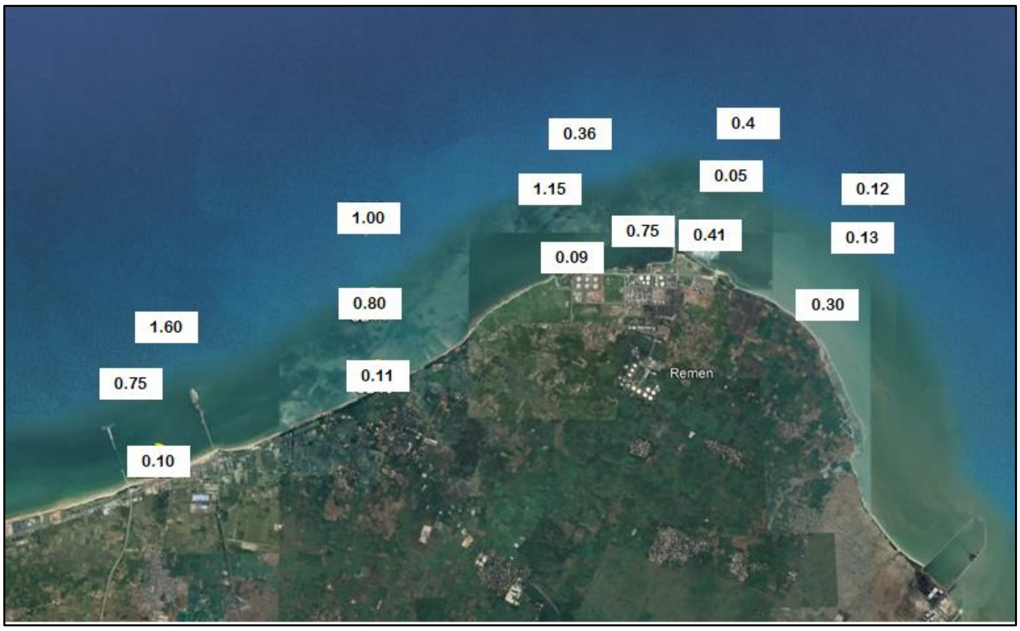

Figure 2. Distribution D50 Bottom Sediment (mm) [7]

3.2. Wave and Sediment Transport Modeling

Coastal dynamics computational modeling is a computer-based system that simulates and solves mathematical equations of beach processes using numerical methods [10]. This modeling includes wave and transport modeling. This modeling aims to obtain the wave height at the SWI and the most optimal (effective) design (layout) of sediment control.

The wave modeling scenario is carried out for a 25-year return period under existing conditions, water level elevation in HWL conditions (+0.96 m from MSL), and dominant wave direction from the northwest. The input waveform for the 25-year return period is a significant wave height of 3.8 m, period 7.8 s and wave direction from 315°. Based on this scenario, the wave height around SWI is around 2.67 m (Figure 3). The wave modeling results shown that there is refraction due to variations in bathymetry, diffraction by gaps between breakwaters, as well as reflections by breakwater structures and other structures at the TPPI port. At some locations, the superposition between the incident and reflected waves produces a wave height that is mutually amplifying or diminishing, depending on the phase difference between the incident and reflected waves.

The bottom sediment in the study area is classified in non-cohesive sediment, so the modeling is done using the MIKE-21 Sand Transport module. This module simulates in coupling between the hydrodynamic model and spectral waves [11]. This sediment transport modeling domain covers an area of 14 km × 10 km. The modeling was carried out for 1 year (January-December 2018). This modeling was carried out with 11 scenarios (design/layout variations), namely existing conditions and 10 variations of sediment control designs. Sediment control design takes into account the shape, length, position (location), and number of groins. The sediment control design was developed until the desired sedimentation rate was obtained.

Based on the modeling results on the existing conditions during January-December 2018 significant sedimentation occurred around the mouth of the sea-water intake, namely + 50.9 cm.

Based on the modeling of various variations of sediment control designs, it is known that the structure greatly affects the average bed level change in the SWI. These results show that the most optimal design has an effectiveness of 99.8%. With this design, the average bed level change in the sea water intake is only about 0.1 cm/year with a maximum value of 24.69 cm (Figure 4).

This means that the total sediment at the mouth of the sea water intake is only about 1.94 m^3/year. The maximum value is mainly due to the accumulation of bedload sediments in the SWI basin or channel. The sedimentation did not originate outside the SWI basin/channel because basically sediment from outside the SWI basin/channel was largely restrained by existing sediment control structures.

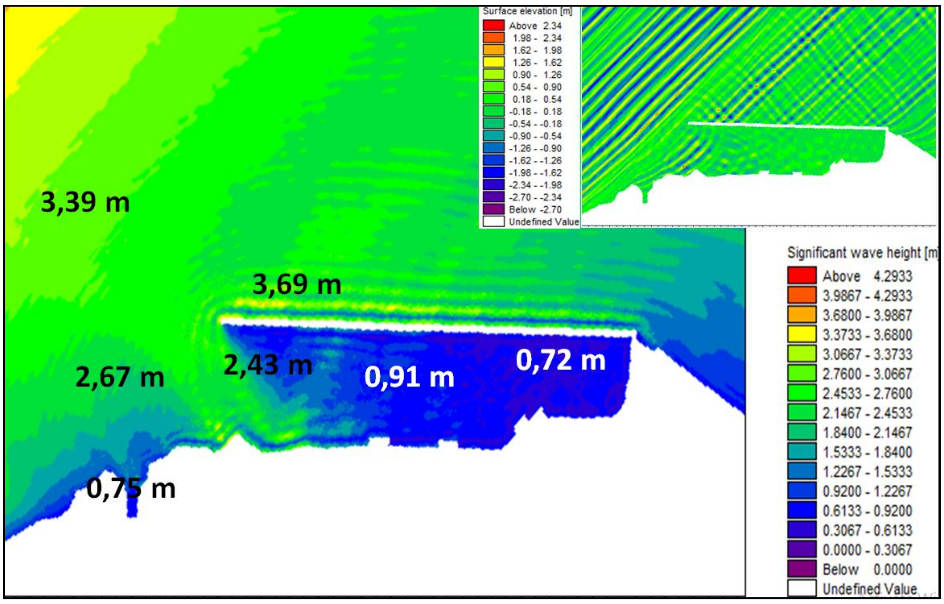

Figure 3. Results of Wave Propagation Modeling for Return Period 25 Years [12]

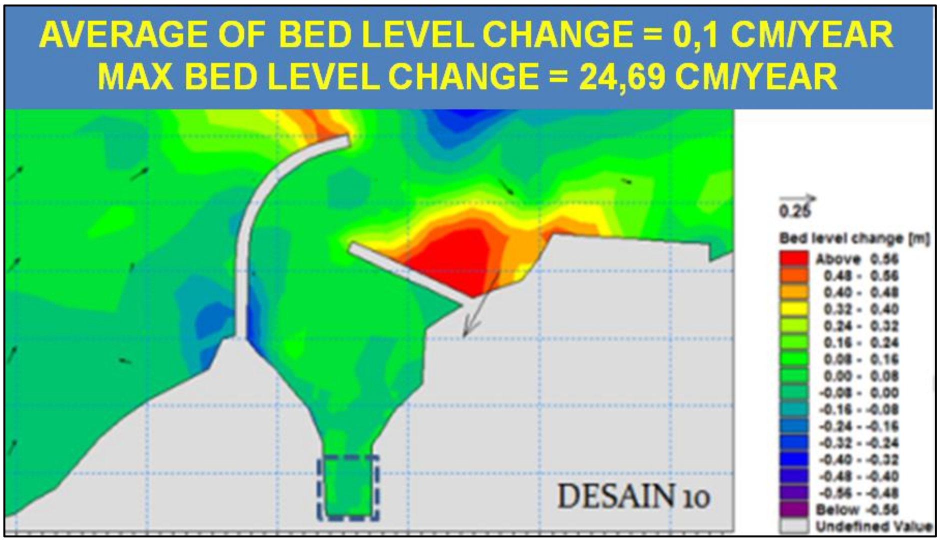

Figure 4. Result of Sediment Transport Modeling for 10th Design [12]

3.3. Design of BPPT-lock Armored Groin

Calculation of the weight of the armor layer on the groin as sediment control structure in this study using the Hudson equation, and the results are shown in the Table 1 below.

Table 1. Calculation of BPPT-lock as Armor Layer with Random Placement

H (m)	γ concrete (ton/m^3)	γ sea water (ton/m^3)	KD	Cot θ	N (Crest)	N (Side)	KΔ	Porosity (%)	W (ton)	W (kg)
2.67	2.2	1.025	13	1.5	3	1	1.11	57	1.43	1,425.5

According to the Table 1, the BPPT-lock weight that required is 1,425.54 kilograms, and it is advised to use a BPPT-lock in the field with weight 1,500 kilograms, or 1.5 tons. The layout of the groin as a sediment control structure in the area of sea water intake (SWI) are shown in the Figure 5.

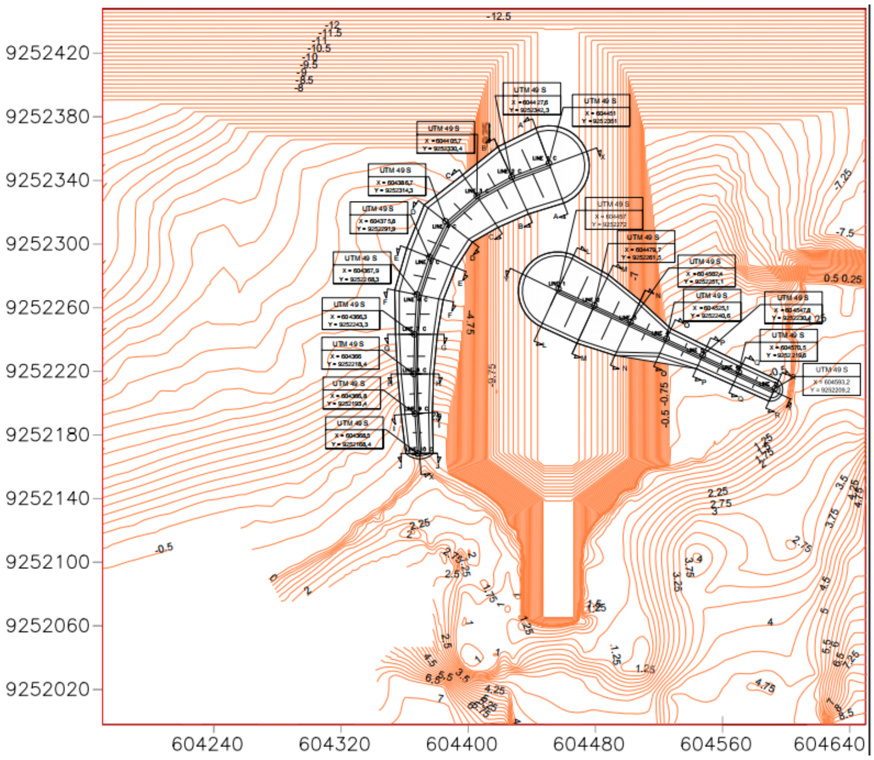

Figure 5. Layout of Groin as a Sediment Control Structure

As for the east side groin structure's cross section (Figure 6), which uses the 1.5 tons of BPPT-lock, the elevation of top structure is +3.2 m with 2.5-7.5 kg gradation of core layer and 150 kg of unit on the secondary layer. However, in addition to the 1.5 tons of BPPT-lock, a 0.75 tons BPPT-lock is required in the other part of the groin structure [12].

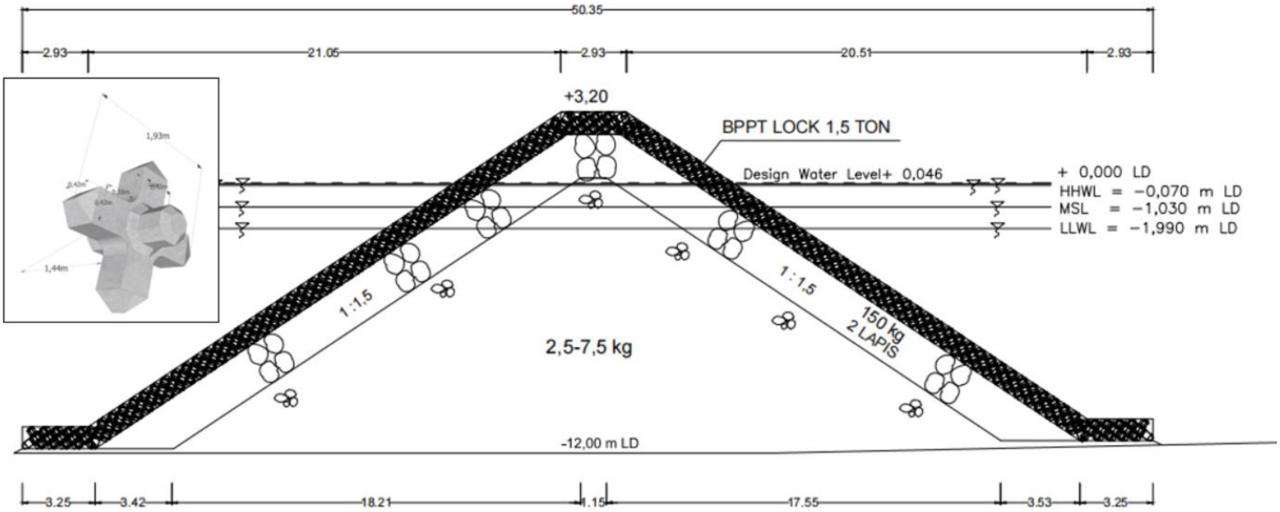

Figure 6. Cross Section of East Side Groin Structure

3.4. Comparison of BPPT-lock with Tetrapod Technically and Economically

With a same design and placement (random), here are the budget of each construction with different armor layer.

Table 2. BPPT-lock Budget

No	Item	Amount	Unit	Unit Price (IDR)	Price (IDR)
1	BPPT-lock 0.75 tons	7,398	unit	1,352,235	10,003,838,968

No	Item	Amount	Unit	Unit Price (IDR)	Price (IDR)
2	BPPT-lock 1.5 tons	4,253	unit	2,157,811	9,177,171,03
3	Move BPPT-lock to yard	11,651	unit	458,705	5,344,371,955
4	BPPT Lock placement	11,651	unit	538,605	6,275,286,85
5	Core stone 1.25 – 7.5 kg	34,376	m^3	325,888	11,202,763,110
6	2nd layer stone 100-200 kg	10,837	m^3	360,888	3,911,190,069
7	2nd layer stone 50-100 kg	8,580	m^3	335,888	2,881,964,455
8	Dredging	10,853	m^3	85,000	922,514,740

Table 3. Tetrapod Budget

No	Item	Amount	Unit	Unit Price (IDR)	Price (IDR)
1	Tetrapod 1.6 tons	9,739	unit	2,126,220	20,707,256,580
2	Tetrapod 3.1 tons	5,694	unit	3,607,058	20,538,585,405
3	Move Tetrapod to yard	15,433	unit	458,705	7,079,194,265
4	Tetrapod placement	15,433	unit	538,605	8,312,290,965
5	Core stone 1.25 – 7.5 kg	34,376	m^3	335,889	11,546,523,519
6	2nd layer stone 100-200 kg	10,837	m^3	535,889	5,807,781,100
7	2nd layer stone 50-100 kg	8,580	m^3	385,889	3,310,970,328
8	Dredging	10,853	m^3	85,000	922,514,740

A groin structure required 0.75 tons BPPT-lock and it is equivalent to 1.6 tons tetrapod. Total budget of groin construction with BPPT-lock as armor layer is around 49,719,101,188 IDR. Meanwhile, total budget with tetrapod armor layer is around 78,225,116,902 IDR. So, groin structure construction with BPPT-lock armored layers required only 64% of groin construction with tetrapod armored layers budget. Meanwhile, the actual number of armor unit were greater than the designed one. It was designed for random placement, but the actual construction was in uniform placement. With layer coefficient ($K\Delta$) of random placement is 1.11 and uniform placement is 1.37, the difference of armor unit number is equal to 1.23. So, uniform placement required about 25% higher number of armor units.

3.5. Implementation

The sediment control structure on this petrochemical factory consists of the west and the east part of the structure. The west groin has been finished thus far, and it measures roughly 240 meters in length. The main sorts of construction of this structure such as preparation, setting up the area of BPPT-lock production, production, maintenance, transportation, and installation.

Figure 7. Location of Groin Structure [12]

Figure 8. Production Area [13]

Figure 9. Installation on the West Groin [13]

4. CONCLUSION

This study was carried out to identify the pattern and rate of sedimentation in front of a Sea Water Intake as well as to develop an engineering solution for reducing the sedimentation rate. The results of the study can be summarized as follows: 1) Based on numerical simulation, it is identified that the existing total rate of sedimentation around the channel in front of the sea water intake (SWI) is 50 cm/year. 2) An optimum design simulation result of a pair of groins constructed along both sides of the channel reduces the average bed level change to 0.10 cm/year and the maximum value of the bed level change is around 24.96 cm/year. 3) Two different dimensions of BPPT-lock armor units were employed for the groin structure, i.e., 1.5 tons and 0.75 tons, which costs only about 64% of the budget required for the same structure with tetrapod armor units.

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