The Effect of Pole Density on Permeable Groin Due to Controlling Longshore Current

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Abstract. Erosion and sedimentation problems that occur, usually solved firstly by finding the cause of erosion and sedimentation literally, due to determining the action to overcome them. In coastal engineering, there are two approaches that can be used to solve such kind of problems; which are the soft approach, i.e. beach nourishment, vegetation, sand by passing, coastal boundary policy; while the hard approach or structural approach are building breakwater, jetty, groin, sea wall and so on. In structural approach, the uses of permeable groin nowadays is one of the new ways to overcome the erosion and sedimentation problems in beaches. To find out how efficient the permeable groin can control the flow along the coast, so called longshore current, a research needed to be conducted focusing on the effect of pole density at permeable groin itself. The ability of controlling longshore current will be the main analysis, in such various variations of pole densities at the permeable groin. It found out that the pole densities of permeable groin can significantly controlled the longshore current; which is if the pole density become higher than the speed of longshore current can be reduced. It also found out that by implementing 40% of pole density, the longshore current can be reduce up 50% respectively.

1. Introduction
Groin is a coastal protective structure made perpendicular to the shoreline and used to control the movement of sedimentary materials mainly to control the amount of current along the coast and sediment transport along the coast [1]. In addition, groins can also be used to withstand the entry of sediment transport along the coast to the port or river mouth. The groin structure has been widely used as a shoreline structure, for example at the port of Richards Bay, which uses four impermeable groin structures mounted in series to protect the parrots along the Richards Bay harbor. The groin structure successfully protects the shoreline from the storm without causing damage to the structure and shoreline. In addition to the coastline of Richards Bay Harbor channel, the groin structure has also been used on Westhampton, Long Island, New York [2] and along the Northwestern Coast [3]. At Northwestern Beach, a coastline overview was observed prior to the existence of a groin structure and after a groin structure, the results of the analysis showed that the series groin structure provides larger current and sediment transport reductions than a single structure. In Indonesia the use of groin structures as shoreline protectors has also been widely used, for example in Pasauran Beach, Serang District, Banten Province [4]. On the coast of Pasauran sediment transport amounted to 7,514.88 m³/year, sediment transport is causing the retreat of the coastline which has been a residential and tourist area.

The use of the groin structure described above is an example of an impermeable groin structure. A high impermeable groin and its length covering the width of the surf zone resulted in sediment transport along the retained coast in the up drift groin section and on the down drift groin of sediment transport...
continues to occur so that erosion occurs in the down drift groin due to the absence of sediment supply to the down drift. Therefore there is a considerable difference in coastline changes in the up drift and down drift groins. To overcome this, groin permeable can be used. The permeable groin has an aperture structure so that there is still a current passing through the structure so that sediment transport to the down drift groin can still occur. The amount of current and sediment transport along the coast in the permeable groin is controlled by the small gap density in the groin structure. The permeable groin structure has also been widely used in particular the permeable groin structure of the mast. One example of the use of permeable pole groins is discussed in [5], the permeable groin on the Baltic Sea coast. The permeable structure of the poles can reduce the flow and sediment transport along the coast but still provide the sediment supply to the down drift groin.

2. Groin Permeable Surface Current Flow through Groin Permeable Obstacles

The longshore current equation based on [6] is the coastal drift caused by differences in radiation stress, where they have studied the theory of radiation stress i.e. the excess flow of momentum generated by waves. The stress radiation theory can be used to describe the various phenomena occurring in the surf zone, for example explaining the setup, parallel currents, rip currents and others. In [7] the current equation along the coast through the permeable groin barriers can be developed from the Longuet-Higgins equation. The development of the current velocity equation along the coast through the permeable groin of the pole is derived from the y-direction momentum equation (parallel to the shoreline) after the obstacles of the groin structure, hence then obtained by the following equation [7],

\[ \langle v \rangle_{\text{groin}} = \frac{5Hb \sqrt{g} \sin \alpha b}{2\pi f + 4C_p} \left( \frac{2\pi \sigma c_{fl}^2}{2\pi d_t} \right) \] (1)

Through the linear wave theory approach for shallow water in [8] the current velocity equations along the coast after permeable groins can also be written as follows [7],

\[ \langle v \rangle = \begin{cases} \langle v \rangle_b & h < Hb \\ 0 & h > Hb \end{cases} \] (2)

With

\[ \langle v \rangle_b = \frac{5Hb \sqrt{g} \sin \alpha b}{2\pi f + 4C_p} \left( \frac{2\pi \sigma c_{fl}^2}{2\pi d_t} \right) \] (3)

with groin density (p) can be formulated as follows [7],

\[ p = \frac{N\pi d_t^2}{4L_g d_t} \times 100% = \frac{N\pi d_t}{4L_g} \times 100% \] (4)

3. Experimental Setup

The effect of parameters of groin permeable density on the control of coastal streams are two things to be observed, i.e. the phenomenon of coastal drift in the permeable groin structure and the permeable groin structure parameters that affect the current along the coast after the permeable groin structure. Theoretically, the parameters of breaking wave height \((Hb)\) and breaking wave angle \((\alpha b)\) are required to determine the amount of current along the coast \((v)\). So in this research phase will be observed changes that occur to the parameters after the permeable groin structure. In addition to current parameters, this stage of the research will also be observed parameters of permeable groin structure i.e. pole diameter.
(\(dt\)), pole spacing (a), and distance between groin structure (B) which influence to the amount of current along the coast.

In the early stages of this study, a model design of the permeable groin structure will be used in accordance with the model design in Table 1. Furthermore, the permeable groin model and measuring instrument are placed in accordance with the drawings of the research design. After the groin model and the measuring instrument are placed in a predetermined position then observations and measurements of influential parameters are taken.

### Table 1. Permeable Groin Model Variation Design

| Model | Diameter (\(d_t\)) (cm) | Pole Spacing (a) (cm) |
|-------|-------------------------|----------------------|
| M2    | 1.5                     | 0.7                  |
| M3    | 1.5                     | 0.7                  |
| M4    | 1.25                    | 0.7                  |
| M5    | 1.25                    | 0.7                  |
| M6    | 1.5                     | 1.0                  |
| M7    | 1.5                     | 1.0                  |
| M8    | 1.25                    | 1.0                  |
| M9    | 1.25                    | 1.0                  |

4. **Experimental Result**

Measurements of coastal currents were carried out on 6 variations of the measurement condition i.e. condition without groin structure, condition with impermeable groin and condition with groin permeable 54\%, 51\%, 47\% and 43\%. If an impermeable or groin permeable structure is used to control the current along the shore, the flow along the mean coast (v) will be reduced due to the obstacles of the groin structure. The reduction of coastal current velocity is shown in Tables 2, 3, 4, 5 and 6. While the ratio of current velocity along the coast to the condition without groin, impermeable groin and permeable groins are shown in Figure 2 and 3.
Table 2. Reduction of current velocity along the coast in impermeable groin conditions

| Breaking Wave Height, $H_b$ (cm) | Average Velocity without Groin (buoys) (cm/s) | Average Velocity after Impermeable Groin (cm/s) | Reductions (%) |
|----------------------------------|-----------------------------------------------|-----------------------------------------------|----------------|
| 5.16                             | 27.94                                         | 5.94                                          | 80.08          |
| 3.52                             | 21.47                                         | 4.43                                          | 82.49          |
| 3.08                             | 18.40                                         | 1.75                                          | 91.2           |

Table 3. Average velocity reduction with permeable groin of 54% ($d_t = 1.5$ cm; $a = 0.7$ cm)

| Breaking Wave Height, $H_b$ (cm) | Velocity without Groin (cm/s) | Velocity in Groin permeability of 54% (cm/s) | Reductions (%) |
|----------------------------------|-------------------------------|-----------------------------------------------|----------------|
| 5.16                             | 27.94                         | 12.95                                         | 53.65          |
| 3.52                             | 21.47                         | 9.55                                          | 55.50          |
| 3.08                             | 18.40                         | 7.84                                          | 57.40          |

Table 4. Average velocity reduction with permeable groin of 47% ($d_t = 1.5$ cm; $a = 1.0$ cm)

| Breaking Wave Height, $H_b$ (cm) | Velocity without Groin (cm/s) | Velocity in Groin permeability of 47% (cm/s) | Reductions (%) |
|----------------------------------|-------------------------------|-----------------------------------------------|----------------|
| 5.16                             | 27.94                         | 13.88                                         | 50.32          |
| 3.52                             | 21.47                         | 10.90                                         | 49.20          |
| 3.08                             | 18.40                         | 8.94                                          | 51.42          |

Table 5. Average velocity reduction with permeable groin of 51% ($d_t = 1.25$ cm; $a = 0.7$ cm)

| Breaking Wave Height, $H_b$ (cm) | Velocity without Groin (cm/s) | Velocity in Groin permeability of 56.67% (cm/s) | Reductions (%) |
|----------------------------------|-------------------------------|-----------------------------------------------|----------------|
| 5.16                             | 27.94                         | 11.27                                         | 59.66          |
| 3.52                             | 21.47                         | 9.13                                          | 57.49          |
| 3.08                             | 18.40                         | 8.53                                          | 53.66          |

Table 6. Average velocity reduction with permeable groin of 43% ($d_t = 1.25$ cm; $a = 1.0$ cm)

| Breaking Wave Height, $H_b$ (cm) | Velocity without Groin (cm/s) | Velocity in Groin permeability of 80% (cm/s) | Reductions (%) |
|----------------------------------|-------------------------------|-----------------------------------------------|----------------|
| 5.16                             | 27.94                         | 12.3                                          | 56.02          |
| 3.52                             | 21.47                         | 10.44                                         | 51.36          |
| 3.08                             | 18.40                         | 9.52                                          | 48.25          |
Figure 2. Relationship between Breaking Wave Height ($H_b$) with Longshore Current Velocity ($v$) from groin with permeability of 54% and 47% at $d_l = 1.5$ cm.

Figure 3. Relationship between Breaking Wave Height ($H_b$) with Longshore Current Velocity ($v$) from groin with permeability of 51% and 43% at $d_l = 1.25$ cm.

Figures 2 and 3 shows that the longshore current velocity occurring after the permeable groin structure is greater than the speed after the impermeable groin. This indicates that the permeable groin current is not completely dissipated by the groin structure. The longshore current happens to be controlled by the size of the groin density; which is the greater percentage of the groin density, the ability of the groin structure in passing the stream will decrease respectively.

5. Conclusion
Groin density ($p$) is a permeable groin parameter that affects the current along the coast; which the smaller the percentage of the groin density than the greater the current that can pass through the groin
structure. So it can be concluded that the longshore current can be controlled by the groin structure through the large percentage of its density. The results showed that 54% of the groins density was able to reduce the current by 53.65% and 47% of the groin density was able to reduce the current by 50.32%. To determine the amount of current to be reduced can be done by adjusting the size of the groin density. This behavior can be expected to be on the same pattern on sediment transport along the coast, respectively.

6. References

[1] Yuwono N, 1992, Dasar-Dasar Perencanaan Bangunan Pantai, Pusat Antar Universitas, Pusat Studi Ilmu Teknik, Universitas Gadjah Mada, Yogyakarta.
[2] USACE, 2002, Coastal Engineering Manual, Washington, D.C.
[3] Abdellah and Balah, 2001, Application of Permeable Groins On Tourist Shore Protection, 4th Inter. Symp. On ocean wave measurement and analysis, ASCE, San Francisco, California, USA, Sep. 3-5.
[4] Dedi Junarsa, 2006, Study of erosion and Solving system at Pasauran beach, Kabupaten Serang – Propinsi Banten. Magister Tesis ITB, Bandung.
[5] Raudkivi, 1996, Permeable Pile Groin, Journal of Waterway, Port, Coastal, and Ocean Engineering, ASCE.
[6] Longuet-Higgins, 1970, Longshore Currents Generated by Obliquely Incident Sea Waves,1, Journal of Geophysical Research, Vol.75, No. 33, 20 November 1970.
[7] Hasdinar Umar, Nur Yuwono, Radianta Triatmadja, Nizam, 2013, Theoretical Approach of Longshore Current Reduction Coefficient Through Permeable Groin, Prociding of 4th International Seminar of HATHI, 6-8 September 2013, Yogyakarta.
[8] Longuet-Higgins, 1970, Longshore Currents Generated by Obliquely Incident Sea Waves,2, Journal of Geophysical Research, Vol.75, No. 33, 20 November 1970.