The Effect of Permeable Groin on Longshore Current

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Abstract: Breaking wave on a beach at certain angle generates longshore momentum flux that causes longshore current. Such longshore current may be controled by coastal structures such as groin. The objective of this research is to study the influence of permeable groin on the velocity of longshore current. Permeable groin may be used to control and hence optimize the magnitude of longshore current and the longshore sediment transport. This research study the influence of permeable groin on the longshore current under various groin permeability. The model used in this research was a fixed bed model with bottom slope of 1:6 (vertical: horizontal). Two different groin permeabilities were selected for the research, these were 46.67% and 80%. The results of this research showed that groin structure modify both the direction and velocity of longshore current. The 46.67% groin permeability resulted in larger reduction of longshore current when compare with that of 80% permeability.

Keywords: longshore currents, groin permeable, groin permeability

1. INTRODUCTION

Longshore current is caused by breaking wave at an angle to the beach line. Such current may transport sediment that have either been disturbed and lifted by breaking wave or those which were still at the bottom undisturbed by the wave. This sediment which were carried along the shore, is called longshore sediment transport. Slowly, this carrying sediment current may cause erosion along the shore.

Groin is one of the beach protecting structures used to control the longshore sediment transport in order to reduce the erosion. There are two types of groin structures: impermeable and permeable. With impermeable groin, longshore current cannot pass through the structure and consequently causes sudden change to the beach line at the up drift and down drift part of the groin. To avoid such sudden change the permeable groin structure is used to enable a certain amount of longshore current and sediment to pass through the groin to the down drift part. With permeable groin structure, longshore current is controlled by the rate of permeability. This research discusses the size of the reduction of longshore current velocity due to permeable groin.

The objective of this research is to measure the longshore current velocity due to permeable groin and determine the rate of longshore current reduction due to such structure. Based on the finding it is expected that the longshore sediment transport through permeable groin may be computed.
2. LITERATURE STUDY AND BASIC THEORIES

2.1. Previous Studies

Researches on longshore current and permeable groin structure have been carried out by several researchers. The authors have studied the influence of pile groin permeable to the steady state current velocity using the 2D models. This research used permeable groin pile with four variations of porosity ratios. Result of this research showed that permeable groin with porosity ratio (a/d) of 80% and 56% reduced the current velocity by 24.9% and 41%, respectively. The larger the groin porosity ratio, the smaller is the reduction of current velocity.

Elfiky, et.al. (2003) studied the influence of breakwater pipes on the wave transmission on 2D physical models. This research used three variations of porosity (a/d): 22%, 46% and 77%. Results of this research showed that wave transmission coefficient (K_T) and wave gradient (H_i/gT^2) has large values for various porosity ratios. A porosity ratio of 22% gave 56% wave transmission coefficient (K_T). Low permeability produced low transmission coefficient.

Abdellah (2002) studied the application of pile permeable groin structure as the protecting structure for the tourism beach in Northwestern, Egypt using the simulation of the beach line and calibration model using the GENESIS software with groin porosity ratio of 27%. Result of this research showed that the beach line changing was functions of groin structure, shore, wave, wind and tide. The use of serial groin gave a result of current reduction and sediment transport that was larger than single groin.

2.2. Wave Breaking

The wave propagation from deep water to the beach experiences changing of form due to reducing depth. In deep water, the wave profile is sinusoidal, and when approaching shallower water, the wave crest begins sharper while the wave trough is flatter and longer. Also, the velocity and wave length lessen gradually but the wave height increases.

Criteria to determine for wave to start breaking are wave steepness and wave height ratio to the water depth (Dominic, et.all, 2004). The criteria may be written as:

1. Wave steepness, H/L < 1/7,
2. \( \gamma_b = \frac{H_b}{h_b} = 0.78 \), \( \gamma_b \) with values of 0.4 to 1.2 depending on the beach slope and breaker type.

2.3. Longshore Current

Longshore current has long been understood as the result of incoming wave to the beach at certain angle (not perpendicular). Modern theory on longshore current has been developed especially in the late 1960-s to the beginning of 1970-s after the Radiation Stress concept was introduced. Incoming wave to the beach direction at certain angle generate longshore momentum flux that causes generating factors to longshore current. In other words, at beach areas with oblique waves (\( \alpha_b > 5^\circ \)), the longshore current is likely to occur.

Longuet-Higgins (1970) derived an equation of longshore current as the follows.

\[
V_o = \frac{5 \tan \beta}{16 C_f} \left( \gamma_b \sqrt{gh_b \sin \alpha_b} \right)
\]  

where \( \tan \beta \) is beach gradient, \( C_f \) is friction coefficient, \( \gamma_b \) is breaking index parameter (\( \gamma_b = \frac{H_b}{h_b} \)) and \( \alpha_b \) is wave breaking angle.

Komar (1979) has also developed a theory of longshore current. Field data analysis by Komar (1979) showed that \( \tan \beta / C_f \) was effectively constant and hence equation (1) may be written as (Komar, 1979)

\[
V = 2.7 \cdot u_{reb} \cdot \sin \alpha_b \cdot \cos \alpha_b
\]  

(2)
where \( u_{mb} \) is maximum oscillation velocity \( (u_{mb} = \frac{\gamma b}{2} \sqrt{gh_b}) \); \( \alpha_b \) is wave breaking angle. In equation (1), it is assumed that \( \alpha \) is small therefore \( \cos \alpha = 1 \). The distribution of longshore current at wave breaking can use the Longuet-Higgins's and Komar's equations.

3. LABORATORY RESEARCH

This research used 3D physical models in the laboratory. Simulation was started without permeable groin model with 3 variations of wave height. Model simulation was carried out at wave basin using wave generator. For each condition of wave height, observation of wave breaking condition and longshore current was recorded. Simulations of each model variation is presented on Table 1. below.

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Variations</th>
<th>Wave Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>Without groin</td>
<td>3 variations</td>
</tr>
<tr>
<td>Model 2</td>
<td>Groin impermeable</td>
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<tr>
<td>Model 3</td>
<td>Groin permeable (d1= 1.5 cm; a = 0.7 cm)</td>
<td></td>
</tr>
<tr>
<td>Model 4</td>
<td>Groin permeable (d1= 1.25 cm; a = 1.0 cm)</td>
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</tr>
</tbody>
</table>

![Figure 1 Sketch of groin permeable model](image1)

![Figure 2 Sketch of beach and groin permeable models](image2)
Simulation was carried out by generating regular wave using wave generator. The heights of incoming wave and wave breaking were measured using the wave height meter, while the wave breaking angle was observed using a video camera. The velocity of longshore current was measured using **Acoustic Doppler Velocimeter (ADV)**. Location of measurement is shown in Figure 3.

In order to be able to determine the longshore current and compare them with the theoretical formulas, the output of this research should consists angle of wave breaking ($\alpha_b$), height of wave breaking ($H_b$), and friction coefficient ($C_f$). Further the effect of groin structure parameters such as the pile diameter (d), distance between piles (a), permeability (a/d), distance between groins (B) and groin length (L) will be simulated to analyze the reducing of longshore current velocity. This Paper will focus on the influence of permeability of the groin (a/d) on longshore current.

### 4. RESULTS AND DISCUSSIONS

The results of each simulation at with and without groin condition, were analyzed and compared to each other in order to identify the groin permeability effective level in reducing the velocity of longshore current.

#### 4.1. Relation between Wave Height and Current Velocity

The velocity of longshore current was influenced by the wave height. Comparison between data of measured and calculated longshore current velocity using Komar’s (1979) equation is shown in Figure 4.
Current velocities without groin was larger than those with groin structure. Groin model with small permeability (46.67% permeability) resulted in a larger reduction of current velocity than one with large permeability (80% permeability). This is due to the pile that hamper the current velocity. The larger is the groin permeability, the larger is the current that may pass through the groin structure.

![Figure 5 Correlation between wave height and current velocity at various groin permeability (a/d = 46.67% and 80%)](image)

**Figure 5** Correlation between wave height and current velocity at various groin permeability (a/d = 46.67% and 80%)

### 4.2. Direction of Longshore Current

The direction of the current can be analyzed using Velocity Vector software which was developed by Triatmadja, 2011. The location of the measurement and the resulted direction of the current without groin structure is shown in Figure 6.

![Figure 6 Location of the measurement and the direction of longshore current without groin structure (T = 1.4 sec; H = 4.16 cm; α = 30°)](image)

**Figure 6** Location of the measurement and the direction of longshore current without groin structure (T = 1.4 sec; H = 4.16 cm; α = 30°)

Figure 6 shows that dominant direction of longshore current is 19° - 41° to normal line perpendicular to the beach. The average velocity is 1.47 cm / s.

The measurement point and the current direction with impermeable groin is shown in Figure 7.
Figure 7 Location of the measurement point and the direction of longshore current with groin impermeable (T = 1.4 sec; H = 4.16 cm; $\alpha = 30^\circ$)

Unlike the previous longshore current (without groin) the direction of longshore current is $34^\circ - 64^\circ$ to normal line. It can be clearly seen that there is an abrupt change of velocity across the groin. Upstream of the groin the velocity is 7.4 cm/s which reduce to 1.62 cm/s downstream of the groin. This is indicate the capability of impermeable groin to control longshore current.

Permeable groin used was a pile groin model with variations of permeability (ratio of piles distances to pile diameters, a/d). Location of the measurement point and analysis of current direction with groin permeable is shown in Figure 8.

Figure 8 Location of current measurement point and track of longshore current at permeable groin condition (a/d = 0.46; T = 1.4 sec; H = 4.16 cm; $\alpha = 30^\circ$)

In between no groin condition and impermeable groin condition the longshore current may be control by permeable groin. As can be seen in Figure 8. The permeable groin resulted in a change of longshore current direction ($24^\circ - 48^\circ$) while the velocity reduce from 3.45 cm/s to 0.72 cm/s. This results represent that simulation on permeable groin which may fit to certain condition on required in the field.

4.3. Longshore Current Velocity Variation at Surf Zone

It has been shown that the permeability of a groin affects the velocity and direction of longshore current. Groin with less permeability significantly reduced the current velocity. Figure 9, Figure 10 and Figure 11 show the longshore velocity variation with impermeable groin (permeability 0%) and permeable groins (46.67% and 80%).
Figure 9 Longshore current velocity variation at surf zone with impermeable groin (wave period, $T = 1.4$ second)

Figure 10 Longshore current velocity variation at surf zone with permeable groin, $a/d = 0.46$ (wave period, $T = 1.4$ second)

Figure 11 Longshore current velocity variation at surf zone with permeable groin, $a/d = 0.80$ (wave period, $T = 1.4$ second)

Please note that the velocity at grid 1 may not be recorded accurately by Accoustic Doppler Velocimeter (ADV) as its depth were too shallow for the recorder. Hence the real velocity may be significantly large than the recorded. The problems can be solved by establishing a different method of recording the longshore current at very shallow water.

5. CONCLUSIONS

1. Groin change both the direction and the velocity of longshore current.
2. A permeable groin may be designed to fit the requirement of reducing longshore current in the field.
3. An Accoustic Doppler Velocimeter (ADV) may not be appropriate to be used for measuring longshore current at very shallow water (< 5 cm) and hence a different method or device should be established.
4. The study has been able to identify the change in velocity and direction of longshore current through impermeable and permeable groins.

5. The percentage reduction of current velocity were 85.5% for impermeable groin, 71% for 46.67 permeability groin and 66.34% for 80% permeability groin.

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