Physical Modelling for the Analysis of Wave Characteristics on Tropical Peat Coast

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Abstract. Coastal erosion problems have been occurring continuously during at least the last 30 years along the coast of eastern Sumatra, particularly in the north part of Bengkalis Island that facing directly the Malacca Strait. In the extreme case, the coastal setback on Bengkalis Island has reached 30 m/year. The transport and deposition of peat material in the tropical coastal area is a unique phenomenon that has apparently never been explored until nowadays. Most studies have focused on the transport and deposition dynamics of sediment of cohesive and sandy material. It is therefore very important to understand the wave characteristics on tropical peat coast in order to countermeasure the problems triggered by this degradative process. The purpose of this research is to develop a physical modelling to understand the wave characteristics on tropical peat coast. Two important parameters such as wave reflection and dissipation were analysed using wave channel and artificial beach in laboratory. The artificial beach was simulated using peat, permeable, and impermeable material with 15° and 90° beach slope. The results showed that the reflection and the dissipation coefficient at peat coast tend to close with the impermeable coast both for 15° and 90° slope.

1. Introduction

Peat is an organic material that is naturally buried under excessive wet conditions. Peat is formed from a variety of organic plant matter that rots and decomposes at various levels. One of the characteristics of peatland is the high content of organic matter where the percentage can reach more than 65% [1]. Indonesia has the largest area of tropical peatlands among tropical countries. The area of peatlands in Indonesia consists of about 20.6 million hectares or around 10.8% of the land area in Indonesia [2]. The largest peatlands are located on the Sumatra island, which is 6.4 million hectares, with 60% or around 3.8 million hectares are located in Riau province. Bengkalis is a regency with the second largest peatland after Indragiri Hilir. Bengkalis Island is one of the islands in Bengkalis regency that about 89% of the island is covered by peat [3].

Coastal peatland is distributed along the coasts of eastern Sumatra, southern Kalimantan, both sides of Peninsular Malaysia, and the Bornean part of Malaysia. Coastal erosion and peat failure (peat landslide) problems have been occurring continuously during at least the last 30 years along the coast of eastern Sumatra, particularly the part facing directly the Malacca Strait. It was found that the contribution of coastal erosion to the loss of peatland area in Riau Province was reaching 160 ha/year [4]. In the extreme case, the coastal setback on Bengkalis Island has reached 30 m/year [5]. During the
last 15 years (2000-2015), the island has lost a total area of 478 ha due to coastal erosion, which was equal to a peat loss of 21.7 Mm$^3$ or 1.27 Mt of carbon [6]. However, some of the eroded peat material was deposited elsewhere, forming peat-blanketed tidal flats [7]. On the northern tip of the island, the such tidal flat has even facilitated the establishment of mangrove vegetation [8].

The transport and deposition of peat material in the tropical coastal area is a unique phenomenon that has apparently never been explored until nowadays. Most studies have focused on the transport and deposition dynamics of sediment of cohesive and sandy material [9], since coastal areas with cohesive and sandy beach, which are more common in the world. It is therefore very important to understand the basic characteristics of coastal peat sediment dynamics in order to countermeasure the problems triggered by this degradative process. Waves that propagate on a beach some of its energy will be reflected (reflection) and partly destroyed (dissipation) through the form of coastal conditions. The distribution of the amount of waves reflected and also destroyed, depends on the characteristics of the incoming waves in the form of periods, wave heights, water depths, and the geometric of the beach profile (slope of the beach profile).

The purpose of this research is to develop a physical modelling to understand the wave characteristics on tropical peat coast. Two important parameters such as wave reflection and dissipation were analysed using wave channel and artificial beach in laboratory. Reflection and dissipation of waves were parameters to measure how much the ability of the beach to reflect and reduce waves. The artificial beach was simulated using peat, permeable, and impermeable material with 15° and 90° beach slope.

2. Method

2.1. Research area
The study was conducted at the Hydraulic Laboratory, Civil Engineering Department, Faculty of Engineering, University of Riau. Physical modelling was carried out using a flume of 500 cm x 25 cm x 7.6 cm. Peat samples were picked up from coastal peat in Meskom Village, Bengkalis Island. The sampling location points are presented in Figure 1.

![Figure 1. Location of peat sampling in Meskom Village, Bengkalis Island](image)

2.2. Simulation set up
The physical modelling was developed using artificial beach and wave generator in the laboratory. The artificial beaches were constructed using peat material (G) as well as permeable (P) and impermeable (I) material. The beach slope for each material was designed perpendicular on 90° (T) and angled 15° (M). The model set up is presented in Figure 2 and Figure 3. The waves were generated with five various wave height, with the range of 1.4 cm to 3.5 cm. To understand the wave characteristics in the artificial beach model, seven points location in front of the beach were measured for every simulation on the parameters of wave height and period.
3. Results and Discussion

To understand the characteristic of wave in the artificial beach using peat material in comparison with permeable and impermeable material, two important parameters such as wave reflection and wave dissipation coefficients were discussed.

3.1. The Reflection Coefficient (Kr)

The wave reflection phenomenon in the peat beach tended to close to permeable beach both on perpendicular slope (90°) and 15° slope as presented in Fig 4.
The reflection coefficients at permeable perpendicular beach decreased with the higher wave height. On the other hand, the reflection coefficients at peat material and at impermeable perpendicular beach increased with the higher wave height. The reflection coefficients of peat soil beach were lower than that of impermeable beach for small wave (less than 10 cm), but they were higher for high wave (more than 10 cm). In case of 15° slope beach, the reflection coefficients on peat material were not so much different with both permeable and impermeable beach material.

**Figure 4.** The correlation between reflection coefficients (Kr) with incoming wave (Hi) in modelling the 90° and 15° slope beach of peat material in comparison with impermeable and impermeable material

### 3.2. The Wave Dissipation Coefficient (Kd)

Figure 5 presents the correlation between wave steepness \((Hi/gT^2)\) and reflection coefficients \((Kr)\) on both of 90° and 15° slope beach of peat material in comparison with impermeable and impermeable material. The figures show that the reflection coefficient \((Kr)\) is directly proportional to the wave steepness \((Hi/gT^2)\) meaning that the greater value of the wave steepness, the greater value of the reflection coefficient on both of 90° and 15°. However, the dissipation coefficient \((Kd)\) is inversely proportional to the wave steepness, meaning that the greater the value of the wave steepness, the smaller value of the wave dissipation coefficient, as presented in Fig.6. It can be seen that peat beach material has the characteristics between permeable and impermeable beach material.

**Figure 5.** The correlation between wave steepness \((Hi/gT^2)\) and reflection coefficients \((Kr)\) on 90° and 15° slope beach of peat material in comparison with impermeable and impermeable material
Figure 6. The correlation between wave steepness ($H_i/g T^2$) and dissipation coefficient ($K_d$) on $90^\circ$ and $15^\circ$ slope beach of peat material in comparison with impermeable and impermeable material

4. Conclusion
This research developed a physical modelling to understand the wave characteristics on tropical peat coast. Two important parameters such as wave reflection and dissipation were analysed using wave channel and artificial beach in laboratory. The artificial beach was simulated using peat, permeable, and impermeable material with $15^\circ$ and $90^\circ$ beach slope. The results showed that the reflection and the dissipation coefficient at peat coast tend to close with the impermeable coast both for $15^\circ$ and $90^\circ$ slope.

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