Experimental Study of Tidal Flat Formation on Coastal Peat

Experimental Study of Tidal Flat Formation on Coastal Peat

Genta Putra Adietama[1], Sigit Sutikno[1,2*], Muhamad Yusa[1], Koichi Yamamoto[3]

[1]Civil Engineering Department, University of Riau, Pekanbaru, Indonesia, 28293
[2]Centre for Disaster Study (PSB), University Riau, Pekanbaru, Indonesia, 28293
[3]Civil Engineering Department, Yamaguchi University, Yamaguchi, Japan

*)Email: sigit.sutikno@lecturer.unri.ac.id

Abstract. Tidal flat formation on the coastal peat is a unique phenomenon that has occurred at western part of Bengkalis Island, Riau Province, Indonesia. It was identified that coastal erosion problems have been occurring continuously during at least the last 30 years along the north part of Bengkalis Island. The materials have moved to the south part of Bengkalis Island, and sedimented as tidal flat. Research on tidal flat in the peatlands has not yet been developed, so this study aims to carried out an experiment study in order to understand the tidal flat formation on coastal peat. The method used in this study is a simulation of tidal flat formation with several wave variations. Simulations were carried out using laboratory experiments with coastal peat samples and sea water at the wave channel. The results show that the waves and the velocity greatly influence the tidal flat formation and its formation rate. In addition, the formation of peat tidal flat was also influenced by velocity settling of the peat particles. The energy for tidal flat formation was the minimum energy generated by waves, that cannot transport the particles move back by reverse flow.

1. Introduction

Generally tidal flats are sandy-muddy depositional systems along marine and estuarine shores periodically submerged and exposed in the course of the rise and fall of the tide [1]. Tidal flat is land formed because of sedimentation process which are mainly influenced by the coastal hydrodynamic. Soil sedimentation will accumulate which can form tidal flat. The tidal flat is formed by sedimentation and by tides or small waves [2]. When the incoming wave has relatively large energy, tidal flat will not be formed because the wave power will erode the accumulated sediment so that the sediment will be carried in the direction of the big wave. Tidal flat formation on the coastal peat is a unique phenomenon that has occurred at western part of Bengkalis Island, Riau Province, Indonesia[3]. The existence of coastal peat in Indonesia has an important role due to Indonesia is an archipelago country. The coastal peat needs to be concerned carefully because it is a fragile ecosystem.

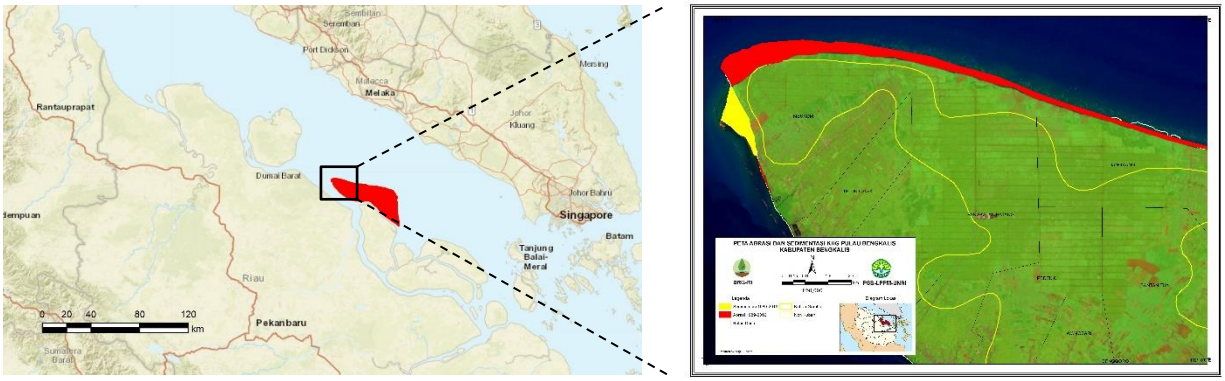
It was identified that coastal erosion problems have been occurring continuously during at least the last 30 years along the coast of eastern Sumatra, particularly in the north part of Bengkalis Island that facing directly the Malacca Strait [4]. The materials have moved to the south part of Bengkalis Island, and sedimented as a tidal flat [5]. The tidal flat mainly composed as peat material that was formed as a new ecosystem[6].

Research on tidal flat in the peatlands has not yet been developed, so this study aims to carried out an experiment study in order to understand the tidal flat formation on coastal peat. The method used in this study is a simulation of tidal flat formation with several wave height scenarios. The scenarios for simulation were carried out using laboratory simulations with coastal peat soil samples and sea water at the wave channel. The effect of waves and flow velocity on the formation of tidal flats in peatlands were further investigated in this study.

2. Method

2.1. Research area

The study was carried out with a laboratory simulation at the Hydraulic Laboratory, Civil Engineering Department, University of Riau using samples of peat and sea water. 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 at Meskom Village, Bengkalis Island as presented in Fig. 1. Bengkalis island which about 89% of the island is covered with peatland, is very vulnerable to coastal erosion [7]. As presented in Fig. 1, the erosion occurs at the north area of the island and the sedimentation at the south area of the island. The tidal flat occurred at the sedimentation area in the south part of the island. Three samples were picked up at the location, i.e. Sample-1 at the mean sea level, Sample-3 at the high tide point, and Sample-2 at the middle between Sample-1 and Sample-3, as presented in Fig.2.



Source: Center for Disaster Studies, University of Riau

Figure 1. Research location at Meskom Village, Bengkalis Island, Indonesia

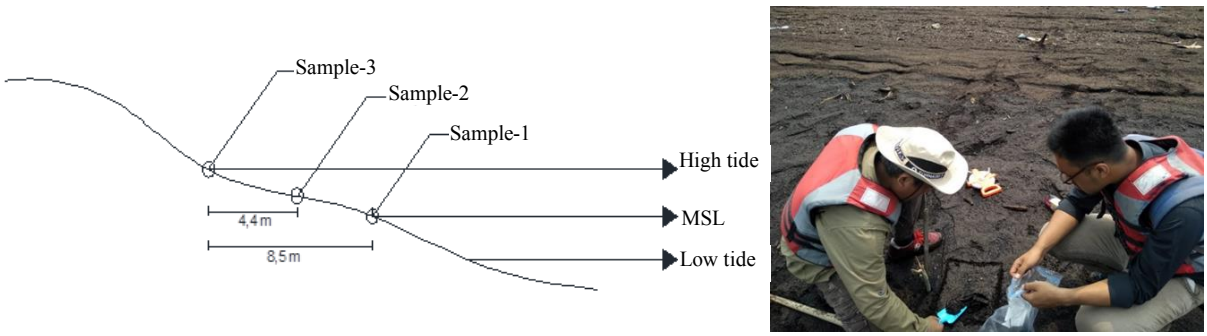


Figure 2. Location of peat sampling at Meskom Village, Bengkalis Island

2.2 Simulation set up and data analysis

Five simulation scenarios were set up using increasing wave height parameter and mixed peat particle with water to investigate which conditions the tidal flat formed. The sample material used was a combination of Sample-1, Sample-2 and Sample-3 with a volume percentage ratio of 26%, 37% and 37% respectively. The wave scenarios for the simulation are presented in Table-1. The flow velocity profile data were measured using a velocimeter which can read the current speed in 3 directions. The velocity data were processed using the Vectricno II application. The experiment simulation was set up as presented in Fig.3. The simulations were run along 24 hours for each scenario. The beach topography profiles and the wave height were measured on the simulation hour of 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, 24.

The simulation data analysis was performed to find the characteristics of each wave variation, to determine the current speed and direction, and to calculate the velocity settling of the sample from the sample data properties. Velocity settling value can be said as a particle falling in the liquid due to

gravity, then the settling speed will be reached if the amount of frictional force (drag force) and buoyancy is proportional to the gravitational force of the object. The results of the analysis were compared with the process of sediment movement until the formation of tidal flat so that it can be known the effect of waves and speed on the formation of tidal flat in peatlands.

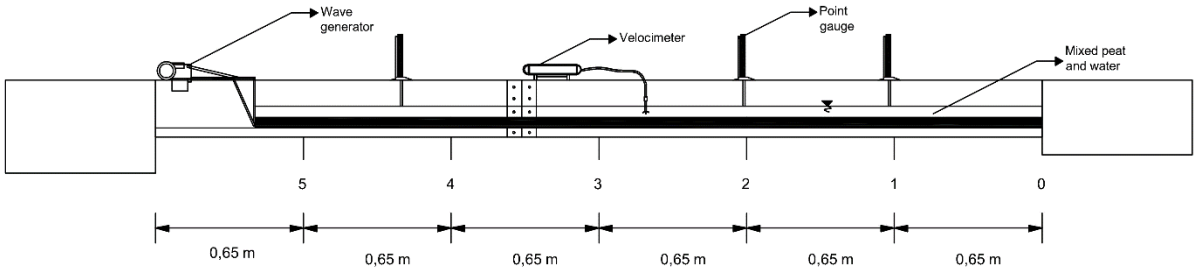


Figure 3. Experiment set up using wave channel at laboratory

Table 1. The wave scenarios and their characteristics for simulations

Scenarios	H (m)	F (Hz)	T (s)	L (m)	C (m/s)	E (N)
1	0.010	0.69	1.43	1.25	0.87	0.14
2	0.011	0.87	1.15	0.99	0.86	0.16
3	0.020	1.55	0.65	0.49	0.65	0.58
4	0.015	2.22	0.45	0.29	0.64	0.36
5	0.015	2.64	0.39	0.22	0.57	0.31

H: wave height, F: wave frequency, T: wave period, L: wave length, C: wave velocity, E: wave energy

3. Results and Discussion

Table 2 shows the simulation results of tidal flat formation for the five scenarios simulation. It can be said that the tidal flat was only formed on the Scenario-1, Scenario-2, and Scenario-3 with the wave height of 0.01, 0.011, and 0.02 m and with the wave period of 1.43, 1.15, and 0.65 respectively, as presented in Table-2. These waves generated sufficient strength to transport the sediment materials and accumulate them to become tidal flats. The wave height and period were less than 0.02 m, and more than 0.65 second respectively, as presented in Table-2.

As presented in Table 2, the characteristics of waves that form a tidal flat have a small wave energy such as the Scenario-1 and Scenario-2, but in the Scenario-3 the tidal flat was formed even with waves height and wave energy greater than the others. Whereas the simulation in Scenario-4 and Scenario-5, the tidal flat was not formed so it can be concluded that the wave is not a factor affecting the formation of tidal flat but the wave only affects the speed of the current.

Figure 4 shows the current velocity recorded on velocimeter during the simulation. Current velocity that occurs was analysed using the vetricno-II application. The current that occurs in the simulation is alternating current with different speeds.

Table 2. The results of the simulation of tidal flat formation with wave variations

Scenarios	Wave height (m)	Wave period (s)	Tidal Flat
1	0.010	1.43	formed
2	0.011	1.15	formed
3	0.020	0.65	formed
4	0.015	0.45	not formed
5	0.015	0.39	not formed

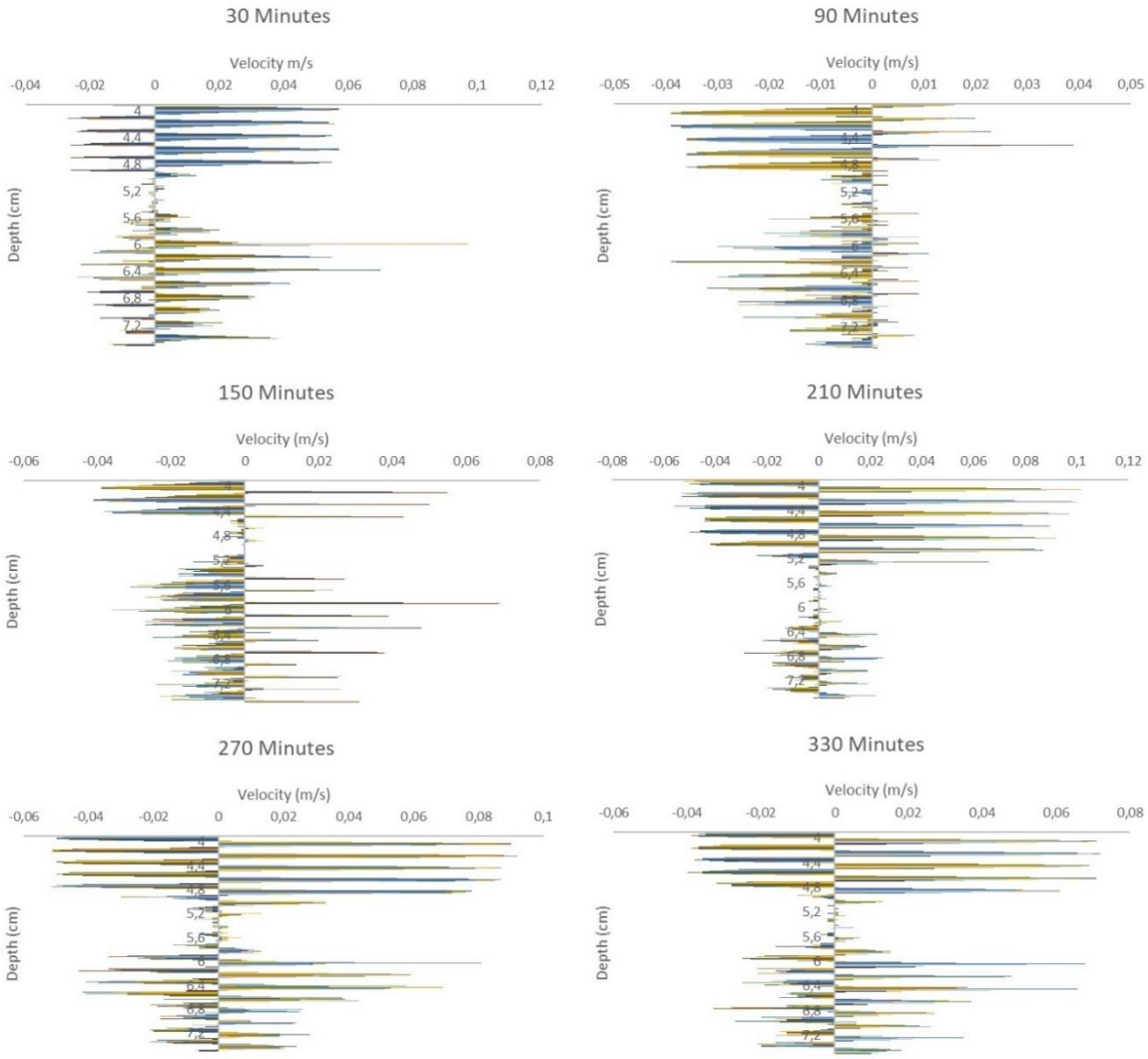


Figure 4. Current velocity profile at each time observation

Sediment transport was analysed by comparing current velocity and velocity settling of peat soil samples. Table 3 shows the velocity settling values of each sample based on the percent soil diameter value. From the current speed velocity graph, it can be seen the maximum incoming velocity value about 0.102 m/s and the maximum reverse current about 0.056 m/s at the 210 minutes measurement as presented in Figure 4. The current velocity was compared with the settling velocity for its sample. If the current value is higher than the settling velocity, then the sediment particles will be transported by the current.

Table 3. Velocity settling value of the sample used

Sample	Soil Density (kg/m^3)	Diameter (m)			settling velocity (m/s)		
		D60	D30	D10	D60	D30	D10
Sample-1	1342	0.0018	0.0008	0.0004	0.672	0.133	0.033
Sample-2	1218	0.0015	0.001	0.0007	0.467	0.207	0.102
Sample-3	1201	0.0011	0.00014	0.00009	0.251	0.004	0.002

Figure 5 shows the process of movement of sediments to form tidal flat. At the beginning of the tidal flat formation process, sediment particles were evenly distributed along the flume. Sediment particles moved gradually to downstream of the channel forming a tidal flat. The tidal flat process rate

was influenced by the amount sediment movement that was generated by currents and waves. The downstream sedimentation will form tidal flat if the reverse flow velocity is less that the settling velocity. The process of sedimentation was influenced by currents and incident waves.

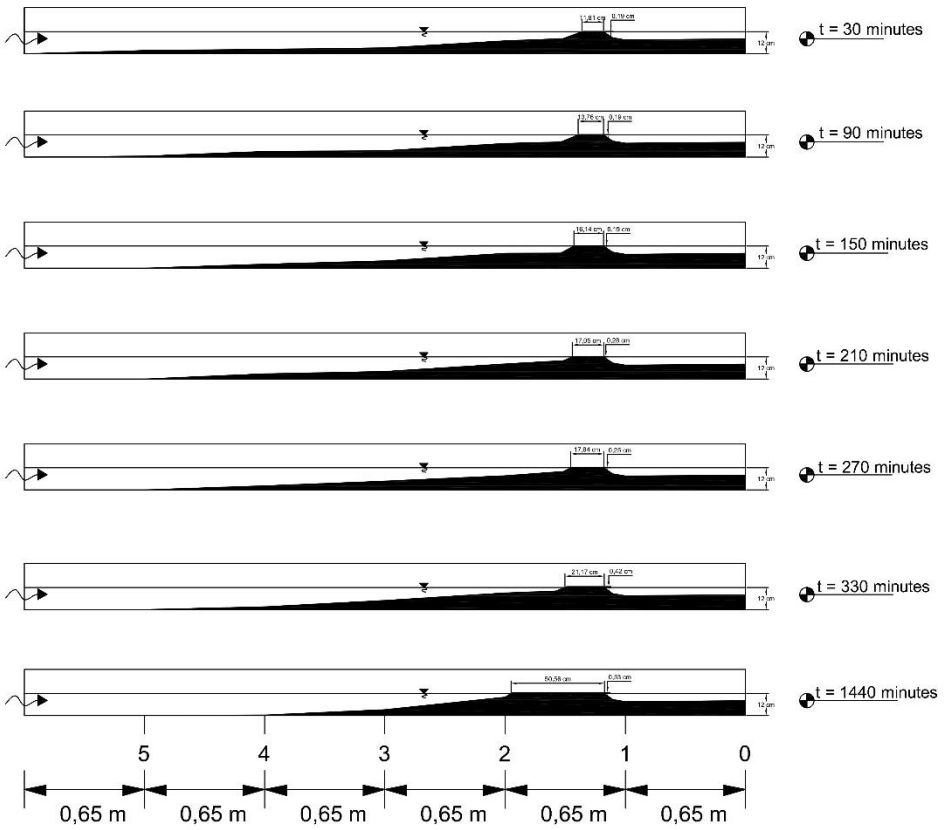


Figure 5. The process of sediment movement in tidal flat formation

4. Conclusion

This research carried out an experiment study in order to understand the tidal flat formation on coastal peat using a simulation with several wave variations. The results show that the waves and the velocity greatly influence the tidal flat formation and its formation rate. In addition, the formation of peat tidal flat was also influenced by velocity settling of the peat particles. The energy for tidal flat formation was the minimum energy generated by waves, that cannot transport the particles move back by reverse flow.

References

[1] Flemming B W 2016 in: Middleton G V (ed.) Encyclopedia of Sediment and Sedimentary Rocks *Tidal Flats* September 2003, Kluwer, Dordrecth 734–737
[2] Friedrichs C T 2012 Tidal Flat Morphodynamics: A Synthesis *Treatise on Estuarine and Coastal Science*
[3] Yamamoto K *et al* 2017 Mangrove Formemation Process Behind The Peat Bar and the Amount of the Carbon Storage in the Tidal Flat *J. Japan Soc. Civ. Eng. Ser. B2 Coastal Eng* **73(2)** I_1573-I_1578
[4] Sutikno S, Sandhyavitri A, Haidar M and Yamamoto K 2016 Shoreline Change Analysis of Peat Soil Beach in Bengkalis Island Based on GIS and RS *Int. J. Environ. Sci. Dev* **7(12)**
[5] Yamamoto K *et al* 2019 Tropical peat debris storage in the tidal flat in northern part of the Bengkalis island, Indonesia *MATEC Web Conf* **6003(276)**
[6] Yamamoto K, Asakuma T, Kagawa H, Sutikno S, Basir N and Kanno A 2019 Occurrence and

Disappearance of Temporary Peat Fan by The Land Slide at The Coastal Peat Coast *J. Japan Soc. Civ. Eng. Ser. B2 Coastal Eng*

[7] Supardi, Subekty A D and Neuzil S G 1993 General geology and peat resources of the Siak Kanan and Bengkalis Island peat deposits, Sumatra, Indonesia *Modern and Ancient Coal-Forming Environments* 45–62