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INVESTIGATION OF THE EFFECTS OF PLANT VARIETY AND SOIL SEDIMENT TO THE COASTAL ABRASION IN WEST SUMATRA

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ABSTRACT: Indonesia has many islands that are suffering from beach abrasion. This phenomenon has been often happening and is categorized in one of the National Disasters. West Sumatra beaches with the total length of about 600 km stretch along the west side of Sumatra Island where directly opposite to the Indian Ocean. The waves from the Indian Ocean in any circumstance may cause abrasion to damage houses and public facilities. Factors that affect coastal abrasion include coastal geometry, wave parameters, soil sediment and beach plantations. An investigation on the plant species and soil sediment on the West Sumatra beach has been done. The effects of the last two factors on beach abrasion are then elaborated in this paper. It is found that some beach vegetations have shown remarkable role to reduce abrasion impact. Meanwhile, the type of soil sediments in which associated with physical properties showed also significant effect. From this study, it was found that vegetation roots will protect the beaches together with the soils. This investigation also concludes that coastal endemic plants in the West Sumatra need to be explored as a mitigation action to reduce the abrasion impact.

Keywords: Abrasion, Marine Vegetation, Plantation Effect, Soil Effect, Disaster Mitigation

1. INTRODUCTION

Indonesia is one of the largest countries with many islands which has very long coastlines. The Indonesian Geospatial Information Agency reported that the total length of the Indonesian coastline reaches about 100,000 kilometers [1]. There are many potential natural treasures and beautiful sceneries along the coastline. Indonesian beaches are often used as a tourist destination for local and international tourists. However, the recent condition of the coastal areas of Indonesia is worrying due to the abrasion. It has been reported that about 100 locations in 17 Provinces with coastline length of approximately 400 km have experienced terrible coastal erosion [2]. The list of coastal areas in Indonesia that are at high risk for abrasion disasters in 2013 including South Aceh, Banda Aceh, Medan City, Surrounding Padang City in Sumatra Island, North Jakarta, Rembang Regency in Java Island, Bali Island, Sikka Regency in East Nusa Tenggara and Selayar in Sulawesi Island [3].

Beach abrasion that is essentially a coastal dynamics influenced by seawater waves has caused many disadvantages such as cutting the accesses, destruction of houses and even the loss of such a beautiful sandy beach (Fig.1). For that reasons, the Indonesian government has included abrasion into one of national disaster [4]. Abrasion is part of the phenomenon of erosion and sedimentation cycles along the coastline. To deal with abrasion, beaches can be protected by providing an engineering construction to reduced the incoming wave energy [5]. However, building such wave protector to prevent abrasion could not restore back the lost of sandy beaches. Further, a hard construction on the beach may also result in unpleasant scenery (Fig.2).

Abrasion becomes a research interest and is extensively studied related to the global warming issue. It has been studied the relationship between sea levels and coastal damage from the 19th to the 20th centuries [6]. It was a strong correlation between the global warming on the damage on beaches. The damage to the beaches has been doubled with the rate of actually sea level rise. It is predicted the coastal abrasion problems that already look severe in the 20th century will be worse in the next century.

Fig.1 Padang Beach in 1890 [7]

Fig.2 The missing sandy beach in Padang

It has been reported there are 14 beaches classified in critical condition [8]. The 14 critical beaches are Air Bangis, Sasak; Pantai Tiku, Pasir Baru, Pariaman, Ketaping, Pasir Jambak, Padang, Bungus, Carocok Painan, Luhung, Surantih, Kambang and Air Haji beaches. From 420 km of the total length of West Sumatera coastline, 45% of them (approximately 180 km) have been damaged by abrasion. With the many of needs on the coastline, the actions are required for protecting beaches from abrasion in West Sumatra.

Abrasion protection has been done by using hard structures, but this way is not natural and resulting bad effect on the environment. A study on the ecological impact of habitat loss due to the presence of hard protective structures along the coastline has been conducted [9]. It was found the surprising drop off the number of seagulls and other seabirds on the protected beach. The study suggested further studies on natural beach protection that including the environmental preservation. The artificial beach rock made of sand solidification for coastal protection may be a prospect of environmental save solution [10].

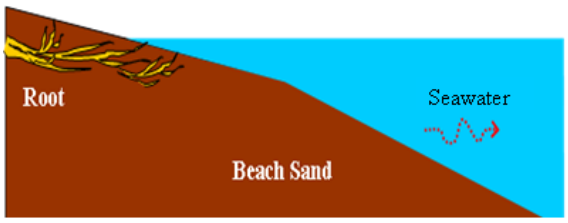

Fig.3 Simulation of sand-roots interaction

In order to protect beaches from abrasion, it is necessary to prevent the sea waves from taking the beach sand particles away from their place. It can be done by constructing wave energy breaker or covering the ground such that the seawater can not transport the sands away. However, those ways are not natural and less beautiful. The more natural way is by planting protective vegetations on the beaches. A study to understand the way of those vegetation roots in protecting beaches from abrasion using numerical simulation has been conducted. [11]. The simulations were successfully demonstrated the mechanism of roots for protecting the sandy beaches against seawater erosion (Fig.3).

Besides the numerical study, the field investigation to observe the effect of vegetation and soil sediment to abrasion has also been done. The field investigations were conducted along the West Sumatra coastline. The investigation found that some kind of marine vegetations can withstand against abrasion or seawater erosion. The results of these investigations are further described in this paper.

2. WEST SUMATRA'S MARINE PLANTS

There are marine vegetations found from field investigation along West Sumatra coastline that empirically can protect beach from abrasion. Mainly there are five kind of marine vegetations exist in the West Sumatra Beaches, that are:

a. Sea-pine,
b. Coconut palm,
c. Mangroves,
d. Pinago, and
e. Ketaping (Terminalia Cattapa).

The on site captures of those trees can be seen in Fig.4 (a to e). The last two kind of tree seems to be in the same family but different species. However, we do not went deeper in to that kind of biological matter.

The abrasion area will be terminated in the zone where there is a vegetation on it. In areas that are not planted, seawater took sand away until several meters into the mainland. Roots are a most important part of vegetation that role the abrasion protection. The marine vegetation roots can creep up to 4 meters from the main wood. The maximum distance of the root extension depends on the soil, planting way and species. For the vegetation where its soil sides have been removed by abrasion, it is found that the roots go only up to about 2.5 meters. This is caused the roots have lost the soil where they need to grow for, are destroyed and taken by the seawater. In order to play as an abrasion protector, the roots and the soil has to take part in symbiotic mutualism.

There are two main types of roots according to

branching pattern as well known: taproot and fibrous root. The taproot is deep-rooted compared to fibrous one. The marine vegetations that are having taproots are Sea-pine, Mangroves, Pinago and Ketaping, meanwhile, Coconut palms grow with the fibrous root. It is believed that the taproot may anchor the tree better to the soil and can take water from deeper part from ground surface. However, the fibrous root is found to be denser than the taproot system. This condition give an advantage to the root system to keep the surrounding soil from being taken by the seawater. Then, a coconut tree is better in preventing abrasion than a sea pine tree.

a. Sea pine b. Coconut palm

c. Mangroves

d. Pinago e. Ketaping

Fig.4 Marine vegetations in West Sumatra

Based on the study on the mechanism of roots as abrasion protection [11], it is found that the roots give unification effect to the surrounding soil. Further, they hold each other and form a bigger mass. The denser roots are the better role in unifying the soil to prevent abrasion. This phenomenon explains the field investigation results that the Coconut palms with denser fibrous root protecting beaches more than the Sea pines with taproot (Fig.5). Even the field observation also found the row of coconut palms are also found survive better than the sea pine trees (Fig.6). This result proves that taproot roots that capable for penetrating deeper, are not necessarily better to protect abrasion than fiber roots.

Fig.5 On site condition of Sea pine and Coconut palm beach

a. Coconut palm beach

b. Sea pine beach

Fig.6 Beaches with marine vegetations

For the same species, the density of vegetation also determines its resistance to abrasion. The vegetations that grow close each other will be more resistant to abrasion than grow in distance. The closer the spacing, the greater the ability to resist abrasion. Clearly, that stand-alone tree will be easily demolished by the seawater than they in a group. The same thing happens for plants that grow out of line towards the sea, will easily be turn

down by abrasion. Therefore, planting of vegetations in the purpose of protection against abrasion should be done in groups with a good pattern (Fig.7).

The Field investigation also found that reducing the number of plants in natural growing mangroves will reduced on abrasion resistance (Fig.8). A group of mangroves that experienced a reduction in the number, finally in a critical condition (Fig.9). Eventually that trees will be gone from its original place. So, the density of marine vegetation is an important factor to protect beaches from abrasion. The spacing which is shorter than maximum the root can go, will let the roots cross each other in the form of organic net. This root net will keep the surrounding soil from transported by seawater. While single standing plants with roots are not interconnected, consequently easy to be overturned by seawater.

Fig.7 Plants in group and stand alone

Fig.8 Reduction of mangrove trees for houses

Fig.9 Reduction of mangrove resulting the dead

3. SOIL SEDIMENT OF BEACHES

In order to investigate the effect of soil sediment for protecting the beach from abrasion, the soil samples have been taken from the beaches along West Sumatra coastline. The samples then are tested in laboratory to elaborate their physical properties. Soil properties are very important engineering as indicator of further engineering behavior such as gradation, strength, and stability. Many references have described the testing procedures and the meaning of the engineering properties of soils [12].

The recent study has mentioned that sediments with predominantly non-cohesive materials may be easily transported by seawater. The factor that can keep the soils staying are gravity and internal friction. The coarse grains with greater masses are also more difficult to be mobilized than fine grains [13].

The sand samples taken and analyzed in the laboratory came from 7 beaches in West Sumatra as shown in map Fig.10. The names of each location and the dominant species of vegetation are as follows:

1. Teluk batang, vegetation Coconut palm
2. Sago painan, vegetation type: Sea pine
3. Guguk Kuranji hilir, vegetation Sea pine
4. Tarusan, vegetation type: Sea pine
5. Surantih, vegetation type: Sea pine
6. Tanjung mutiara, vegetation type: Sea pine
7. Bukit Buayo, vegetation type: Ketaping

The sieve analysis results of the samples are shown in Fig.11. Furthermore, based on the sieve analysis, the sand soils have a low coefficient of uniformity (Table 1). This means that the soils are in uniform gradations. In general, the soil type from the beaches are sandy soil in medium until loose density. In Tanjung Mutiara and Tarusan, the sediment is dominated by fine silty sand. Since those sediments are predominantly non-cohesive materials, then they may be easily transported by seawater. Since those sediments are predominantly non-cohesive materials, then they may be easily transported by seawater.

Based on the findings the sand beaches in West Sumatra are composed of sediments that easily eroded by seawater that is confirmed with the field investigation. The sediments have the relatively small the size of fine to medium sands that are

easily transported by seawater. In addition, the gradations of the soils are uniform which indicates less advantage in terms of stability. It has been explained that the vegetations together with the soil can protect the abrasion, therefore the existing vegetation on the beach must be maintained for the existence of the beaches in the future.

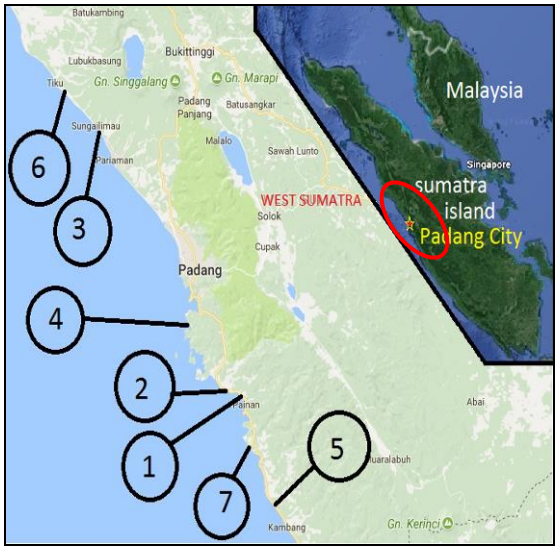

Fig.10 Original sites of the soil samples

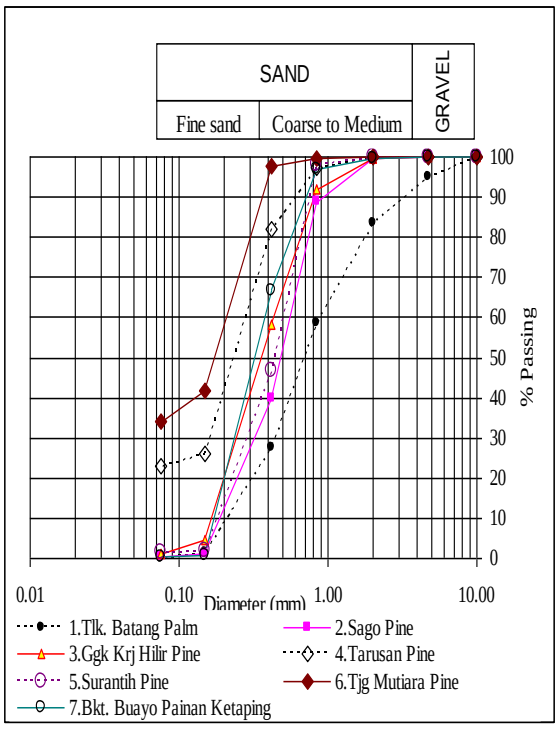

Fig.11 Sieve analysis of sand samples

Table 1 Physical properties of sand samples

Parameter	Symbol	Location number							Unit
		1	2	3	4	5	6	7	
Wet unit volume	γ	1.84	1.95	1.86	1.74	1.85	1.46	1.80	t/m^3
Dry unit volume	γ	1.35	1.48	1.48	1.31	1.42	1.03	1.37	t/m^3
Void ratio	e	0.93	0.87	0.61	0.76	0.76	0.76	0.76	
Saturated water content	w	32.58	31.24	28.14	36.80	32.68	46.77	32.30	%
Sieve analysis	Gravel	4.97	0.10	0.00	0.00	0.00	0.00	0.13	%
	Sand	95.00	98.90	99.43	76.93	98.53	65.80	99.30	%
	Clay	0.03	1.00	0.57	23.07	1.47	34.20	0.57	%
Mean size	D_{50}	0.7	0.49	0.35	0.21	0.42	0.18	0.31	mm
Coef. Uniformity	Cu	4.29	2.89	2.80		2.94		2.11	
Coef. Curvature	Cc	1.07	0.92	0.77		0.92		0.71	

4. CONCLUSIONS

Indonesian government decided that abrasion has become one of national disasters that resulted in disadvantage coastline changes. Based on the field investigation that has been done there are several marine vegetations that can grow up in decades. The field study also found that the marine vegetations were effectively able to protect beaches against abrasion. At least there are five species of endemic marine vegetations found along the West Sumatra coastline.

This study showed that the beach sediments in West Sumatra are composed of fine to medium sands that easily eroded by seawater. It has been explained using finite element that the roots play a role to unify the soil mass that hold each other to prevent abrasion. Therefore, it is necessary to conserve the existing coastal vegetations as well as planting new specific trees so they will protect the beaches together with the soils. The absence of vegetations on the beaches consequently will result higher vulnerability to abrasion.

5. ACKNOWLEDGEMENTS

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