Comparison study of beach geometrics and beach sand gradation related to abrasion potential based along the West Sumatra Province

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Abstract. The West Sumatra beach is very beautiful and has much diversity in terms of their natural properties. This paper elaborating the diversity of the West Sumatra Beach related to their abrasion potential. Field investigation conducted to collect the nature diversities such as the plantation, sands and the geometric. The sand samples have been taken from beaches and brought to the laboratory to investigate their physical properties. The geometric of the beaches were analysed to gain the specific parameter which are comparable each other. The special study on the role of vegetation on abrasion protection as well as numerical modelling of their mechanism also had been studied and reviewed in this study. Those diversities then are turned into the engineering parameter and linked each other to gain their relation to abrasion potential. This study than can redraw the relation between the physical soil properties as well as the beach geometric with the abrasion potential of the beaches. The plantations on the beaches also gave a good correlation to the abrasion problems. The study can give better understanding between the beach abrasion problems with their nature of geology and biology as well as human activities. This study then suggested that to protect the beach abrasion it is necessary to investigate many things including many fields such as engineering, coastal, geology, biology as well as social science.

Introduction

West Sumatran coast is very beautiful and has a lot of diversity in terms of their nature. This paper describes the diversity of the West Sumatera Coast with the potential for abrasion. Abrasion is a term to describe the coastal erosion that occurs due to destructive ocean waves and currents. Abrasion is a process of coastal erosion by destructive ocean waves and ocean currents, commonly referred to as coastal erosion [1]. Based on Law Number 24 of 2007 [2] abrasion is a process of coastal erosion by sea wave power and damaging ocean currents triggered by the disturbance of the natural balance of the coastal area. Such erosion leads to the depletion of coastal areas from the closest to seawater due to being the first target of erosion. If left abrasion continue to undermine the beach so that the sea water will inundate the areas that used to be tourist attractions or residential areas and shopping areas on the beach. Such abrasion phenomena have already appeared in several coastal areas where coastal abrasion has dredged at least 40 kilometres of coastal areas. Abrasion and sedimentation actually occur naturally in every waters and form cycles, depending on the dynamics of the waters at a given time [3].
Recent studies suggest that sediments with predominantly cohesive substances can be easily transported by sea water. Factors that can keep the ground there remain are internal gravity and friction. Coarse grains with larger masses are also more difficult to mobilize than fine grains [5]. Soil properties are a very important technique as indicators of further abrasion behavior such as gradation, strength, and stability. Many references have described the test procedure and the meaning of soil engineering properties [6].

### Abrasion protection

The effort to develop coastal protection aims to prevent coastal erosion and coastal flooding due to overtopping. Based on the structure of the beach security is divided into two, namely soft protection and hard protection. Abrasion protection has been done using hard structures, but this eliminates the natural and not beautiful conditions.

Dugan et al. in 2008 [7] has conducted a study of environmental impacts on habitat loss due to the presence of hard protective structures along the coastline. Their study found surprising results in the decline in the number of seagulls and other seabirds who like to perch on the beach. With many needs on the shoreline, the action is needed for coastal protection from abrasion. This study concludes the importance of further studies on natural coastal protection involving environmental management and conservation.
Coastal vegetation and observations in the field

Coastal vegetation has a very important role as a prevention of abrasion. Coastal plants generally have long and strong roots that are able to withstand the substrate of the wave [8]. Planting with coastal vegetation is highly recommended because coastal vegetation has a very fast, cheap and accessible growth and has the ability to quickly recover in the event of a disaster. For vegetation where the side of the soil has been removed with abrasion, it is found that the roots are only up to about 2.5 meters. This is because the roots have lost ground where they need to grow, destroyed and taken by sea water. In order to play a protective role of abrasion, roots and soil must play a role in the symbiotic mutualism [9].

Figure 3. The root on the surface

Marine vegetation found from field investigations along the coastline of West Sumatra can protect the coast from abrasion. Especially there are five types of marine vegetation in West Sumatra Beach, namely:

- Sea Pines,
- Coconut,
- Mangrove,
- Pinago, and
- Ketaping (Terminalia Cattapa)

The location of abrasion research can be seen in Figure 4.
The following table shows the type of vegetation available at the study site:

**Table 1. Conditions of location research**

| NO | Location       | Vegetation | Picture       | The slope (%) | D30 (mm) |
|----|----------------|------------|---------------|---------------|----------|
| 1  | Tanjung Mutia  | Sea pines  | ![Picture](image1.jpg) | 30            | 0.2      |
| 2  | Guguk Kuranji Hilir | Sea pines | ![Picture](image2.jpg) | 20            | 0.4      |
| 3  | Tarusan        | Sea pines  | ![Picture](image3.jpg) | 30            | 0.2      |
| 4  | Painan         | Sea pines  | ![Picture](image4.jpg) | 15            | 0.5      |
| 5  | Teuk Batang    | Coconuts   | ![Picture](image5.jpg) | 10            | 0.7      |
| 6  | Bukit Buaya    | Ketapang   | ![Picture](image6.jpg) | 25            | 0.3      |
| 7  | Suranthi       | Sea pines  | ![Picture](image7.jpg) | 20            | 0.4      |
The results of field investigations based on coastal slope indicate that the smaller the coastal slope the greater the diameter of coastal sediment grains.

![Graph of D50 vs. the slope](image)

**Figure 5.** The graph of D50 vs. the slope

The mean diameter percentage of the average grain pass (D50) was obtained from the sieve analysis test (Table 2) while the coastal slope was obtained based on field observations.

**Physical properties of sediments of West Sumatra**

The effect of soil sediments to protect the beach from abrasion is to take samples from the study sites and determine the physical properties of soil sediments. Determine the physical properties of soil sediment are to bring samples from the location to the laboratory. Laboratory tests conducted to determine the nature of coastal sediments are as follows:

- Testing of sieve analysis
- Weight volume test
- Test moisture content
- Test direct shear

From the laboratory test above the following results are listed in the Figure 6 and Table 2 below.
Table 2. Properties of soil from all research locations

| Parameter                      | Symbol | Location number | Unit   |
|--------------------------------|--------|-----------------|--------|
| wet unit volume                | 𝜇      | 1 2 3 4 5 6 7   | t/m³   |
| dry unit volume                | 𝜇₉     | 1.0 1.5 1.2 1.5 | t/m³   |
| water content                  | w      | 46.8 26.1 36.8 31.2 32.6 32.3 32.7 | %      |
| sieve analysis                 |        |                 |        |
| Kerikil                        |        | 0.0 0.0 0.0 0.1 |        |
| Pasir                          | 65.8   | 99.4 76.9 98.9 95.0 99.3 98.5 | %      |
| Lempung                        | 34.2   | 0.6 23.1 1.0 0.0 0.6 1.5 | %      |
| size average                   |        |                 |        |
| Dₘ₄                            | 0.2    | 0.4 0.2 0.5 0.7 0.3 0.4 | mm     |
| The diameter of the corresponding to 10%, 30%, 60% passes sieve |        | D₁₀ 0.17 0.19 0.21 0.21 0.18 0.18 | mm     |
|                                |        | D₅₀ 0.25 0.17 0.34 0.45 0.24 0.29 | mm     |
|                                |        | D₉₅ 0.2 0.37 0.29 0.57 0.8 0.39 0.5 | mm     |
| Koefisien uniform              | Cu     | 2.8 2.9 4.3 2.1 2.0 |        |
| Koefisien curvature            | Ce     | 0.7 0.9 0.9 0.7 0.7 |        |

From Figure 6 and Table 2 it can be concluded that:

- The seven samples belong to the type of sandy soil. Sandy soil has a low coefficient of uniformity.
- Relatively small diameter sizes of fine to medium sands that are easily transported by sea water.
- Land gradation is uniform that indicates the beach is potentially abrasion.

Numerical simulation with program Plaxis

To understand the root mechanisms of vegetation protecting the shore from abrasion, numerical modelling involves the interaction of roots and soil with the effect of attracting sea water. This numerical simulation uses the finite element model (Plaxis). The root mechanism for the coastal protection model is carried out under the three conditions:

- Beach without roots
- Roots below ground level
• The roots reach the ground level

![Simulation model](image)

**Figure 7.** Simulation model

The root strength for the purposes of analysis is based on the 30,000 kN/m² wood strength and the 6.0x10⁶ kN/m² elastic modulus. The soil mechanics parameters used for simulation were obtained from the coastal sand test (Table 3). Other values and parameters of the test results are shown in (Table 2). Infinite element simulation for beach sand is considered a geo-material that follows Mohr-Coulomb's constitutive law. While the roots are modelled as a geo-synthetic element that can only withstand against the tensile forces.

**Table 3.** Properties of soil for the calculation of the Plaxis

| No | Parameter               | Value  | Unit   |
|----|-------------------------|--------|--------|
| 1  | dry unit volume         | 12.37  | kN/m³  |
| 2  | wet unit volume         | 17.37  | kN/m³  |
| 3  | water content           | 36.8   | %      |
| 4  | cohesion                | 0.94   | kN/m²  |
| 5  | Internal friction angle | 32.3   | deg    |
| 6  | Modulus elasitisitas    | 25000  | kN/m²  |
| 7  | Poisson ratio           | 0.25   |        |

Output from simulation results with Plaxis are shown in Figure 8 and Figure 9. Simulation results in the form of displacements showing the elements of land drawn by sea water. In the land situation, there are no roots and roots not reach to the surface, the sand drawn back by seawater is only on the surface. This shows the seawater eroding the beach surface. As for the condition of the roots to the surface of the seawater go deeper because of the suction by the roots.
Figure 8. Displacement soil element

Displacement legend:

- **0.02m**
- **0.01m**
- **0.0**

The area of land affected by water suction is shown as a tense element in Figure 9. The results indicate that the working mass of the soil holds to its appeal to its limits.
Figure 9. Displacement soil element

For conditions of no roots and roots do not reach the surface, the simulation results show that only the soil on the surface is affected so that the sand surface is easily carried by sea water. When the roots reach the surface, the affected mass of the earth becomes larger. It can be seen that the tense ground mass enters the deeper ground. The simulation results show that in situations where the roots are spread to the surface, the coast has better protection against abrasion.

Conclusion

- The result of field investigation based on coastal geometry shows that the smaller the coastal slope the greater the diameter of the grains of coastal sediment and vice versa.
- The seven samples belong to the type of sandy soil. the sandy soil has a low coefficient of uniformity. In general, coastal sediments in western Sumatra have relatively small diameter sizes from soft to medium sands that are easily transported by sea water. In addition, land gradations are uniform which indicates the coast is potentially abrasion.
- The simulation results show that in situations where the roots spread to the surface, the coast has better protection against abrasion.
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