Proceedings of EnCon2008
2nd Engineering Conference on Sustainable Engineering
Infrastructures Development & Management
December 18 -19, 2008, Kuching, Sarawak, Malaysia

ENCON2008-C-30

Preliminary Study on Sediment Load at Kampung Sungai Lurus Shoreline

Zarina Md Ali, Siti Nazahiyah Rahmat, Mohd Adib Mohammad Razi,
Noor Aliza Ahmad and Nur Aishah Sabri

Abstract—**Coastal erosion impinges directly on many aspects especially tourism sector. Due to this problem, a study was carried out at Kampung Sungai Lurus shoreline to determine sediment shear stresses and characteristics of sediment load. Parameters needed were oceanography data and characteristics of sediment load. Sediment shear stress, τ_o was calculated by Prandtl-Von Karman equation and critical shear stresses, τ_c were figured by using Smerdon and Shield method. Results figured that sediment shear stress, τ_o value is 21.76 N/m^2, while Smerdon and Shield method gave 1.92 N/m^2 and 0.0251 N/m^2 respectively. Both methods showed sediment shear stress were greater than critical shear stress ($\tau_o > \tau_c$). It shows that erosion happened at this area. Besides of regular maintenance, soft engineering techniques were suggested to attenuate and dissipate wave energy at shoreline.**

***Keywords*:** sediment shear stress, critical shear stress and sediment characteristics

I. Introduction

The coastal zone has been one of the most intensely utilized segments of the landscape. A shoreline may be composed of loose sediments such as gravel, sand or mud is reshaped dynamically as it is acted upon by waves, currents and winds continuously [1]. Despite the different wave climates that exist around the world and variations in coastline composition, the nature and behavior of beaches are found to be similar with one another. Other than that, coastal developments can affect coastal zone processes by changing the rate and/or characteristics of sediment transport to the coast, adjusting the level of wave energy flux to the coast and directly interfering with coastal sediment transport process [2]. National Coastal Erosion Study of Malaysia had concluded that from 4809 km of Malaysian coastline, 29% are facing critical erosion [3]. It has been receiving amounts of attention because coastal erosion impinges directly on many aspects such as industry, transportation, residential and recreational.

In the study of sediment transport, incipient motion is important to define precisely when the sediment particle will begin to move according to flow condition and most incipient motion criteria are derived either from shear stress or velocity approach [4]. On the other hand, bed elevation is determined by the balance between sediment supply and sediment transport capacity. The shore stability requires that the applied shear stress, τ_o remain below erosive levels which quantified by the soil critical shear stress. The critical shear stress, τ_c is defined as the stress at which soil detachment begins or the condition that initiates soil detachment. If the critical shear stress is higher than the effective stress, the erosion rate is considered zero [5]. Bed load varies with the n-th power of the excess shear stress which is the difference between the bed shear stress and critical shear stress for incipient motion. [6]

As preliminary study, the objectives are to determine sediment shear stresses and characteristics of sediment load at the shoreline. There are several approaches for determining τ_c which are determined in flume studies, estimated based on soil parameters such as particle size and soil specific gravity, measured *in situ* with a submerged jet test device, or assumed zero [5]. Beside that, sediment properties of single particles such as particle size, density, specific weight etc is very important in the sediment transport study [4].

Zarina Md Ali is with Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia (UTHM), Batu Pahat Johor, Malaysia (phone: 607-4537397; fax: 607-4536070; e-mail: zarinaa@ uthm.edu.my).

Siti Nazahiyah Rahmat is with Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia (UTHM), Batu Pahat Johor, Malaysia (e-mail: nazahiya@ uthm.edu.my).

Mohd Adib Mohammad Razi is with Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia (UTHM), Batu Pahat Johor, Malaysia, on study leave at Faculty of Civil Engineering, Universiti Technology Mara (UiTM) (e-mail: adib@ uthm.edu.my).

Noor Aliza Ahmad is with Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia (UTHM), Batu Pahat Johor, Malaysia (e-mail: aliza@ uthm.edu.my).

Nur Aishah Sabri was with University Tun Hussein Onn Malaysia (UTHM), Batu Pahat Johor, Malaysia as undergraduate student.

II. LOCATION OF STUDY AREA

Kampung Sungai Lurus (Figure 1) is located in Senggarang, Batu Pahat was selected as the location of study due to the shoreline damages. In 1980's, a 4 km of rip rap revetment was built along the shoreline by Department of Irrigation and Drainage (DID), Malaysia. A revetment is a form of cladding or protection placed on the sloping surface or structure to stabilise and protect against erosion as result of waves or currents. Most revetment systems will have been designed and constructed for a specific design life depending on the function of the revetment [7].

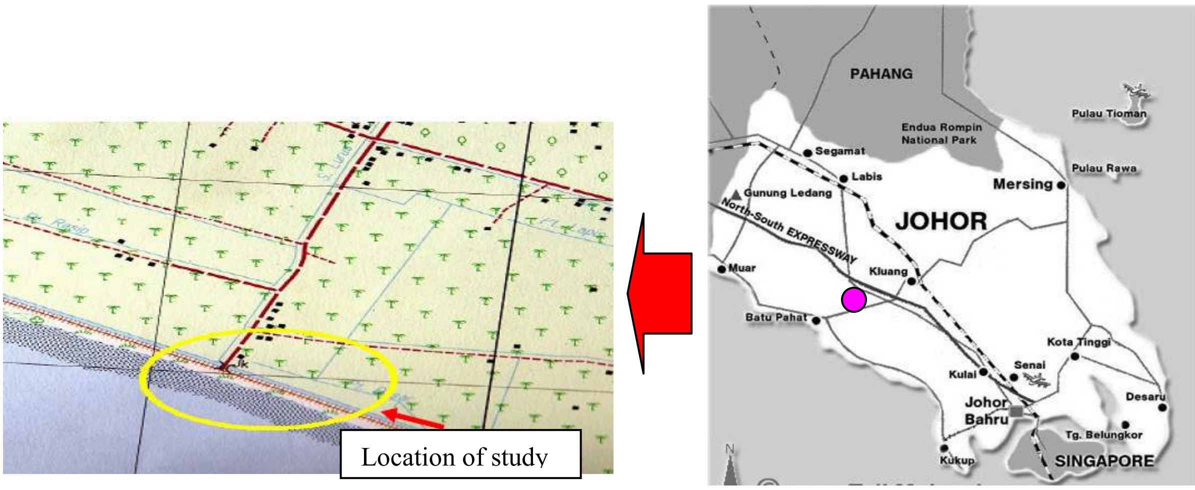


Figure 1: The location of Kampung Sungai Lurus

III. METHODOLOGY

Ocenagraphy Data

Wind blowing over the surface of water body will transfer energy to the water in the form of a surface current and by generating waves on the water surface [2]. By that, wave and surface current flow are very important in determining the shear velocity. Wave and tides table 2006 were provided by Malaysia Metrological Department and Hydrography unit, Malaysian Royal Navy respectively. The annual tides data was collected from Kuala Batu Pahat station (01°48' North, 102°53'East) and used to determine the maximum depth of water. The maximum velocity of current flow was measured by current meter during the high tides.

Laboratory Work

Laboratory tests were carried out to determine the characteristics of sediment load. The samples were collected at 1.5m depth from water surface level and to analysis for moisture content, Atterberg limit, particles size distribution and density and specific gravity.

1. Moisture content test was used to determine the percentage of water content in soil sample. The conventional oven method was selected because the study did not involve chemical content in soil.
2. Atterberg limit was carried out to obtain the precise water contents in soil to determine the liquid limit (LL) where the soil starts to flow like a liquid and the plastic limit (PL) where it ceases to be plastic and becomes brittle.
3. Sieving analysis was used 300g from each 3 samples to determine the particle size distribution, with sieve sizing are 4.00mm, 2.36mm, 1.18mm, 0.60mm, 0.30mm, 0.212mm, 0.15mm and 0.075mm.
4. Other characteristics such as specific gravity, bulk density, and bulk unit weight were examine from laboratory test and required in calculation of void ratio (e), porosity (n), degree of saturated (Sr), dry density (ρ_d) dan dry unit weight (γ_d).

Analytical Method

Erosion process occur depends on shear stress, τ_o and critical shear stress, τ_c values. The occurrence of erosion process can be known when τ_o is greater than τ_c otherwise the process will not happen. The initial velocity was determined to identify the beginning of erosion process.

Shear Stress, τ_o

Shear stresses, τ_o is proportional to drag force [4] and if a given soil does not have sufficient shear strength to resist such shear stresses, failures in the forms of landslides and footing failures will occur [8]. Shear stress was determined by Prandtl-Von Karman equation;

$$\tau_o = \rho_{seawater} U_*^2 \quad (1)$$

where, $\rho_{seawater}$ = density of seawater, 1025 kg/m^2 and, U_* = shear velocity = 5% (U_{max} + U)

The calculation of shear velocity, U* was included the velocity of current flow, U and wave maximum velocity, U_{max}. Value of U was measured during the high tides period to obtain the maximum velocity of current flow, while U_{max} was determined by equation 2;

$$U_{mak} = \frac{\pi H}{T \sinh(2\pi(d/L))} \qquad (2)$$

where, H = height of wave, T = wave period, d/L = obtained from Shore Protection Manual

Critical Shear Stress, τ_c

Sediment transport (bed load) is result of sediment movement in the direction of flow and critical shear stress, τ_c must be exceed to begin the particle movement [9]. Two methods were selected in determining the critical shear stress, τ_c in N/m^2, which are Smerdon method and Shield method [9]. Smerdon method was calculated by using chart which shows in Figure 2 and the value of plasticity index (PI) for sediment load. On the other hand, critical shear stress for Shield method can be calculated by the equation below;

$$\tau_c = F_{rd}^2 \rho_{seawater} g \Delta d_s \qquad (3)$$

where, $\rho_{seawater}$ = density of seawater, 1025 kg/m^2, g = gravity, d_s = sediment particle diameter,d_{50} which obtain from particle size distribution, $\Delta = \left(\frac{\rho_s - \rho_{seawater}}{\rho_{seawater}} \right)$ with, F_{rd}^2 = obtain from Sheilds diagram (Figure 3) which depends on $Re^* = \left(\frac{U_* d_s}{\nu} \right)$ with, U* = shear velocity and ν = kinematics viscosity =10^{-6}m^2/s.

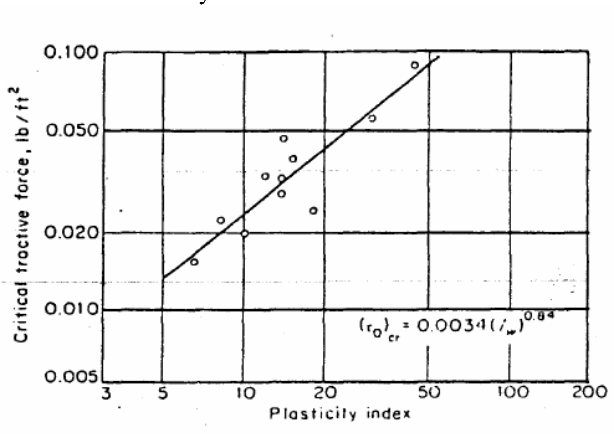


Figure 2: Smerdon Chart

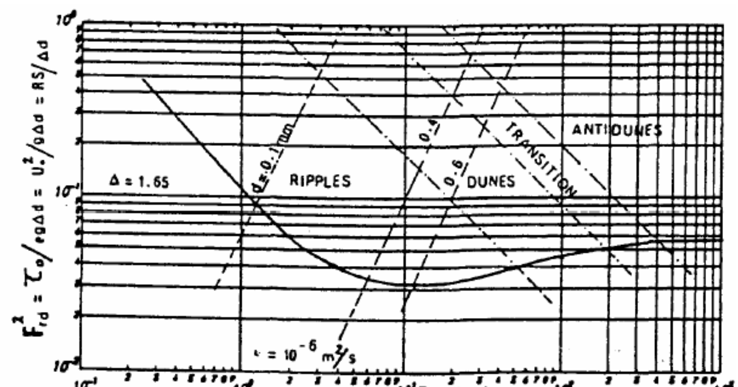


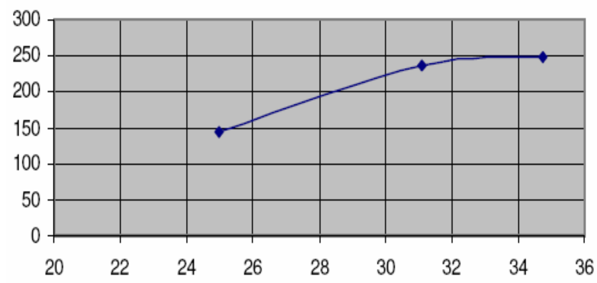
Figure 3: Sheilds Diagram

IV. RESULTS AND DISCUSSION

Sediment Characteristics

Results from the laboratory work were found that the average of moisture content and specific gravity of sediment load were 13.86% and 1.41 respectively. Besides that, Atterberg Limit test has configured that liquid limit (LL) is 30.28% based on the Figure 4. The graph also shows that moisture content is 25% to 35% versus cone penetration. Plastic limit (PL) and plasticity index (PI) for sediment is figured below than 20% which are 11.70 % and 18.58% respectively. Others characteristics that were measured are bulk density ρ_b and bulk specific weight, γ_b as 1200kg/m^3 and 11.77kN/m^3 respectively. Besides, dry density, ρ_d, dry specific weight, γ_d void ratio e, degree of saturated, Sr and porosity were calculated and tabulated in Table 1.

Cone Penetration (mm)



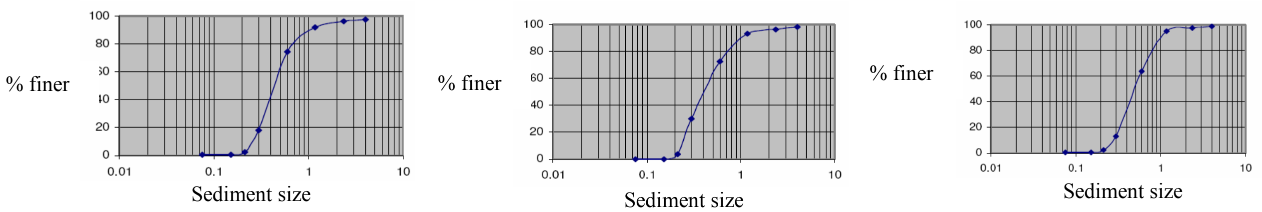
Moisture Content (%)

Figure 4: Moisture contents versus cone penetration (mm)

Table 1: Other characteristics of Sediment Load

Characteristics	Values
dry density, ρ_d	1053.93 kg/m^3
dry specific weight, γ_d	10.34 kN/m^3
void ratio, e	0.34
degree of saturated, S	54.48%
Porosity, n	3.94

Figure 5 (a), (b) and (c) were illustrated the particle size distribution between 0.075mm to 4.00mm sieving size for 3 samples of sediment load. The graphs show that more than 90% of soil particles passed through a 1.18mm sieving pan. Meanwhile, mass retained at 4.00mm sieving pan for sample A, B and C are 2.2%, 1.6% and 1% respectively. Almost all the particles passed through a 0.075mm sieving pan except sample A with 0.2g. The type of sediment was categorized as sand



(a) Sample A (b): Sample B (c): Sample C

Figure 5 (a), (b) and (c): Sieve Analysis Result for 3 samples of sediment

Based on the results above, particles movement was influenced by types of soil which is sand. The sediment load has 64% of fine sand and categorized in medium plasticity. Other characteristics will influence the transportation of soil to the coast. The particles of sediment have tendency to moveable if wave and current flow energy has greater energy to influence the structure of soil.

Oceanography Data

From the observation, wave formation was affected by wind blowing when the shore facing towards Straight of Malacca. Results from the in-situ measurement recorded that average height of wave is ranging from 0.5m to 1m in 4 to 5 seconds. The highest of water level was figured as 3.3m from the tides tables. Others from that, the maximum velocity, U for current flow was measured as 1.823m/s, while wave height, H, wave period, T and water surface level (where sediment samples were taken), d are 1m, 5s and 1.7m respectively. Besides that, kinematics viscosity, v and density for seawater, $\rho_{seawater}$ are referred as 10^{-6}m^2/s and = 1025kg/m^3

Shear Stress, τ_o and Critical Shear Stress, τ_c

From equation 2, the maximum value for wave, U_{max} was calculated as equal to 1.090m/s when d/L is 0.08729 (referred to Shore Protection Manual when d/L_o = 0.04359). Meanwhile maximum velocity for current flow, U was measured as 1.823m/s. Then, the total velocity from wave and current flow is 2.913m/s. The shear velocity, U_* is taken 5% of total velocity which is equal to 0.0545m/s. As a result, sediment shear stress, τ_o has been calculated as 21.76 N/m^2 with $\rho_{seawater}$ = 1025kg/m^3 by using equation 1.

On the other hand, critical shear stress, τ_c value by Smerdon diagram yield 0.04lb/ft^2 or 1.92N/m^2 when plasticity index (PI) was figured as 18.58%. However, calculation of critical shear stress, τ_c by Shield method (equation 3) produced 0.0251N/m^2 with F_{rd}^2 equal to 1.521x10^{-3}. From the results, shear stress is higher than critical shear stress value either by Smerdon or Sheilds method.

Therefore, transportation of sediment load has been proven occurred. The initial velocity, U_o was calculated to predict the beginning of occurrence by using Smerdon equation. Thus, critical shear velocity was calculated as $U_{*c} = (\tau_c / \rho)^{1/2}$ is equal to 0.048m/s and the initial velocity was calculated as, $U_o = 100 \times U_{*c} / 5 = 0.96$ m/s. The early occurrence of erosion process can be predicted when initial velocity reaches 0.96 m/s.

Revetment Condition

From the observation, some parts of revetment were damaged especially at the toe but the backside of revetment was protected from wave action. It is because the height of structure is higher 1.04m than water surface level. This condition will be decreased their function as coastal defence (Figure 6).Wave impact is one of important failure modes and should be considered when assessing the stability of revetment. The most severe wave loading occurs when plunging breakers break on the structure, causing very high impact pressures of short duration. These impact pressures are much localised, normally at or below the still water level. Wave impacts can cause brittle failure of rigid revetments. In the case of flexible revetment, where brittle failure is unlikely to occur, impacts over a number of cycles can cause fatigue and deformation of the revetment [7].

Figure 6: The condition of revetment at the area.

V. CONCLUSION

As conclusion, erosion process occurs at the study area when shear stress (21.76 N/m^2) of sediment is higher than critical shear stress either by Smerdon (1.92 N/m^2) or Shields (0.0251 N/m^2). The characteristics of sediment load also participate in erosion process besides the involvement of wave and current flow. Although the revetment was built at the shoreline, the erosion process continuously happens and damaged the toe of revetment.

By that, the revetment is require a regular maintenances or others methods which suitable such as sea wall, breakwaters groins, training wall and concrete blocks. Besides of hard structures, soft engineering techniques are also applied for the particular beaches that can serve to protect against shoreline erosion by themselves. For instance, beach nourishment, mangrove replanting, sediment filled geo-textile breakwaters and pressure equalization module. These techniques will attenuate and dissipate wave energy before it reaches the land.

ACKNOWLEDGMENT

The authors would like to thank the Malaysia Meteorology Department and Malaysia Royal Navy for their help in providing oceanography data.

REFERENCES

[1] E. Bird "Coastal Geomorphology: An Introduction". Chichester, Wiley & Sons. 2nd edition, 2008, pp. 133-200.
[2] R. M. Sorensen. "Basic Coastal Engineering". Springer. 3rd Edition, 2006.
[3] www.jps.gov.my, date: 23 October 2008
[4] C.T. Yang "Sediment Transport: Theory and Practice". Krieger Publishing Company. 2003. pp 1-35
[5] L. A. Clark, T. M. Wynn. "Methods For Determining Streambank Critical Shear Stress And Soil Erodibility: Implications For Erosion Rate Predictions" Soil & Water Division of American Society of Agricultural and Biological Engineers .2006. No.052019. pp 95 – 106
[6] P. Bruun. "Port Engineering: Volume two". Gulf Publishing Company. 4th edition
[7] K. Mc Connell. "Revetment Systems against Wave Attack – A design manual." Thomas Telford, 1998, pp. 7-13
[8] C. Lui and J.B. Evett. "Soils and Foundations". Prentice Hall. 2004. pp 9-44
[9] C. Nalluri, and R.E. Featherstone, Civil Engineering Hydraulics. Blackwell Science. 4th edition, 2001, pg 362 – 392