A STUDY ON CRITICAL SHIELDS PARAMETER OF SLAG MATERIAL UNDER STEADY CURRENTS

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Abstract. Materials used in this study were obtained from a steel-mill company. The material is a by-product of the steel-mill company, which some amount of it is aimed to be deposited around coastal area. Herein, this material is called as slag material. Currents and waves may erode the material and transported to other places. Therefore, it is necessary to conduct a series of experiments studying critical shields parameter characteristics of this material. Some tests were conducted to analyze material properties, such as sieving analysis, specific density, and porosity. Permeability tests were also done to all material types. Experiments were continued to measure shear velocity (u_*) which is later used to calculate shields parameter(θ). As comparison, a similar set of experiments was conducted on three groups of natural sands.

Keywords: slag, permeability, shields parameter

1. Background

Depositing grain materials on the bed of water body such as tidal flat and beach may bring some possibilities. Due to currents and waves, the material may be eroded, suspended, or transported to other areas. Sands are widely used to create artificial tidal flat and beach nourishment. However, in some cases, the deposited sands on the area are transported to other areas after some time (Dean and Dalrymple, 2002). Slag material has a bigger specific density than sands. Therefore, hypothetically, slag material is more difficult to be transported from designated area than sand. Aim of this study is to investigate the movement characteristic of slag material which is later used to analyze in what circumstance that slag material may benefit to solve coastal problems. The idea of the movement characteristic is expressed in critical shields parameter.

2. Material Properties and Permeability Tests

This study was started by investigating some material properties. Firstly, the slag material was divided into three groups of grain size, which are grain size diameter bigger than 1.0 mm (Slag A), between 0.5 mm and 1 mm (Slag B), and smaller than 0.5 mm (Slag C). Three kinds of natural sands were also analyzed. Grain size analysis of the three groups was conducted by using a set of standard sieving equipments. Further on, specific density and porosity were tested for each material by following Japan Industrial Standard No. A1202. Results of the tests are shown in Table 1. The notation d_{15} indicates the grain diameter for which 15 % of the grains by mass is finer. Sieving analysis results show that the slag gradation is different with the chosen natural sands. Meanwhile, porosity tests give a relatively close value among the material groups except for Sand A.

Sands and slag material permeability coefficients were also tested in this study. Permeability coefficient is defined as a rate of water flowing through a porous media, such as slag or sands. Permeability coefficients obtained from this study were plotted against mean grain size (d_{50}) of each material, as depicted in Figure 1. The figure shows that the trend of the permeability coefficients is similar except for Sand A

which has a smaller porosity than other group materials.

Table 1. Material Properties Tests of Slag and Sands

Material	d_{15} (mm)	d_{50} (mm)	d_{85} (mm)	ρ (kg/m^3)	Porosity
Slag A	1.180	1.680	2.250	3877.0	0.458
Slag B	0.620	0.780	0.940	3877.0	0.471
Slag C	0.080	0.215	0.380	3877.0	0.438
Sand A	0.850	1.220	1.850	2461.0	0.300
Sand B	0.240	0.320	0.440	2471.0	0.428
Sand C	0.160	0.200	0.250	2600.0	0.397

3. Critical Shields Parameter

Critical shields parameter is an expression of the ratio of force produced by the bed shear-stress acting to move a grain on the bed, to the submerged weight of the grain counteracting this (Soulsby, 1997). Shields parameter is defined as $\theta = \tau_o / [g(\rho_s - \rho)d]$. Here ρ_s is density of sediment grains, ρ is density of water, d is diameter of sediment grains, and g is gravitational acceleration. The shields parameter can be plotted against dimensionless grain size (D_*), which is $D_* = \left\{[g(\rho_s / \rho - 1)]/\upsilon^2\right\}^{1/3} d$. For critical shields parameter, Soulsby (1997) have invented an equation to represent the critical value. The equation is $\theta_{cr} = {}^{0.24}/_{D_*} + 0.055\,[1 - \exp(-0.020\,D_*)]$.

Shields parameter experiments were conducted by using a flume and an Acoustic Doppler Velocimeter (ADV) to measure velocity profiles. Results of this study were plotted in Figure 2 below. From the figure, it can be seen that slag critical shields parameters are smaller than sand shields parameters. This result proves that slag materials are more difficult to move than sands under currents. In the next research, slag material movement characteristic will be studied under waves.

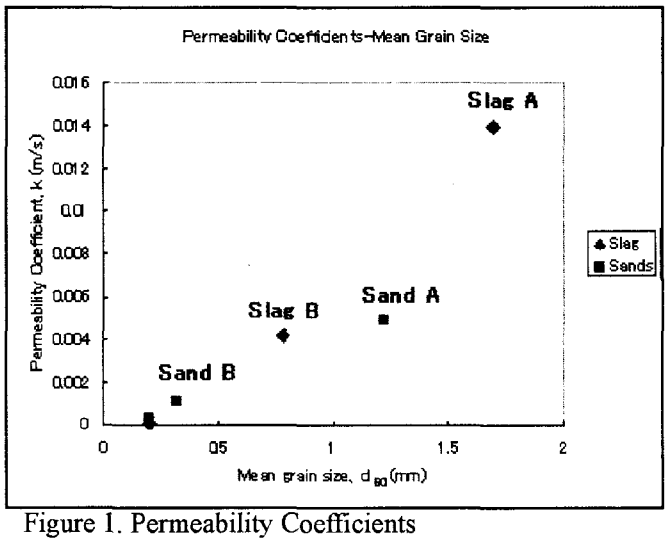

Figure 1. Permeability Coefficients

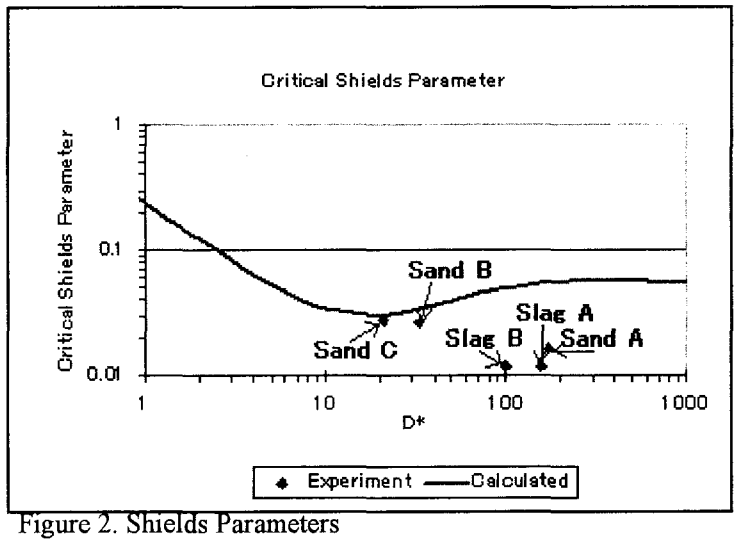

Figure 2. Shields Parameters

References

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