Suspended Behavior of Clay on Mixed Sediment under Regular Wave Action

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Keywords: sediment transport, mixed sediment, washout, experimental study, armoring

The prediction of sediment erosion is an important issue in coastal engineering projects. Natural coastal sediment is mixed sediment composed of cohesive particles (clay), semi-cohesive particles (silt) and non-cohesive particles (sand and gravel). Sediment movement occurs when the fluid force near that particle is larger than the stabilizing force of a particle. However, on mixed sediment, the interparticle cohesive sediment move and suspend earlier than the non-cohesive sediment because the cohesive sediment is composed of fine particles. This phenomenon is called "washout effect" [1]. If the cohesive sediment around the non-cohesive sediment is suspended in advance, sand has less resistance power in a second step. As a result, mixed sediment can be easily eroded [2]. Therefore, we need to consider the wash effect when we analyse the mixed sediment erosion. Our main objective was to investigate the relation between regular wave action and the time variation of clay fraction pf on the claysand mixtures. Furthermore, we tried to estimate the dominant parameter of the washout effect.

In this study, we conducted hydraulic model experiments on the sediment mixed clay and sand, and we investigated the clay washout phenomenon from mixed sediment with different wave conditions and clay content. Figure 1 shows an experimental flume and the installation locations of the measuring equipment. The laboratory experiments were carried out at Nagoya University in a wave flume that was 0.7 m in width, 0.9 m in depth, and 30 m in length. In this study, only the Main Channel was used. The mixed sediment prepared was put into an acrylic soil tank up to 16cm depth from the acrylic bottom portion after a predetermined amount of sand (median particle diameter D_{50} = 0.9 mm, specific gravity of the sand s =2.65) and kaolin (D_{50} = 0.001 mm, specific gravity of the sand s =2.65) were mixed and stirred. Clay fraction p_f (= the weight of clay/ the weght of mixed sediment) are 0, 5 and 10%. To observe the velocity near the bottom layer and to estimate bottom shear stress, electromagnetic velocity meters (V1 and V2) were installed at a height of 10 mm from bed surface. Three turbidity meters (S1 and S2) were installed to measure the suspended clay concentration at a height of 10 mm from bed surface on the same position as V1 and V2. Water surface elevations were measured by capacitance-type wave gauges in 5 parts of the flumes.

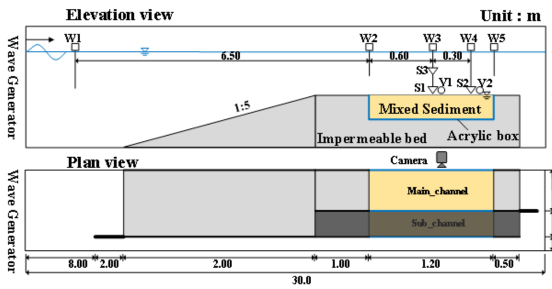

Fig. 1 Set-up for laboratory wave flume and installed instrument

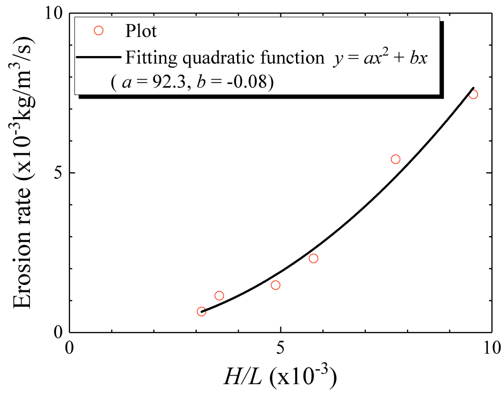

Fig. 2 The relation between erosion rates calculated by averaging the amplitude of suspended sediment concentration and wave steepness H/L in initial 10 waves.

The main findings of these experiments are as follows. It was confirmed that the suspended clay concentration is higher on mixtures with 10% clay fraction than when the clay content is 5%. These results show that the shear stress acting on bed surface promotes the increase in the erosion rate because a mixed sediment composed of 10% clay has a larger contact area with the fluid than a sediment that contains only 5% clay. Generally, when we consider the initial motion of particles, we use the bottom shear stress as a dominat parameter [3]. Regarding the mixtures composed of 10% clay, the clay washout effect depends on the bottom shear stress. Therefore, in this condition, we can estimate erosion rate using traditional parameter. On the other hand, for the mixed sediment with 5% clay, the erosion rate of the interparticle clay did not depend on the bottom shear stress and was positively correlated with the wave steepness. Fig. 2 shows the relation between the wave steepness H/L and the erosion rate E_c. H is wave height at W3, T is wave period at W3 and L is wave length. It was confirmed that the erosion rate increases with the wave steepness according to a quadratic function. This result suggests that clay is shielded by sand particles under the condition with lower clay fraction. As the physical meaning of this relation has not been investigated yet, our future work will focus on the mechanism of clay washout based on the relation between the wave steepness and armoring by sand.

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