Suction removal of Sediment from between Armor Blocks at non-uniform bed

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Abstract: This paper presents the results of an experimental investigation on suction removal of non-uniform sediment from between armor blocks/stones placed on a loose bed. It was found that the vortices that form in the holes between the armor blocks are key to the suction process. The critical condition for the onset of suction was determined. Grain size variation of the sediment and texture of the sediment surface were evaluated before and after suction.

Key words: Armor layer, nonuniform sediment, turbulence intensities, steady current, Shields parameter

Introduction

One of the methods widely used for scour protection is rock dumping on a bed material like sand or gravel. When such a rock layer (armor layer) is exposed to a steady current, sand underneath will be agitated by the flow turbulence. When the flow turbulence reaches values larger than a critical value, bed material sucked from between the armor blocks. This will cause the armor blocks to sink, leading to a general lowering of the armor layer. The armor blocks need to be designed such that the suction of bed materials and resulting sinking of the blocks is not very extensive. The interaction between an armor layer and the base sediment bed has been subjected of a great many investigations. Raudkivi & Ettema (1982) focused on the stability of the armor layer itself. Raudkivi & Ettema (1985) concentrated on a scour around a cylindrical bridge pier in a sediment bed with an armor layer of coarser sediment. Worman (1989) was concerned with the initiation of erosion of the base sediment bed underneath an armor layer used as a protection measure around a bridge pier. Subsequently, Worman (1992) has investigated the incipient motion of the base sediment covered by an armor layer with different coverage ratios. Sumer et al. (2001) studied suction of the base sediment covered by an armor layer with different coverage ratios. In the present work suction of the non-uniform material under the armoring layer are investigated.

Experimental setup

The experiments were carried out in a recirculating water flume, 0.5 m wide, 0.5 m deep and 12.35 m long. The working section of the flume was 8.0 m long. One layer rough-

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ness elements (crushed stones) were replaced all working section. The sediment box was built in the flume, 75 cm and 5 cm deep and fine sediment replaced for supplying porous media under the roughness elements generated from crushed stones having mean height 3.7 cm and standard deviation 0.67 cm. In the middle of the sediment box, velocity measurements were performed NORTEK Acoustic Doppler anemometer 10 MHz with 25 Hz sampling rates. A hole between the stones targeting for velocity measurements and turbulence quantities were carried out in/around holes for understanding the mechanism of turbulence at rough wall flow. Water depth was kept constant as 20 cm over the roughness elements. Flow between the roughness elements (in the hole between the stones) flow visualization experiments were made. A miniature, waterproofed digital camera (Philips PCVC 740K) was placed on the bottom to view a hole between the stones. To view the entire hole, the camera (with a focusing distance of 4.5 cm) had to be placed far from it. To avoid an unrealistically large hole, the entire space between the stones was split into two parts with a fully transparent glass plate.

RESULTS AND DISCUSSIONS

In the presented study, four kinds of experiments were conducted: (1) velocity measurements, (2) Flow visualization experiments, (3) single particle experiments (4) sediment bed experiments. Velocity measurements were realized between the stones (into the targeting hole) and also all depth and flow properties like turbulence characteristic, Reynolds shear stress determined by using it. Velocity measurements were agreed with given values in the literature for rough bed. Flow visualization experiments were made for determining of the mechanism of suction removal sediment from between the stones. These observations were indicated vortex formation into the hole between stones that causes the suction .It was found that the vortices that form in the holes between the armor blocks are key to the process. The sediment swept into these vortices is entrained into the main body of the flow by these same vortices (the suction removal of sediment from between the armor blocks). The critical condition for the onset of suction was determined with single particle and sediment bed experiments (uniform and non-uniform

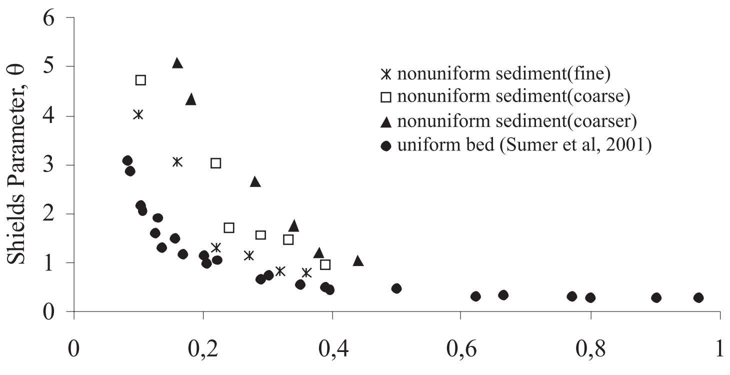

Figure 1. Critical Shields parameter for suction out for uniform and non uniform sediment against d_{50}/D

sediment). It was found that the onset of suction is governed by there parameters: (1) the Shields parameter (based on the sediment size); and (2) the ratio of sediment size to stone size, d/D and (3) coarseness of the non uniform material under the armor layer. The variation of the critical Shields parameter for suction as a function of d/D was determined for a broad range of the parameter d/D, namely, $0.001 \leq d/D \leq 1$. When the sediment layer under the getting coarser, filter layer occurs under the armoring layer itself. In the Figure 1 critical condition for suction are presented for uniform and different non uniform bed material under the armoring layer. From the figure, coarseness of the non-uniform sediment needs high shields numbers for suction then the finer ones.

Conclusions

- The vortex that forms in the hole between the stones is the key element in the process. The sediment is swept into this vortex and is eventually put into the main body of the flow when the vortex is shed and entrained into the flow.
- The critical condition at which the sediment is sucked from between the stones (the onset of suction) is governed by two parameters, namely, the Shields parameter u (based on the sediment size) and the ratio of the sediment size and the stone size, d/D (or $d50/D$).
- Nonuniform sediment has more resistance against suction than the uniform one.
- Fine sediment is sucked out from the holes between the stones and filter layer generated itself in the holes and it reduce suction of the sediment

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