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Maity, H.; Mazumder, B. S.

Coherent Flow Structures over Scour Marks Generated by Obstacles of Different Shapes

COHERENT FLOW STRUCTURES OVER SCOUR MARKS GENERATED BY OBSTACLES OF DIFFERENT SHAPES

H. Maity[1] and B. S. Mazumder[2]

The primary objective of this study is to better understanding the mechanism of formation of different kinds of bedform structures due to obstacles immersed on the plane sediment beds in unidirectional fluid flow. Experiments have shown how local scour develops around obstacles of different shapes, like short cylinder, cubic and ellipsoid of identical thickness, in non-cohesive sediments. The study shows that obstacle is the dominant cause of the initiations of scour pattern. Obstacle and the stagnation eddy together onset the scour hole at the bottom of the sediment bed, when the critical pressure gradient associated with the initiation of scour is reached. The pressure drop between the stagnation pressure upstream and wake pressure downstream of the obstacle induces this hydraulic gradient. This study explores the temporal development of scour around obstacles resting on flat bed composed of uniform, cohesionless sediment. Two basic forms of erosion take place around obstacles:- (1) Luff erosion, which occurs at the upstream side of the obstacle and is caused by an eddy formation at upstream of obstacle, (2) Lee erosion, which occurs at the downstream side of the obstacle with turbulent wakes at downstream of obstacles.

Figure 1 shows the current crescent in the bedding plane of ancient sedimentary structure. The formations of crescentic scour marks are available in cross-bedded sediments depending on the orientation and plunge of the long axes of the pebbles/bluff bodies. In order to understand the basic mechanisms of formations of crescentic scour structures, Sengupta [1966] carried out field experiments placing pebbles on the loose sand bed in a recent stream to form as replica [Sengupta 1966, Figure 4; Collinson and Thompson 1982], that might be used as indicators of ancient flow parameters in the light of modern analog as *present is the key to the past*.

Experiments were conducted in a re-circulating 'closed circuit' laboratory flume. Both the experimental and the re-circulating channels of the flume have identical dimensions of 10m length, 0.50m width and 0.50m height. To perform the tests, a sand bed of thickness h'=4cm and 5m long covering the entire width (50cm) of the flume was laid at the bottom. The median particle diameter d_{50} of the sand was 0.25mm. The specific gravity of sediments used for the experiments was 2.65. Series of experiments were conducted over the sediment bed of known grain-size distribution using three different obstacles of different shapes, like short cylinder, cubic and ellipsoid of identical thickness placed at the center line of the flume. For each experiment, single obstacle was placed at the center line over the sand bed transverse to the flow at the measuring station 6m downstream of the channel inlet (Fig. 2.).

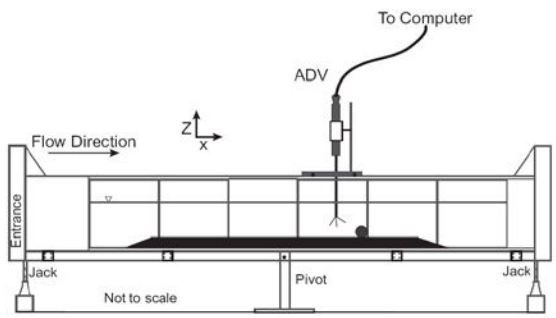
Flow depth was kept constant at H = 0.30m., flow discharge $0.015 m^3$/sec.was setup undisturbed to form scour-shaped structures around the cylinders and consequently to attain perfect equilibrium conditions in the scour marks (Fig. 3.).

[1] Ph.D. Scholar, Fluvial Mechanics Laboratory, Physics and Applied Mathematics Unit, Indian Statistical Institute, Calcutta 700 108, INDIA (maitym_r@isical.ac.in)

[2] Professor, Fluvial Mechanics Laboratory, Physics and Applied Mathematics Unit, Indian Statistical Institute, Calcutta - 700 108, INDIA (bijoy@isical.ac.in)

The obstacles placed on a sand bed, on the way of a unidirectional flow, develop a crescent-shaped scour mark on the bed. The scour is caused by generation of vortex developed on the upstream side of the obstacle. Sand grains eroded by this vortex are deposited on the downstream side of the obstacle as wakes. The turbulent flow field within the equilibrium scour mark was measured in a laboratory flume using 3-D Micro acoustic Doppler velocimeter (Micro-ADV). The scour marks named as current-crescent preserved in geological record are traditionally used as indicators of palaeo-current direction. The distribution of mean velocity components, turbulent intensities and Reynolds shear stress at different positions of the mark will be presented. We also estimate here the joint probability density function of fluctuating velocity components (u', w') applying the cumulant-discard method to the Gram-Charlier at different locations over the scour mark. It is observed that the initiation of scour is predominantly caused by obstacle due to the pressure gradient across the obstacle.

(a)



(b)

Figure 1 (a) Bedding plane showing current crescents. Proterozoic Kaimur formation, Maihar, M. P, India. (b) Figure 2: Schematic diagram of the experimental set-up

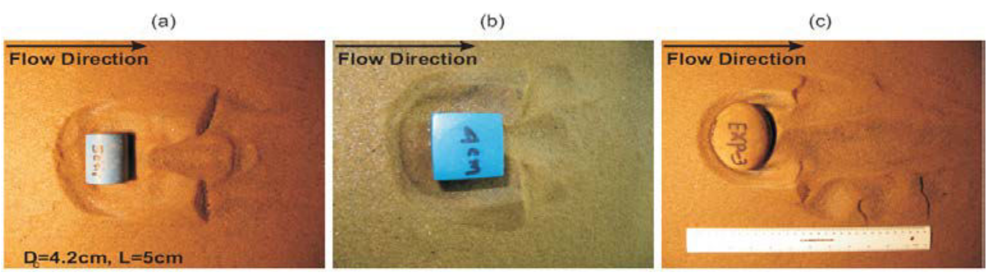


Figure 3 The equilibrium scour holes developed at the upstream of three different obstacles for Q =0.015m^3/sec.

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