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The Effect of Continuous Natural Roughness on *hydraulic jump* Characteristics on The Stone Ramps

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Introduction: The hydraulic jump happens when flow transfers from supercritical regime to subcritical regime. The hydraulic jump on smooth bed is called the classic hydraulic jump. One way to increase the energy dissipation in a hydraulic jump is to roughen the bed. Elements including stabilizers and baffle blocks are commonly used as the energy dissipators in stilling basins to stabilize the location and decrease the length and conjugate depths of the hydraulic jumps. If roughness elements are placed uniformly on the bed and orthogonal to the flow direction, the formed jump is addressed as the hydraulic jump on rough bed. Recently, implementing short energy dissipaters and environment friendly rough beds have attracted attention and justify more research in these fields. Recent studies have addressed hydraulic jump on rough beds ([14], [5], and [12]). Relative roughness parameter first defined by Rajaratnam to investigate the jump characteristics and other researchers then used this parameter to investigate the characteristics of jump on rough bed. In this research, similar experiments to Pagliara et al (5) are designed to study continuous and natural rough beds.

Materials and Methods: All the experiments have been arranged and carried out in the hydraulic laboratory of Ferdowsi University, Mashhad Iran. Hydraulic jump characteristicswere measured in a horizontal rectangular flume, 0.30 m wide, 0.50 m deep, and 11 m long, with smooth glass side walls.The rough bed was simulated by gluing a layer of uniform gravel material with middle diameter 3.5mm and 11mm on a glass plate which was placed on the flume, throughout its length .In the physical model, to simulate a supercritical flow with three constant initial depths including 1 , 1.5 and $2cm$,a steel sluice gate is installed. Furthermore, to stabilize the location ofhydraulic jump and create a free-surface jump, a sharp-crested weir with the same width as the channel width is installed at the end of the flume. Water contraction usually occurs after the sluice gate is avoided by a steel plate welded on the sluice gate. So, the initial depth y_1 equals the gate opening. According to the experimental procedure, after placing theuniform roughness heights on channel bed, the pump runs and water flows slowly into the flume. Then, discharge increases to reach the desired value and the sluice gate opening is set up to have the hydraulic jump formed at a distance of $2cm$ ahead of the gate. These circumstances maintain enough for data recording. The parameter d_{50} of gravel particles considered as the most sensible characteristic. The subcritical depth y_2 was measured from the profile survey, where the water surface began to be essentially level.

Results and discussions: In the smooth and rough beds experiments show that variation in initial depth does not have any effect on decreasing the conjugate depths ratio. The conjugate depths ratio decreases as the roughness increases. The difference between conjugate depths ratio of rough beds with middle diameter 3.5mm (B) and 11mm (C) appears when the Froude number exceeds 7.5 and for Froude numbers greater than 10, a significant drop can be observed in the conjugate depths ratio diagrams from rough bed B to C. The horizontal distance between the beginning and end point of a hydraulic jump is considered as the length of the hydraulic jump. Dimensionless length of the hydraulic jump is presented as L_j / y_2 which is usually considered as a function of Fr_1. For Froude number greater than 10, the dimensionless length of the hydraulic jump is nearly constant. Then, the ratio of L_j / y_2 for Froude numbers greater than 10 seems to be independent of supercritical Froude number and is just a function of roughness. In all experiments the length of the hydraulic jump decreases compared with the smooth bed under conditions that bed roughness is not subjected to water jet.

Conclusions: Experiments demonstrated that in the rough bed by increasing roughness, the conjugated depths ratio decreased compared with the classical hydraulic jump. The variation of initial depth of flow does not have any effect on reducing conjugate depths ratio and dimensionless length of the hydraulic jump. The length of the hydraulic jump in rough beds on average reduced between 28.5% and 47% with respect to the classical hydraulic jump which causes reduction in length of the stilling basin without bed roughness.

Keywords: Roughened Bed, Coarse grained channels, Conjugate depth, Length of jump