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Analysis of flow properties along a rectangular meandering channel in a gravel bed.

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Abstract

The depth average velocity distributions in a strongly meandering channel with a sinuosity of 1.06 is studied experimentally in this research for rough channel beds. Basically, in this paper 3D velocity analysed at apex and crossover. The flow pattern and movement of the local maximum velocity at various points along the meander path between two subsequent bend apex regions are discovered through the analysis of velocity profiles. To compare the flow parameters in meandering channel. This paper describes how rigid gravels in a meandering channel affect the flow characteristics at two relative depths of 0.33 and 0.44, which alternately produce submerged flow conditions. Son Tek 16 MHz -ADV was used to record the velocity distribution in three dimensions. We were able to record, and categorise the velocity zones in channel. The depth average velocity values have increased at both the apex and crossover regions as the relative depth of the flow has decreased.

Keywords: ***Meandering channel with gravel bed; Velocity profiles; Son Tek 16 MHz -ADV; Win ADV Software.***

1. Introduction

The channel's depth and width both affect how the velocity is distributed. Differences between the depth ranges depending on the channel features, from zero at the channel bottom to a maximum value, either at the water's surface or some distance below it. The major factor affecting the velocity distribution's nonuniformity is the bed shear stresses. Since the channel boundary's roughness or smoothness affects the flow turbulence structures, roughness and shear are the main variables affecting the velocity distribution. When the channel's width is taken into account, it is found that the middle portion of straight channels has the highest velocity. This flow despite being present in straight channels, features are not present in meandering channels. Sinuosity or the crossover angle are used to measure the meandering of a channel. The ratio of the channel's curved distance to its straight distance is used to calculate sinuosity. On the other hand, the crossover angle is the angle formed by the bend apex and crossover sections. In meandering channels, the flow is often unclear. In general, rivers rarely run uniformly and straight. They are frequently observed in a curved or meandering shape. This pattern is often followed by rivers to reduce energy loss. Where single channels stray from straightness, meandering channels are equilibrium features that represent the most likely plan geometry.

The experimental study on the velocity variation in a highly meandering channel was necessitated. Few literatures are available on meandering channels with higher bed roughness particularly the detailed comparison of longitudinal velocity between different roughness. Hence, the present study incorporated the experimental investigation on roughened meandering channels with sinuosity of 1.06. The variation of longitudinal velocity for the channels is studied in detail for a complete meander path. The flow pattern in a 90° mild bend was investigated statistically and experimentally by Naji Abhari et al. who concentrated on the distributions of velocities, streamlines at various water levels, and shear forces. The results showed how the secondary flow and centrifugal force had a significant impact on the flow pattern in a channel bend. Khatua et al. studied the evaluation of roughness coefficients in meandering channels. Mohanty anticipated lateral depth-averaged velocity distribution in a trapezoidal meandering channel, and a quasi-1D model Conveyance Estimation System (CES) was applied to the same meandering channel to analyse the depth-averaged velocity.

In this paper, experimental investigation is performed to study the velocity distributions in a highly meandering channel of sinuosity 1.06 with 30° crossover angle for rough channel bed. The flow pattern and movement of the local maximum velocity at various points along the meander path between two sequential bend apex regions are discovered by analysis of the velocity profiles.

2. Methodology

The experiments were conducted by utilizing the laboratory facilities available in the hydraulics laboratory, National Institute of Technology Rourkela Fig. 1. The meandering channel setup is made up of size 10 m length, a width of 1.7 m, and height 0.9 m with a steady bed incline according to the planned scaled model drawing of slope 0.001. The main channel of the meandering compound channel features a rectangular cross section, measuring 0.28 m in width and 0.12 m in depth. Table 1 displays the channel's complete specification. Test evaluations were conducted in a mildly sinuous compound channel with a bend point of 30° and a sinuosity of 1.06 that was created using a Perspex sheet with a thickness of 7–10 mm and a channel roughness of $n = 0.01$ and placed over the base of craftsmanship work. It is advantageous to perform the tests under stable head conditions and a Reinforced Cement Concrete overhead tank was erected upstream of the channel to transport the water to the test flume. The volumetric tank collects all the water supplied to the channel and follows it to the sump tank with a considerable commitment to the continuous water supply. Overflow water is transported back to the sump tank through the line associations. The distribution system for the water supply to the channels is completed by the installation of three diffusive syphons with a 10HP maximum capacity and suction and conveyance pipes. To straighten the flow and reduce turbulence, a stilling chamber with a baffle arrangement is placed at the channel's entry. To maintain a constant level in the channel, a variable tailgate setup plan is fixed at the downstream side of the channel. The tailgate adjustments were used to provide a quasi-uniform flow. The experiment readings were taken 3–4 hours after the flow process started in the channel. The test part, measuring 2.2 meters in length, was selected at a distance of a distance of $3.85 < x < 6.05$ (x measures the distance of test section from the inlet portion in flow direction), where the flow was completely developed and devoid of backwater effects.

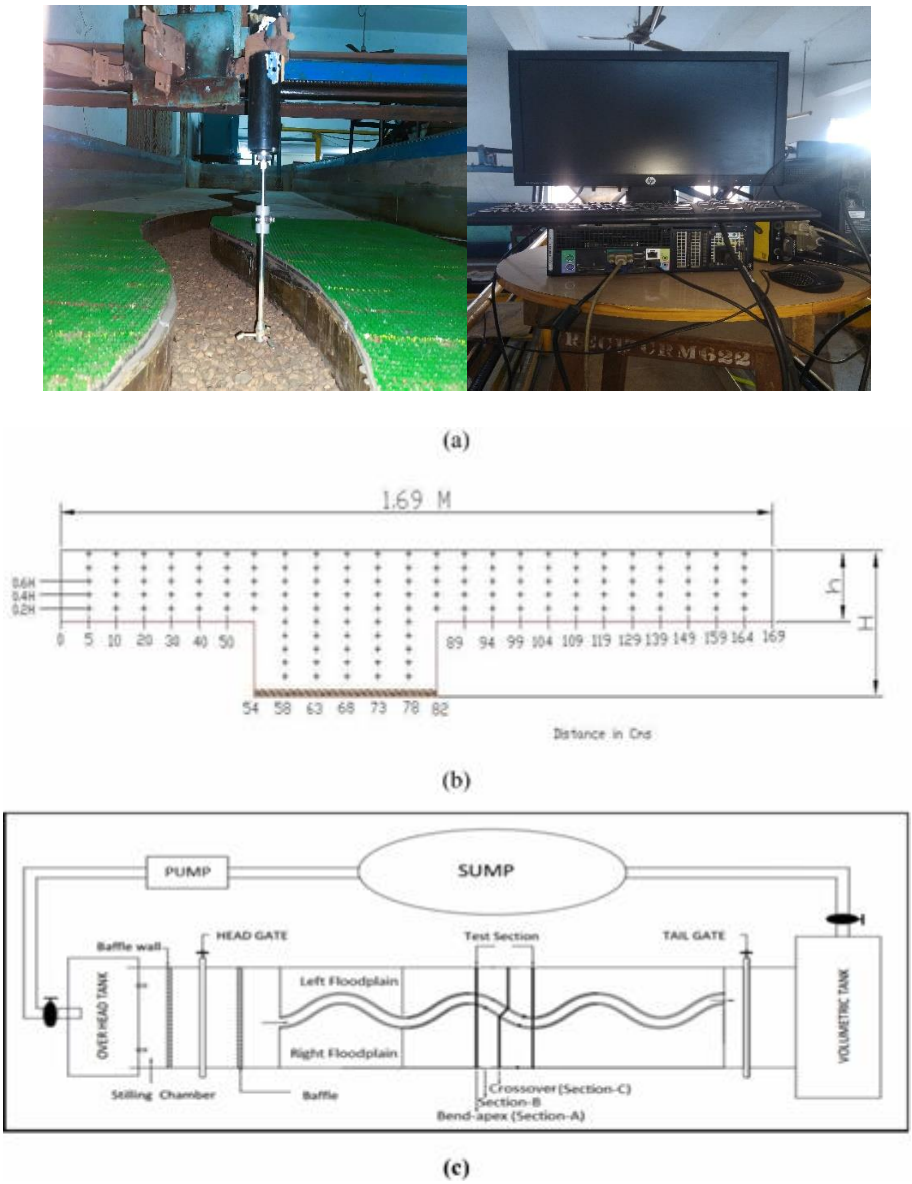

Fig. 1. (a) Experimental setup of meandering channel with gravel and ADV, (b) Locations for measuring of point velocities using Son Tek 16 MHz -ADV, (c) Schematic view of an experimental setup and water recirculation system.

The depth of flow at any individual section is not constant in the case of a meandering channel. As the rectangular channel has a 0.001 slope, the lateral distance is proportional to the vertical distance, demarcated as 0.2h, 0.4h, 0.6h, and 0.8h. Tail gate on the rear end of the flume is adjusted for maintaining a constant water depth of around 0.05 m, throughout the meander path. This is done for the rough case of meandering channels.

Table 1 List of specifications of channel parameters.

Channel Parameters	Value
Length of channel	10 m
Width of the channel	1.7 m
Slope of the channel bed	0.001
Main channel arc angle (degrees)	30
Sinuosity of the channel	1.06
Meandering belt width	0.61m
Wavelength of the channel (λ)	2.23
Depth of main channel (h)	0.12m
Width of main channel (b)	0.28m

Over the main channel bed, a 9 mm river gravel bed is laid down. The experimentation setup was installed in a narrow channel, and the movable bridge arrangement is placed over it. The three-dimensional velocity readings were taken using the advanced equipment called Son Tek 16 MHz Micro-Acoustic Doppler Velocimetry (ADV). The apex portion of the test section, where the curvature effect is maximum, and the cross-over portions are where the velocity reading was taken. In Fig. 1b, the velocity grid used to record the velocity values was displayed. For very precise datasets, all of the point velocities were finally filtered using the WIN ADV software . The signal to noise ratio (SNR) and correlation value in this approach are kept at 15 and 70, respectively.

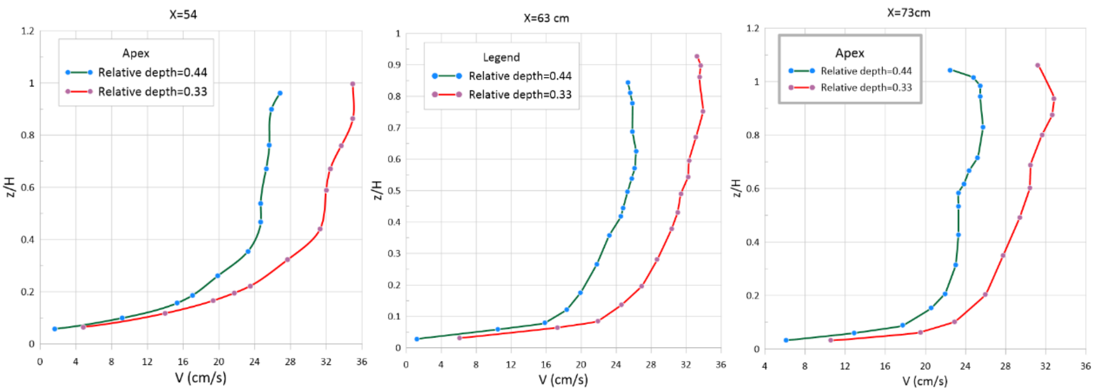

Fig. 2. Sectional velocity profiles at Apex portion.

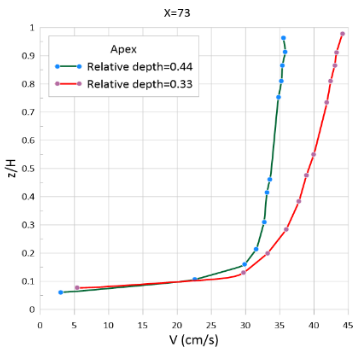

Fig. 2. (continued).

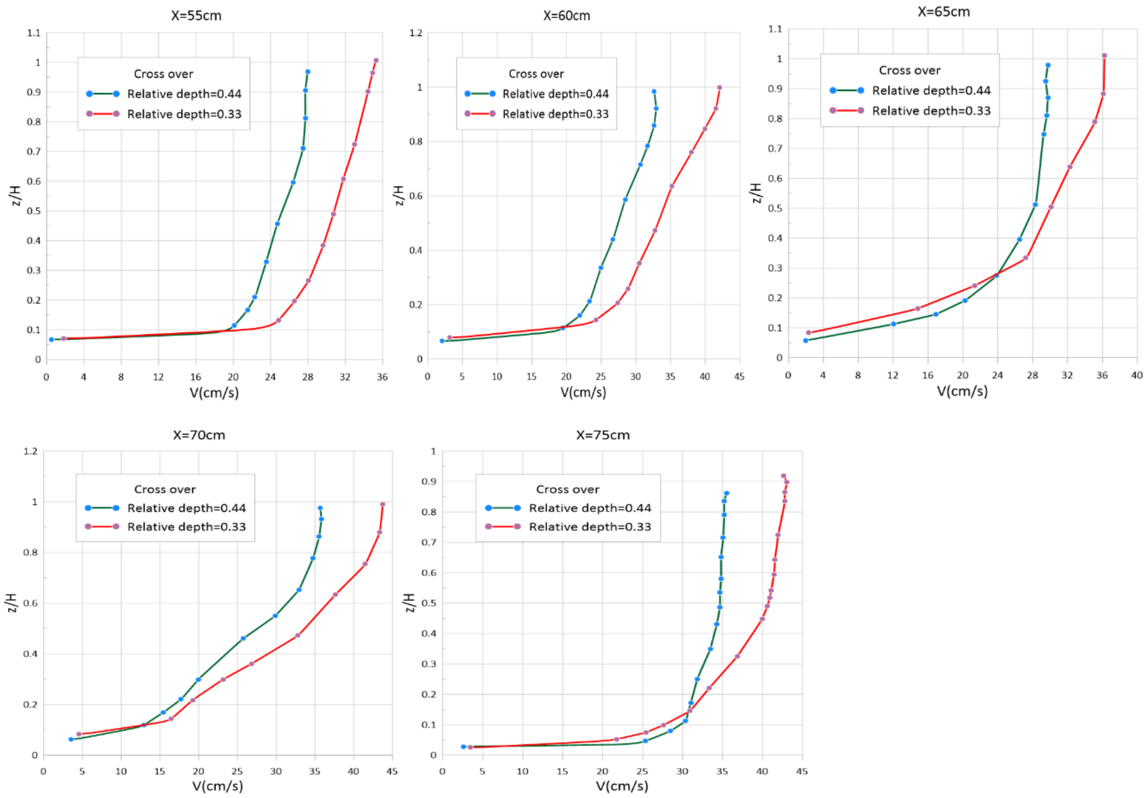

Fig. 3. Sectional velocity profiles at Crossover portion.

3. Results and Discussion

Accurate prediction of velocity profiles and its calculation of depth averaged velocity is important for the estimation of the discharge carrying capacity of any channel. Here, along the channel, width was divided into 25 sections. The velocity profiles were calculated using a down and up probe of ADV at each section. Here the apex portion was selected because it is the point where maximum erosion and deposition occurs, and another section was chosen at the crossover portion, where the meandering path of the channel becomes straight. It is known that the depth-averaged velocity will occur 0.6H from the free surface or 0.4H from the channel bed. Depth averaged velocities were calculated for both apexes and cross-over portions at two relative depth conditions (0.44 and 0.33) which is displayed in Fig 2. This sinuous channel at the apex portion, the velocities were maximum at the outer side of the concave portion. Depth averaged velocity,

$$Uavg = \frac{1}{H}\int_0^H udz \tag{1}$$

ADV up and down probes were used to record the streamwise velocities in the x, y, and z directions. The velocity profiles at various apex and crossover portions, taking into account both relative depths, are shown in Figs. 2 and 3, respectively. At two relative depth conditions, relative depth 0.44 and 0.33 respectively, the streamflow velocities in the x direction were recorded at both the apex and crossing region. The velocity values have increased at both the apex and crossover regions as the relative depth of the flow has decreased. Cross-over section values of velocities were low as compared to the apex portion because there was less curvature effect.

4. Conclusions

An experimental study has been carried out to determine the impact of gravels on the flow characteristics in a meandering channel at two relative depth values, of 0.33 and 0.44. The following results are obtained from a close examination of the flow parameters in the meandering channel with gravel base.

- From the experiment results it is seen that depth average velocity variation at apex and cross over.
- The depth average velocity values have been found increased at both the apex and crossover regions as the relative depth of the flow has been decreased.
- Cross-over section values were low as compared to the apex portion because there was less curvature effect.

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