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Water surface profile along a meander path of a sinous channel

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ABSTRACT: *Meandering channel flows are ambiguous for natural flow systems such as rivers. This pattern of flow is generally followed by rivers to minimization the energy losses.Due to existence of secondary flow, flow characteristics in channel bends are much more complicated than those in straight channels. In channel bends, the secondary flows occur due to imbalance between centrifugal force and pressure gradient. In other words, close to the inner wall and also at the channel bed, pressure gradient exceeds centrifugal force and conveys water in a transverse direction towards the inner wall. At the free surface centrifugal force drives the flow to the outer wall. The interaction between the main flow and the secondary flow forms the so-called helical flow at the bend. Hence, water surface, on entering a bend finds a non-linear transversal slope due to centrifugal force. This slope is greater in the inner half than its outer half. Understanding this characteristic of flow in a channel bend is very important in designing hydraulic structures at such locations.Knowledge of the characteristics of surface profile at different sections is important in flood modelling and forecasting which helps in the design of hydraulic structures.In this paper, An experimental investigation has been carried out to study the transverse profiles of water surface of a meandering channel. Investigation has been made at different sections along a meander path i.e from one bend apex to another where the water surface profile changes its course at the cross-over.*

Keywords: *cross-over, meander path, meandering channel, transverse profile*

I. INTRODUCTION

Due to the existence of secondary flow, flow characteristics in channel bends are much more complicated than those in straight channels. Some researchers have carried out extensive studies on flow characteristics in channels with different bend angels by using the experimental and numerical models. Shino[1] developed turbulence models and studied the behavior of secondary flows and centrifugal forces for straight and meandering channels. Blanckaert and Graf [2] investigated channel bed level changes at a 120º sharp bend with a movable bed using an experimental setup. They reported a minor secondary rotating flow cell at the outer wall of the bend.

As numerical hydraulic models can significantly reduce costs associated with the experimental models, their use has been rapidly expanded in recent decades. Booij[3] and VanBalen et al. [4]modeled the flow pattern at a mildly-curved 180º bend and assessed the secondary flow structure using large eddy simulation (LES).Bodnar and Prihoda[5] presented a numerical simulation of the turbulent free-surface flow by using the k-ε turbulence model and analyzed the nature of non-linearity of water surface slope at a sharp bend. Zhou et al. [6] using the two-dimensional depth-averaged model, simulated the flow pattern in 180° sharp bend and 270° mild bend, with and without consideration of the secondary flow and claimed that, given the effect of the secondary flow, the simulation results in the first state has a better agreement with the experimental results. Khatuaet al. [7] studied evaluation of roughness coefficients in meandering channels.Dash and Khatua[8] formulated the roughness coefficient for meandering channels.Ottevanger et al. [9] studied bed and wall shear stresses in meander bend by using a three-dimensional numerical model and then presented a correction factor in order to calculate shear stress related to velocity values. NajiAbhari et al. [10] studied the flow pattern in a 90° mild bend numerically and experimentally. In this study, they focused on the velocity distributions, the streamlines at different water levels and the distribution of shear stresses and they did not study water surface profiles. The results showed that the flow pattern in a channel bend is heavily influenced by the secondary flow and centrifugal force. Bonakdari et al.

[11] investigated the flow pattern at a 90º mild bend using numerical model, artificial neural network and genetic algorithm. But they only focused on the velocity components.

In this paper, the transverse surface profile is studied throughout a meander path of a highly sinuous meandering channel of sinuosity 4.11. The surface profile data are studied to find the flow pattern and validate that the water level increases towards the outer wall and decreases at the inner wall while moving over a curve. Another aspect of study especially in this paper is to find the patter of flow when the channel changes its sign at the cross-over.

II. Methodology

Experimental Setup

For carrying out research in meandering channels, experimental setup was built in Fluid mechanics and Hydraulics Laboratory of NIT, Rourkela. A meandering channel having trapezoidal main channel (bottom width 0.33m,depth 0.065m and side slope 1:1and wide rectangular floodplains having total width 3.95m was built inside a steel tilting flume of around 15m length(Fig.1) was built inside a steel tilting flume. The bed and wall of channel was made with Perspex sheet (6 to 10 mm thick), having Manning's n value=0.01, cut to designed shape and dimension, glued with chemicals and put in position.

Fig. 1 Photograph of the Experimental Channel

Position of Measurement

All observations are recorded along a meandering path from one bend apex to the next corresponding bend apex through the cross-over. Series of point gauges with moving bridge arrangements are made to measure the water depth at different points of the flow passage of the channel. The mesurements are taken at different reaches along the meander path for every depth. Similar readings are taken for different discharge and different flow depths at steady state conditions. A section at crossover perpendicular to both the inner and outer curves of the meandering channel is drawn and extended unto the bend apex line. An angle of 120^0 is formed for both the curves. These curves are divided into 6 equal sections of 20^0 each to the centre line. Channel sections along the width are drawn at these points. The sections A through M are considered for measurement of the transverse profiles.

Measurements are taken from left edge to the right edge of the main channel in the direction of flow. The lateral spacing of the grid points has been taken as 4cm.

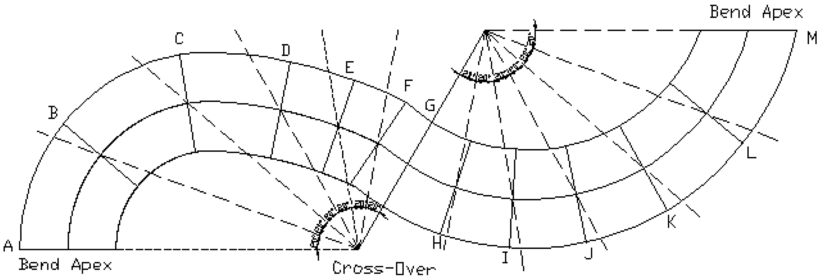

Fig. 2 Defined cross-sections along the Meander Path

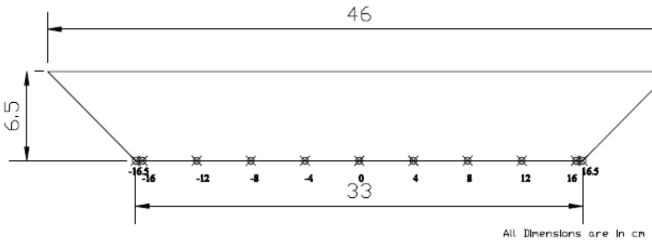

Fig.3: Typical vertical section of the channel.

III. DISCUSSION AND RESULT

A single discharge is maintained at a time and the surface profile data are taken throughout the meandering path across the channel. Experimentation is carried out at different discharges. However a single discharge data is represented in this paper. The discharge is maintained at $3.5x10^{-3}$ m^3/s.

At the initial sections, i.e. from section A to F, the depth of water at the outer wall is higher than the inner wall. Hence water at the left hand side of the main channel remains higher than the right hand side. Refer Fig. 4. From sections F to H, i.e. close to the crossover (section G), the water level somewhat tries to level itself and behaves as a straight channel in that particular portion.

After the crossover, when the channel changes its sign, the water surface profile now increases on the right hand side of the main channel and decreases on the left hand side. Therefore in the curve after the crossover, the depth of water is higher on the outer wall than on the inner wall.

Data represented in Fig.4 are for sections at the bend apex A and M, the crossover C and two in-between sections for both the curves.

At the bend apex, sections A and M, the surface profile is not level as the channel continues as a sine curve. As can be seen in Fig.1.

From the above illustration it is observed that the transverse surface profile at the outer wall always remains higher than the inner wall. It is also observed that the water surface profile in and around the crossover maintains a level height.

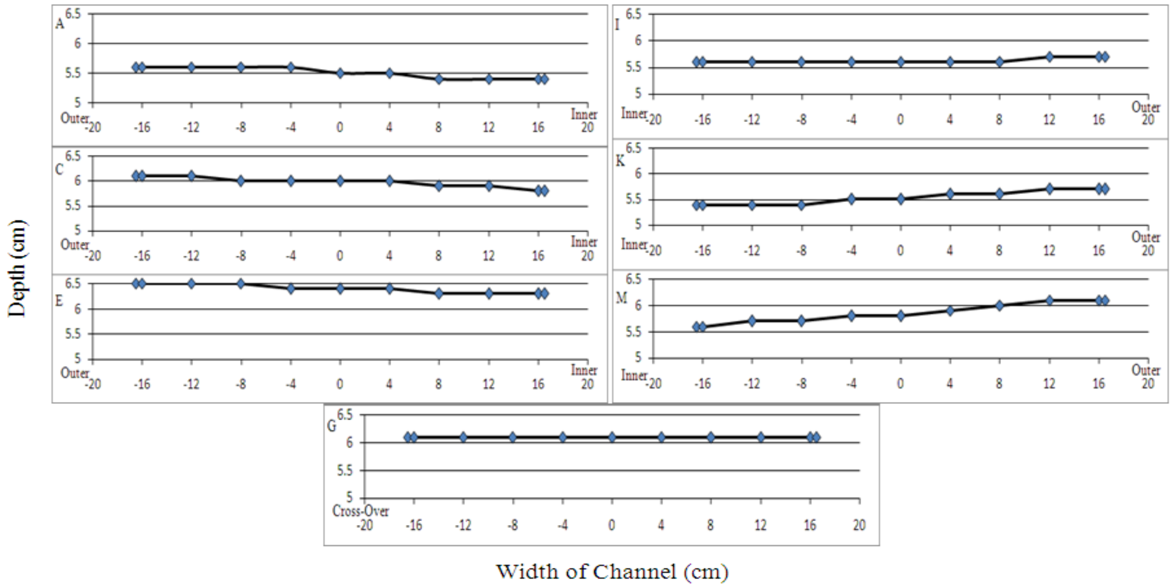

Fig. 4 Transverse water surface profile at different sections

IV. CONCLUSION

The following conclusions can be presented in this work

1. An experimental investigation has been carried out to measure the depth of flow at different points along the meander path of a meandering channel to the impact of meandering effect on flow depths of a meandering channel for the same discharge.
2. Variation of flow depths at different points has been studied. We have measured the flow depths for different flow velocities and discharges.
3. The wavelength of the experimental reach of meandering channel has been divided into different sections along the centre line to study the change in flow depth for given discharge of flow.
4. From the flow profile study of the meandering channel it is seen that when the discharge increases, the depth of flow at both the inner and outer wall increases, however for the same discharge, the depth of flow at the inner side is less as compared to the outer side.
5. This methodology can be applied to calculate the flow profile and depth of a meandering river. This will help for flood prediction and flood management purpose.
6. The present research work is providing information for getting water surface profile of a meandering channel of sinuosity more than 4.

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