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Velocity Distribution in Compound Channel Flows by Numerical Modeling

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ABSTRACT : *Rivers are always stuffs of attractiveness and the significant livelihood of an expenditure. compound section of a natural channel generally comprises a wider and rougher flood plain than main channel. The flow process in the open channel becomes more complicated at over bank stages due to the different hydraulic condition prevailing in the main channel and the adjoining flood plain. As the shallow flood plains offer more resistance to flow than the deep main channel, the velocity tends to be higher in deeper main channel than the shallow flood plain. This variation of velocity between deep main channel section and the adjoining shallow flood plains raise the lateral momentum transfer, which further complicates the flow process.*
In the present work an experiment for the depth average velocity at different points of the channel cross section in lateral direction is carried out by using ADV, for a compound channel having width ratio2.923 with differential roughness (the ratio of base n value of flood plain surface roughness to main channel roughness) 2.0833m^(-1/3)sec. The numerical model using ANSYS fluent as a result of developing simulation model for velocity and flow depth are compared with laboratory data for flow in a compound channel that consists of a main channel and symmetric flood plains set at a fixed bed slope. Reasonable agreement between the numerical results and experimental data is shown for steady uniform flow located at a section at a distance of 8.5m from the start end.
Keywords: *compound rough channel, depth average velocity, differential roughness, momentum transfer, simulation model. Velocity contour.*

I. Introduction

An open channel is a passage in which liquid flows with a free surface .In other words the pressure is impressed on free surface is atmospheric. An open channel can be natural or artificial. Depending upon the shape, a channel is either prismatic or non-prismatic. A channel is said to be prismatic when the cross section is uniform and the bed slope is constant. Ex. Rectangular, trapezoidal, circular, parabolic. A channel is said to be non-prismatic when its cross section and slope changes. Ex: River &Stream. It is seen that, the river generally exhibit a two stage geometry (deeper main channel and shallow floodplain called compound section) having either prismatic or non-prismatic geometry (geometry changes longitudinally).A compound section of a natural channel generally comprises a wider and rougher Floodplain than the main channel. The flow process in the open channel becomes more Complicated at overbank stages due to the different hydraulic conditions prevailing in the main channel and the adjoining floodplains. For overbank stage, the resulting velocity distribution is generally not uniform across the cross-section; in particular the velocity tends to be higher in deeper main channelthantheshallowerfloodplain, as in these compound channels the shallow floodplains offer more resistance to flow than the deep main channel. The velocity variation raise lateral momentum transfer between the deep main channel section and the adjoining shallow floodplains, which further complicates the flow process, leading to the uneven distribution of flow and shear stress in the mainChannel and floodplain regions. In prismatic compound channels with roughed floodplains the resulting interactions and momentum exchanges is increased. This extra momentum exchange is very important parameter and should be taken into account in the overall flow modeling of a river. So research is still underway to develop methods which are physics based, have universal applicability and simple to apply. Because of the practical difficulty in obtaining sufficiently accurate and comprehensive field measurements of velocity and shear stress in compound channels under unsteady flood flow conditions welldesigned laboratory investigations under steady flow conditions are still preferred as a trusted method to provide the information concerning the details of the flow structure. Such information is important in the application and development of numerical models aimed atsolving certain practical hydraulic problems (i.e. to understand the mechanism of sediment transport, analysis of river migration, to prevent bank erosion in river channel, design stable channels, flood risk management, etc.).Knight and Hammed (1984) extended the work of Knight and Demetrious (1983), to the compound channels having rough floodplains. By adding roughness elements, the floodplains were roughened. They studied the influence of differential roughness between floodplain and main channel on the process of lateral momentum transfer using dimensionless channel parameters (e.g. the width ratio, depth ratio, Roughness ratio and aspect ratio). Myers et al. (2001) presented of an experimental results of a compound channel having fixed and mobile main channel along with two rough floodplains. They investigated velocity and discharge relationships illustrating the complex behaviour of compound channel river section. Hin and Bessaih (2004) investigated velocity distribution, stage-discharge relationship and the effect of momentum transfer in a straight compound channel having a rougher floodplain than the main channel. They artificially roughened the floodplain by using wire mesh.Seckin (2004) investigated the reliability and performance of four different one dimensional methods of computing the discharge capacity for compound channels by conducting a series of experiments in a compound channel having a smooth main channel and smooth or rough floodplains. For the study, he roughened the floodplains in four different ways using metal meshes. The metal meshes had a width of35.5cm, a height of14.5cm and an angle of 30o and were placed at 4 different intervals spacing on each floodplain in order to provide a particular roughness. A separate series of experiments were undertaken to find out their exact resistance properties of floodplain roughness werecreated.Most experimental efforts have been concentrated on homogeneous roughness (smooth) compound channels constrained to low width ratio (width of compound channel / width of main channel base).Therefore, the present study intend to obtain information about the influencing capacity of differential roughness on flow structure such as depth-averaged velocity, in an idealised compound section having width ratio(α)=3.

II. METHODOLOGY

In order to find out the effect of diversity in floodplain roughness and main channel roughness on the flow characteristics (i.e. boundary shear distribution, flow distribution, depth-averaged velocity, variation in overall and zonal Manning's *n* and discharge)during over flow condition in a compound channel, experiments were conductedunder controlled laboratory conditions in the Fluid Mechanics and Hydraulics Laboratory of theCivil Engineering Department at the National Institute of Technology, Rourkela, India.

Table 2.1

SL NO	DESCRIPTION	EXPERIMENTAL CHANNEL
1	Channel type	Compound channel with rough flood plain
2	Flume size	15m×1.9m×0.125m
3	Geometry of main channel section	Trapezoidal(side slope1:1)
4	Channel width	65 cm at bottom and 90 cm at top
5	Bed slope of channel	1:1
6	Main channel height	0.125m
7	Relative depth	0.4
8	Flood plain roughness	Gravel(0.025m^(-1/3)sec)
10	Channel bed slope	0.0022

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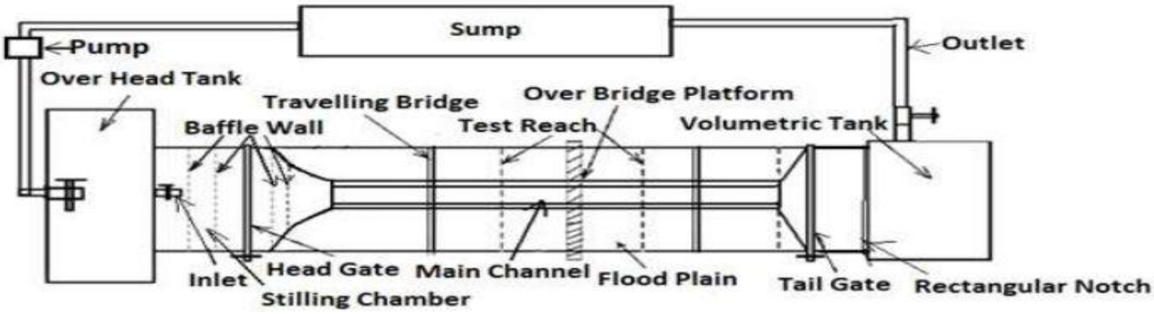


Fig 2.1: PLAN VIEW OF EXPERIMENTAL SET UP OF THE CHANNEL

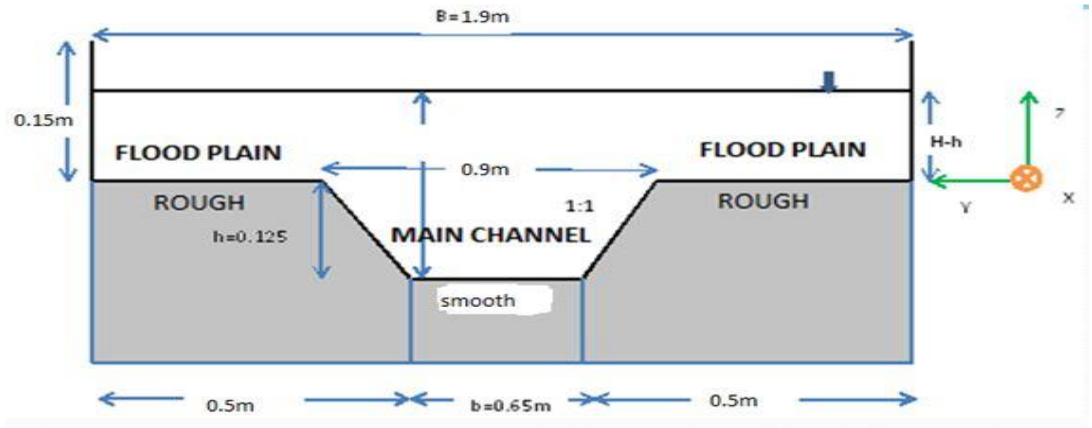
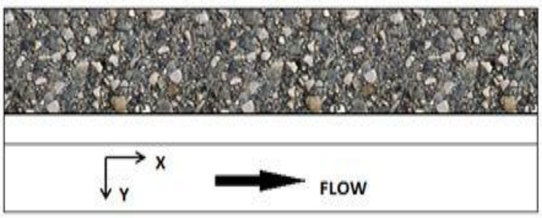


Fig 2.2: CHANNEL FRONT VIEW



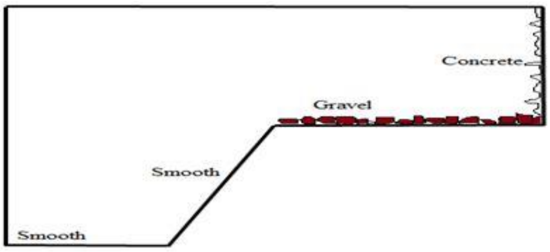


Fig 2.3: PLAN VIEW OF FABRICATED CHANNELFig 2.4: 1/2 CROSS SECTIONAL VIEW OF CHANNEL

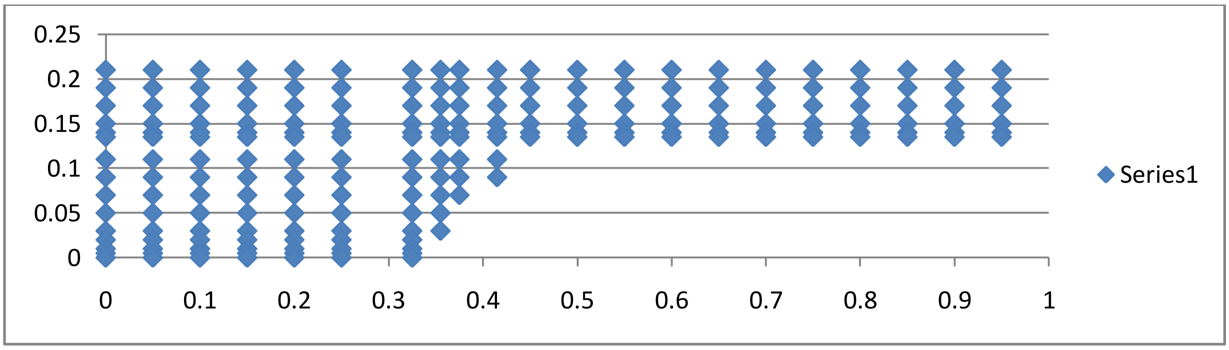


Fig 2.5: TYPICAL GRID POINTS FOR MEASUREMENT OF VELOCITY

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Description Of Numerical Model Parameters

In this study, Fluent, for model verification a Computational Fluid Dynamics simulation tool is used which is based on the three-dimensional form of Navies-Stokes equations. Generally a finite volume method(FVM) is used in CFD. Both structured and unstructured grids is used in Fluent .The governing equations are discretized in both space and time in free-surface modeling e.g. VOF (*15*) and height of liquid (HOL) or LES, which generally requires transient simulation. Hereford turbulence modeling Large Eddy Simulation model is used. The LES equations are discretized in both space and time. In this study the algorithms adopted to solve the coupling between pressure and velocity field is PISO, the pressure implicit splitting of operators use in Fluent (*16*). A no iterative solution method PISO is used to calculate the transient problem as it helps to converge the problems faster. When the residuals of the discretized transport equation reach a value of 0.001 or when the solution do not change with further iterations, the numerical solution is converged. To promote the convergence of the solution the changing variables are controlled during the calculations. For the simulations with an unsteady solver, the difference in the mass flow rates at the velocity inlet and pressure outlet is monitored to be less than 0.01% in the final solution. Furthermost, a number of extra time steps are added to verify the steadiness of the flow field in the final solution.

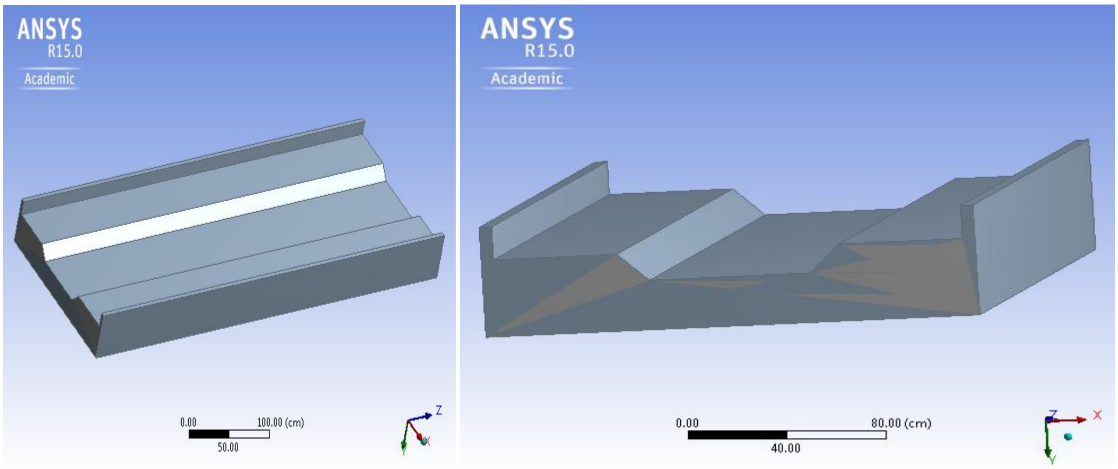

Fig 2.6: GEOMETRY OF COMPOUND CHANNEL WITH ROUGH FLOOD PLAIN

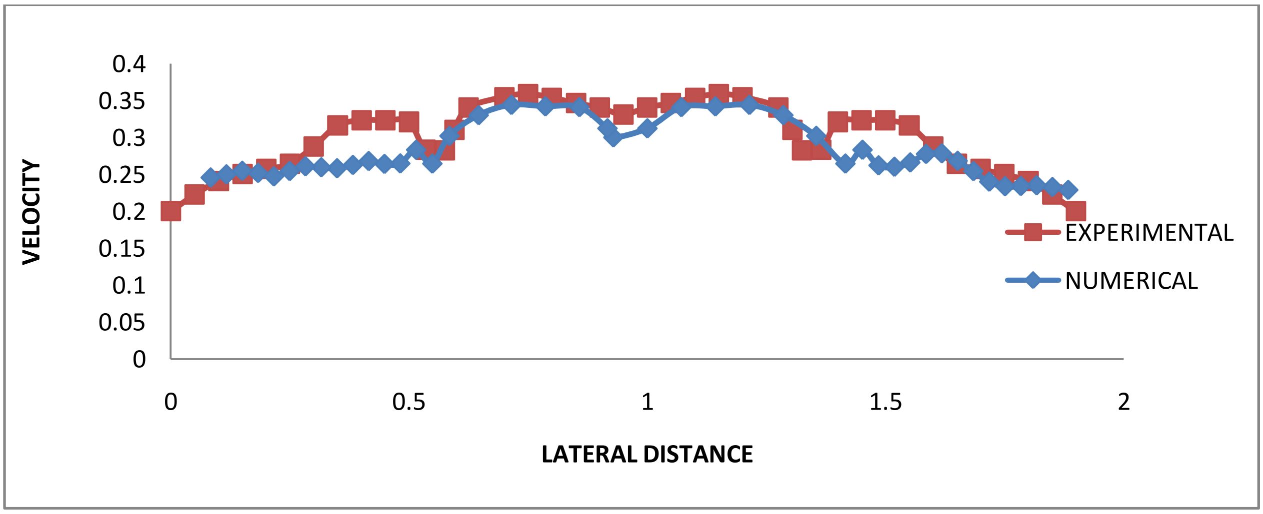

Fig 2.7: VALIDATION OF DEPTH AVERAGE VELOCITY

Once normal depth conditions were established for a given discharge, point velocity measurements made across one section of the channel at z = 0.4h from the bed. ateach lateral position, a number of readings were taken at constant intervals and then averaged to reduce error.

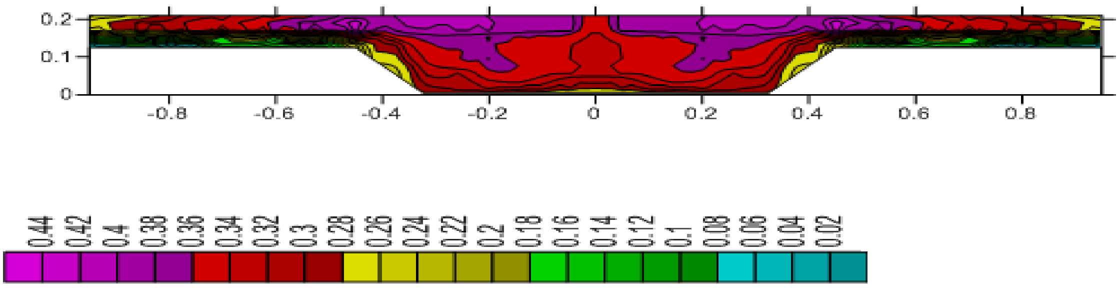

Fig 2.8: VELOCITY CONTOUR IN USING EXPERIMENTAL DATA

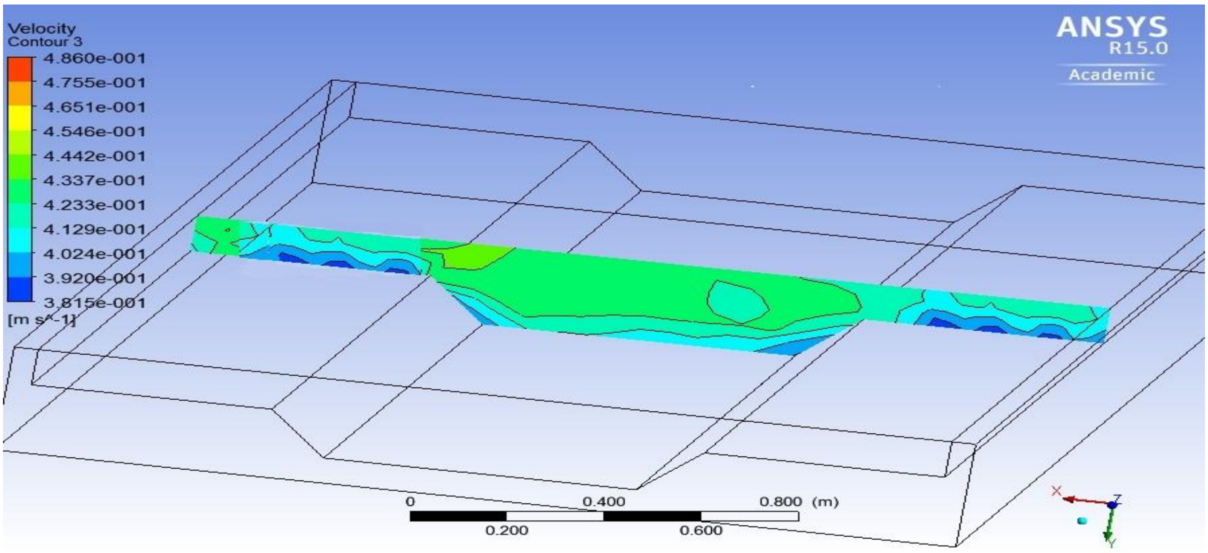

Fig 2.9: VELOCITY CONTOUR USING ANSYS

III. Conclusion

- The overall depth-averaged velocity in main channel increases with the increase in differential roughness (i.e. the percentage of flow increases with the increase in differential roughness), whereas decreases in floodplain region.
- The variation in depth-averaged velocity, in main channel and flood plain region is minimum in case of differential roughness (ɤ)=1. The variation increases with the increase in differential roughness.
- The overall discharge found to increase with the increase in depth of flow and decrease with the increase in differential roughness, which may be attributed to the fact that at higher depth of flow, the effect of differential roughness as well as that of the momentum transfer between main channel and flood plain, decreases.
- The concentration of maximum velocity contour is always found in main channel. The concentration found to decrease with the increase in depth of flow.
- The velocity variation on floodplain is found to be maximum for lowest depth of flow, then gradually stabilizing with the increase in depth of flow, whereas the variation is reverse in main channel.
- The overall range of variation in velocity is found to increase with the increase in differential roughness.

- The percentage of flow in main channel is found to increase with the increase in differential roughness, which may be attributed to that fact that the resistance to flow, offered by floodplain in comparison to main channel increases with the increase in differential roughness value (as main channel is smoother than floodplain).

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