Experimental & Numerical Analysis of Depth Average Velocity & Boundary Shear Stress In Simple Prismatic Channel

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Abstract- *The Channel is analyzed by two parameters i.e. Boundary Shear Stress and Depth Averaged Velocity by Experimental and Numerical Analysis. Experimental Analysis carried out in NIT, Rourkela and numerical analysis carried out using CES Software. However, the data analysis to be complete with the earlier research paper. As boundary shear stress & depth averaged velocity is an important parameter in open channel flow so experiments are carried out in simple prismatic channel. These experimental channels comprising of rectangular main channel having size 18 x 0.34 x 0.113m. The boundary shear stress distribution cannot be determined easily as they depend upon the velocity field, the shape of the cross section and the boundary roughness. The experimental results were taken as the reference and CES software & Birmingham analysis result of boundary shear stress & depth averaged velocity is compared with it.*

Keywords- Simple Prismatic Channel, Depth, Lateral Distance, Depth Averaged Velocity, Boundary Shear Stress, ADV, Pitot Tube, CES, Birmingham Analysis

I. INTRODUCTION

Every living being needs at least water to survive. The main source of water is rainwater and it is not available throughout the year. Nowadays due to globalization and industrialization the cycle, period, nature, quality, quantity etc. of the rainfall and rainwater is disturbed. This disturbance affects human as well as natural vegetation. So, to equalize the water cycle and make water available at every situation, hydraulic structures like dams and artificial reservoirs are building. However, these structures are built to store water and to convey this water further, channels or canals are constructed. Channels or canals are an artificial path constructed to convey water to desired place which mostly work on gravitational flow concept. To design these channels or canals various design parameter are to be considered. Depth average velocity and boundary shear stress plays a vital role in fluid flow running throughout the cross section of an open channel. However, study of these parameters is required to overcome hydraulic and engineering problems. The boundary shear stress depends upon the shape of the channel and the depth average velocity depends upon cross sectional area and discharge.

II. LITERATURE REVIEW

Research papers being national and international all emphasize on the depth averaged velocity & boundary shear stress. While analyzed the channel various parameter are consider i.e. depth averaged velocity, boundary shear stress, manning's constant, channel roughness etc. effect of these parameters on channel are studied. Calibrations of channels are done with using various models, software and actual setup.

III. METHODOLOGY

Table no. 3.1 Details of experimental parameters

Sr.No.	Item	Specification
1	Main Channel Geometry	Rectangular
2	Width of Main channel	0.34 m
3	Full depth of main channel	0.113 m
4	Slope of Channel	0.002
5	Experimental Position	8 m from outlet
6	Flume size	18m X .34m X 0.113m

Experimental analysis are done at Hydraulic Engineering Laboratory at NIT, Rourkela considering two parameters i.e. Depth averaged velocity & boundary shear stress. Depth averaged velocity is calculated at three depth 7, 9, and 11 cm by using acoustic Doppler velocimeter (ADV). ADV is based on Doppler's Shift Principle and it takes reading by transmitting sound waves by up probes and down probes for different flow depths. Boundary Shear Stress found out by using pitot tube. Difference in heads calculated by measuring level of static and dynamic heads of pitot tube and then Patel's formula were used for calculation of boundary shear stress as follows :

$$\Delta p = (\Delta h)\sin\theta \; ; \qquad (3.1)$$

$$x^* = \log_{10}\left(\frac{\Delta p d^2}{4\rho v^2}\right) \qquad (3.2)$$

$$y^* = \log_{10}\left(\frac{\tau d^2}{4\rho v^2}\right) \qquad (3.3)$$

Here d is the external diameter of the Pitot tube (0.477 mm) and v the kinematic viscosity ($1.004 \; X \; 10^{-6} m^2/s$) and Δp the difference in static and dynamic pressure. x^* is found using (3.1) and given the value and its respective range, we find y^* using the following:

$$0 \leq y^* < 1.5$$
$$0 \leq x^* < 2.9$$
$$y^* = -.0060x^{*3} + 0.1437x^{*2} - 0.1381x^* + 0.8287 \qquad (3.4)$$

$$1.5 \leq y^* < 3.5$$
$$2.9 \leq x^* < 5.6$$
$$x^* = y^* + 2\log_{10}(1.95y^* + 4.02) \qquad (3.5)$$

$$3.5 \leq y^* < 5.3$$
$$5.6 \leq x^* < 7.6$$

And hence τ can be calculated using these equations.

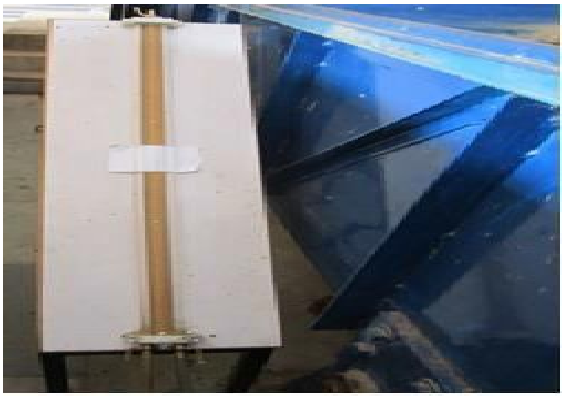

Fig.No.3.1 Inclined manometer

Fig.No.3.2 Acoustic Doppler Velocimeter

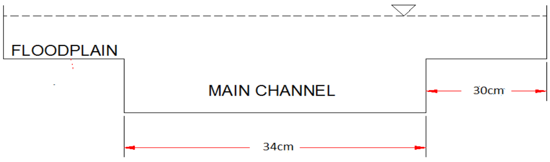

Fig. 3.3 Channel Cross Sectional View

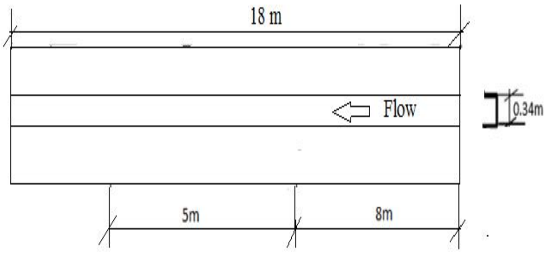

Fig. 3.4 Top view of channel

Numerical analysis is done by using CES (conveyance Estimate System) software by giving the input of manning's constant, geometry of channel and slope of channel which give the depth averaged velocity & boundary shear stress. The experimental results were taken as the reference and CES software result of boundary shear stress & depth averaged velocity is compared with it.

IV. RESULTS

The results obtained from experimental analysis is validate with numerical analysis. From the experimental data we can found that the velocity increases as increases in the flow depth.

Validation of Birmingham data is upto 11.6%.

Validation of NITR data upto 12% which is in acceptable limits.

CES gives better results than experimental analysis for both Depth averaged velocity and boundary shear stress.

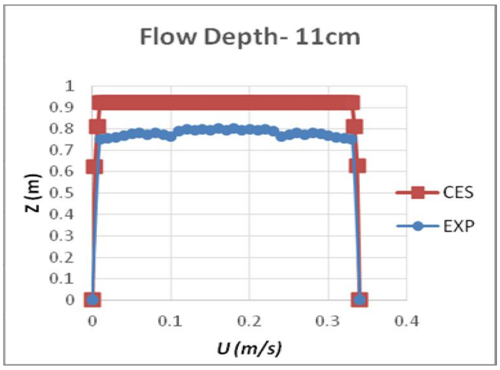

Fig.No.4.1 Comparison of depth averaged velocity at flow depth 11cm

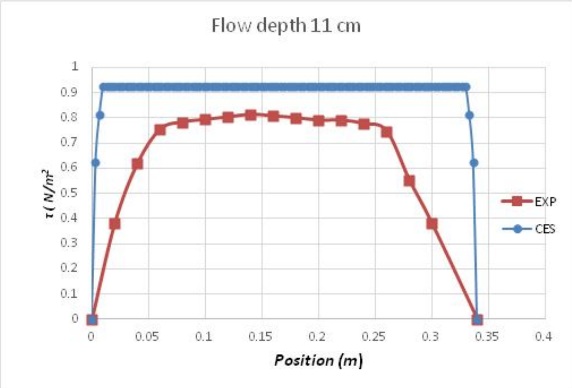

Fig.No.4.2 Comparison of boundary shear stress at flow depth 11cm

V. CONCLUSION

Following findings and conclusions were draw from this present research work:

- From the experimental analysis we got point to point data from the wetted perimeter of the various sections of the channel and further plotted in graphs and analyzed the distribution of boundary shear stress. The analysis shows that the boundary shear stress is maximum at the center and gradually decreases as it moves towards the boundaries of the main channel.
- The boundary shear stress distributions are plotted from the data computed from the CES using roughness i.e. Manning's constant and slope of the main channel for different sections, which was compared with the boundary shear stress graph plotted from the experimental data.
- The results obtained by the CES software nearly coincide with the experimental results of the boundary shear stress hence it seems that CES has better results than experimental data.

REFERENCES

[1] Das, B. S., Khatua, K. K., & Devi, K. (2017). Prediction of Depth-Averaged Velocity and Boundary Shear Stress Distribution in a Single-Stage Channel by Lateral Distribution Method. In Proceedings of the International Conference on Nano-electronics, Circuits & Communication Systems (pp. 397-407). Springer, Singapore.Tominaga, A., &Nezu, I. (1991). "Turbulent structure in compound open-channel flows". Journal of Hydraulic Engineering, 117(1), 21-41.

[2] Wormleaton, P. R., & Hadjipanos, P. (1985). "Flow distribution in compound channels. Journal of Hydraulic Engineering", 111(2), 357-361.

[3] Ghosh, S., Elsawy, E., Jena, S., Novak, P., Myers, W., & Sellin, R. (1972). Discussion. Boundary Shear Distribution In Open Channel Compound. Proceedings Of The Institution Of Civil Engineers, 51(3), 629-635.

[4] Myers, R. C., & Elsawy, E. M. (1975). "Boundary shear in channel with flood plain". Journal of the Hydraulics Division, 101(ASCE# 11452 Proceeding).

[5] Knight D. W. and Demetriou J.D. (1983). "Floodplain and main channel flow interaction." J. Hydraul. Eng., ASCE, 109(8), 1073–92.

[6] Knight, D. W., and MacDonald, J. A. (1979). "Open-channel flow with varying bed roughness." J. Hydraul. Div., Am. Soc. Civ. Eng., 105(9), 1167–1183.

[7] Rajaratnam, N., & Ahmadi, R. (1981). Hydraulics of channels with flood-plains. Journal of Hydraulic Research, 19(1), 43-60.

[8] Knight, D. W., & Hamed, M. E. (1984). Boundary shear in symmetrical compound channels. Journal of Hydraulic Engineering, 110(10), 1412-1430.

[9] Knight, D. W., & Patel, H. S. (1985). Boundary shear in smooth rectangular ducts. Journal of Hydraulic Engineering, 111(1), 29-47.

[10] Tominaga, A., & Nezu, I. (1991). Turbulent structure in compound open-channel flows. Journal of Hydraulic Engineering, 117(1), 21-41.

[11] Rhodes, D. G., & Knight, D. W. (1994). Distribution of shear force on boundary of smooth rectangular duct. Journal of Hydraulic Engineering, 120(7), 787-807.

[12] Shiono, K., Muto, Y., Knight, D. W., & Hyde, A. F. L. (1999). Energy losses due to secondary flow and turbulence in meandering channels with overbank flows. Journal of Hydraulic Research, 37(5), 641-664.

[13] Patra, K. C., & Kar, S. K. (2000). Flow interaction of meandering river with floodplains. Journal of Hydraulic Engineering, 126(8), 593-604.