

# Detail Laboratory Investigations for Longitudinal and Lateral Velocity Distributions in Smooth and Rough Surfaces

Lakshmi Mitra<sup>1</sup>, Prof. (Dr.) Mimi Das Saikia<sup>2</sup>

M.Tech. Student, Department of CE, Assam Down Town University, Panikhaiti, Guwahati, Assam, India<sup>1</sup>

Professor, Department of CE, Assam Down Town University, Panikhaiti, Guwahati, Assam, India<sup>2</sup>

**ABSTRACT:** In an open channel flow, the velocity profile depends upon the bed material of the channel, the discharge, the slope of the channel etc. Two experiments have been done with same discharge and keeping the slope constant. The first experiment has been done with PVC as the bed and side material. In the second case keeping the bed and side material same stones of different sizes are put throughout the channel. For both the cases the velocity profile both lateral and longitudinal section has been drawn. It is seen in the first case that the velocity profile is very much uniform through the channel but as stones of different sizes are put there is no symmetric in the profile and it is very much invariable. Velocity at different depths and different sections both in X and Y directions are taken with the help of pitot tube. As the velocity profile depends upon the roughness of the bed material, a graph of coefficient of roughness (Manning's  $n$ ) and Froude's no. for both the cases is also compared.

**KEYWORDS:** Open channel flow, velocity distribution, velocity profile, discharge, bed slope, bed material.

## I. INTRODUCTION

The measured maximum velocity in ordinary channel appears to occur at free surface (Chow, 1973). The maximum velocity occurs below the water surface for turbulent flow, and in case of laminar flow, it occurs at the water surface (Fig 1 & Fig 2). But for turbulent flow with shallow water depth and high velocities, the maximum velocity may be near or at the water surface. The location of the maximum velocity along the longitudinal bed slope or stream wise direction in the velocity distribution at a cross section is different in laminar flow than turbulent flow. The velocity depends upon the coefficient of roughness of the bed and wall material of a channel. If there is vegetation in the bed or wall of a channel then the velocity and the coefficient of discharge becomes very less. Because of the roughness of vegetated channels are very complicated to design. Velocity distribution is important in channels for protection from erosion, sediments transport and deposition on the bank etc. The roughness of the channel causes the curvature of vertical velocity distribution curve to increase. The influence of surface wind on velocity distribution is practically zero also the sides of channel have no influence on velocity distribution in the central zone. Central zone exists in rectangular channel only when  $B > 5$  to 10 times of depth of flow.

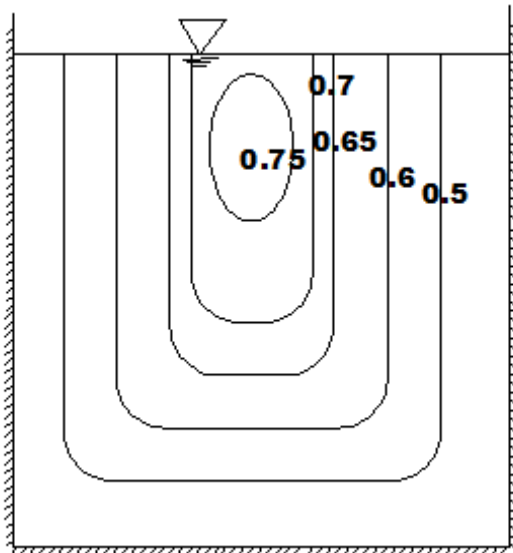


Fig 1 Distribution in Rectangular Channel

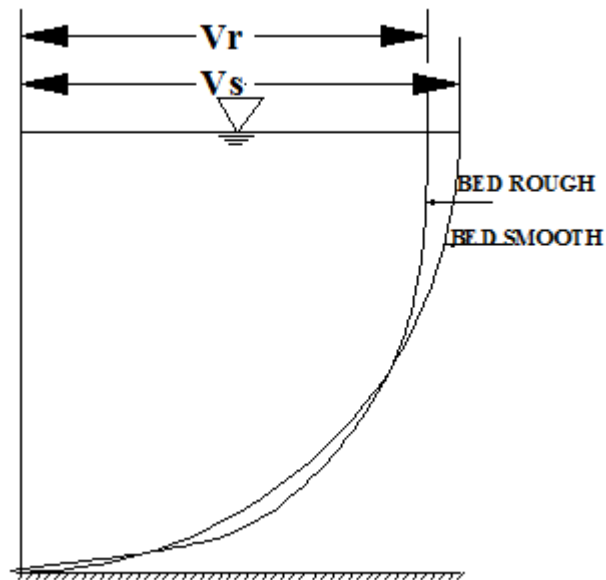


Fig 2 Effect of Roughness in velocity distribution profile

## II. RELATED WORK

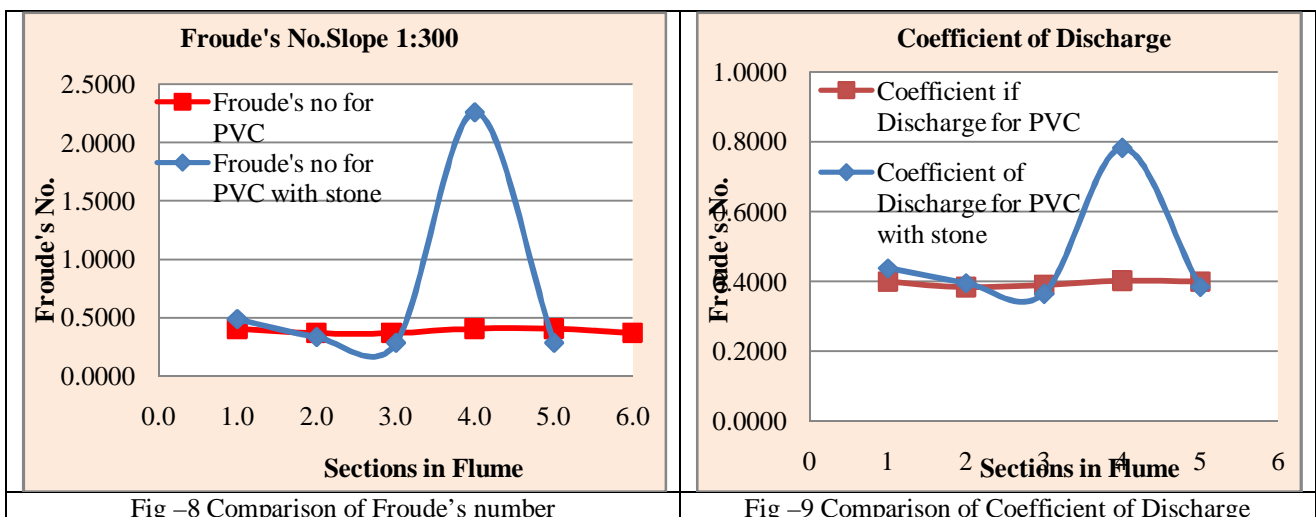
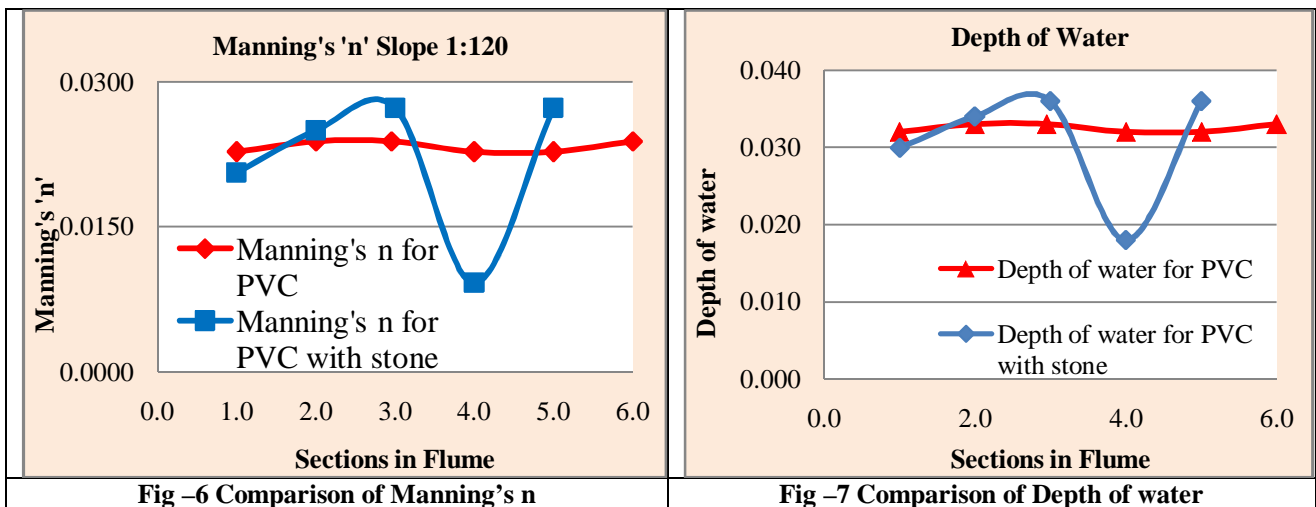
In 2000 Hooper F. and Kohler S. L. explained that the mean velocity is taken as the average of velocities at the 0.2 and 0.8 of depth and in any open channel flow the velocity distribution depends upon the bed and side material of the channel, slope of the channel, shape and size of the channel etc. In 2002 Yen B. C. observed that in open channel the velocity depends upon the cross sectional area, the bed slope of the channel and roughness of the bed and wall material of the channel. In 2003 Plant W. J. et.al. computed the discharge by measuring the surface velocity by microwave sensor and found mean velocities using the surface velocity along with the measured depth. Marjang Nat (2008) used three dimensional hydraulic modeling to developed a turbulent model for computing surface velocity coefficient and discharge for prismatic open channel. Patel K. (2012) tested different hydraulic structure in open channel flow considering the different roughness constant and different flow rate and also examined the velocity profile In 2013 Yonesi H. A. et.al. evaluated the slope of the channel with the help of experimental data for the discharge between the main channel and floodplain, roughness coefficient, depth, average velocity and compared the result with the prismatic channel. He found the velocity distribution at the entrance, middle and end of the channel. Faruque M. A. A. (2014) carried out lot of labatory experiments and found the effect of roughness and Reynolds number on mean velocity in both outer and inner scaling.

## III. EXPERIMENTAL RESULTS

Two experiments are conducted in the laboratory of Assam downtown University in a channel with 6m length, 0.30m wide and 0.46m deep. In the first experiment, PVC is taken as the bed and the side material and in the second experiment with the same bed and side material stones of different sizes are put in the channel (Fig3, Fig4 & Fig5). A comparison between the velocity profile both in longitudinal and lateral direction is done keeping the discharge  $Q = 3.41 \times 10^{-4}$  cum/sec and slope 1:120 as constant for both the cases.



Comparison of depth of water, Manning's "n", state of flow and coefficient of discharge has been shown from Fig-6 to Fig-9.

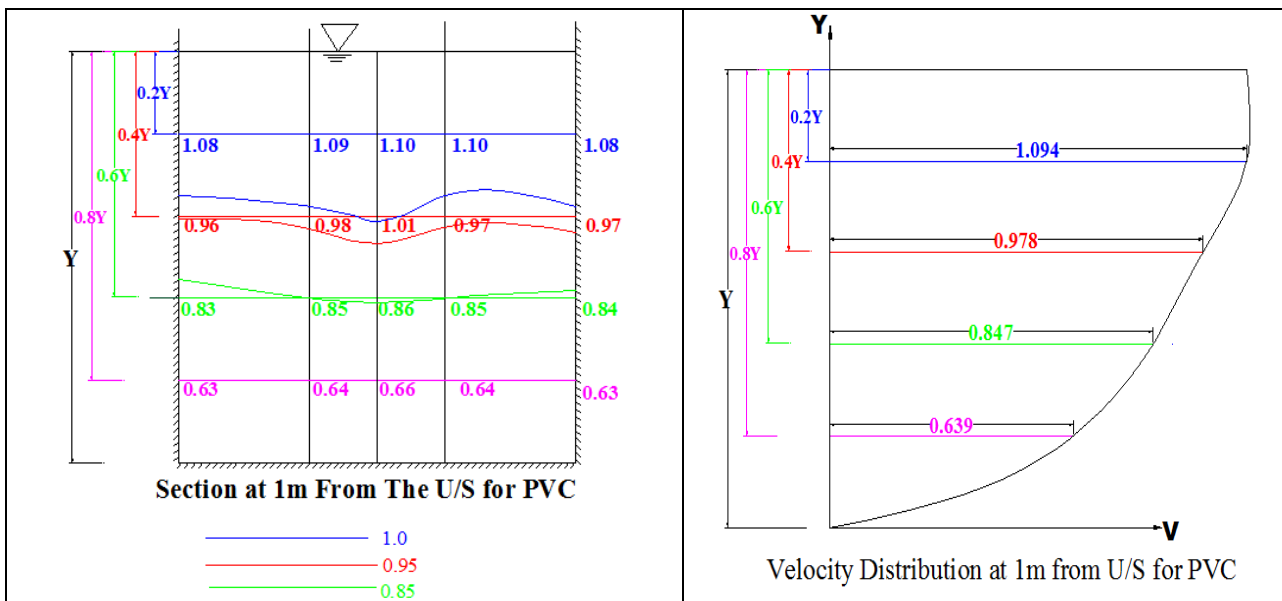


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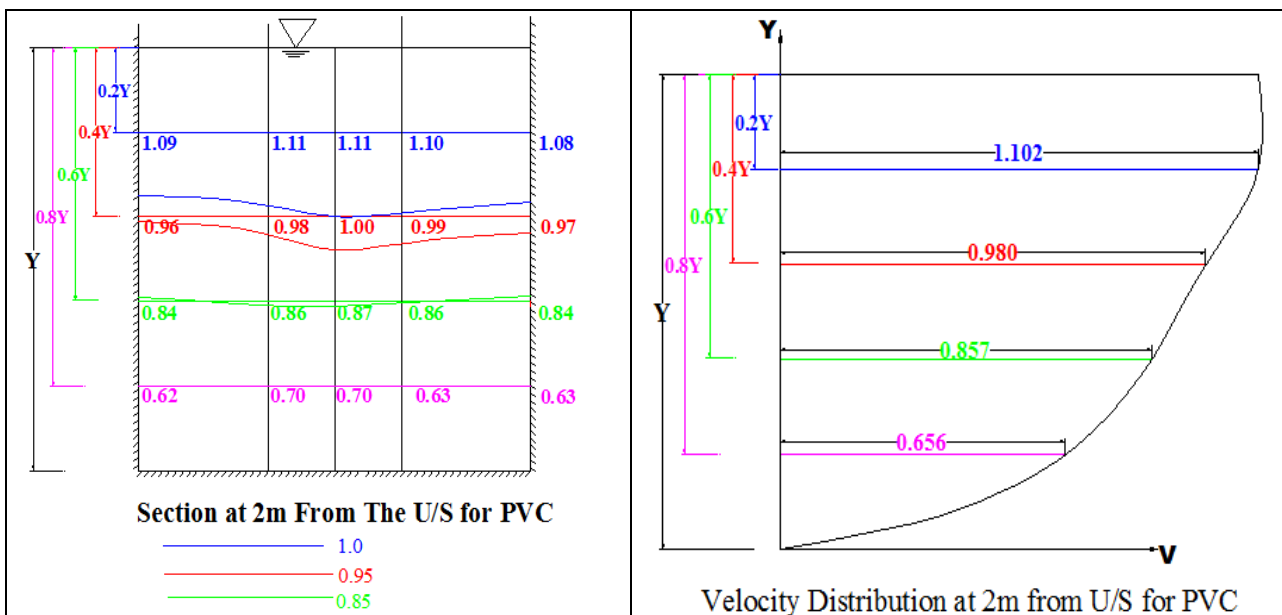
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The effect of smooth bed and side material (PVC) of channel on velocity distribution at different sections has been shown from Fig-10 to Fig-14 and the velocity at different depths of water throughout the channel has been shown from Fig-15 to Fig-18.



**Fig –10** Velocity distribution and effect of roughness in velocity distribution at section 1m from U/S for bed and side material PVC

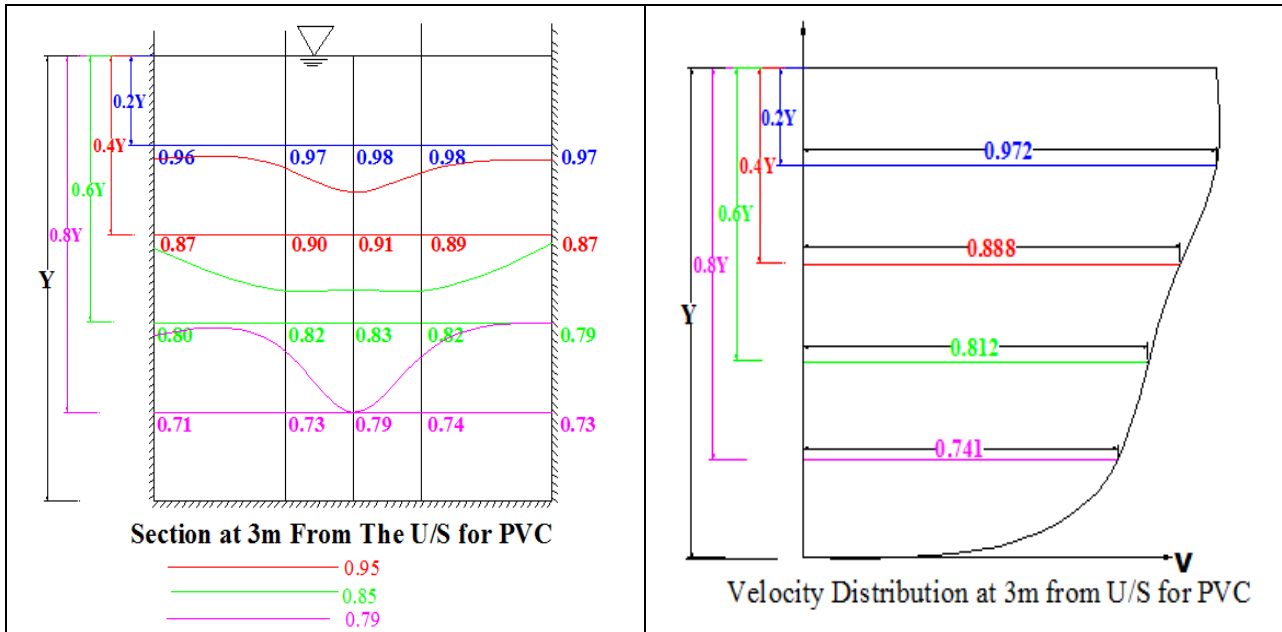


**Fig –11** Velocity distribution and effect of roughness in velocity distribution at section 2m from U/S for bed and side material PVC

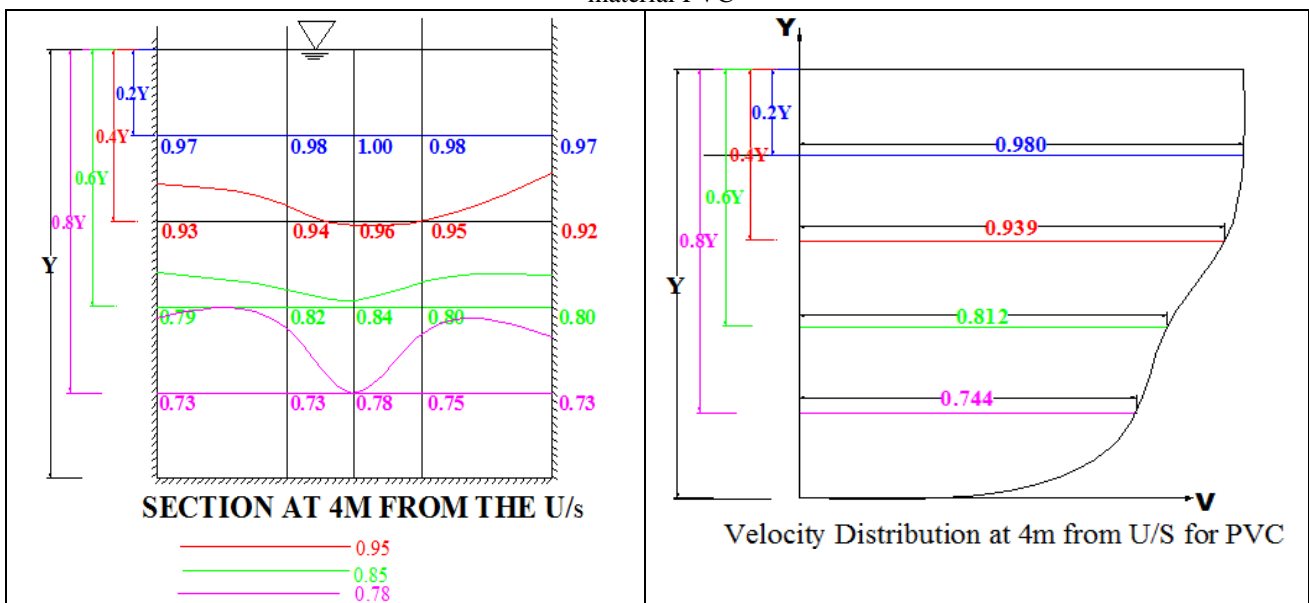
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**Fig -12** Velocity distribution and effect of roughness in velocity distribution at section 3m from U/S for bed and side material PVC

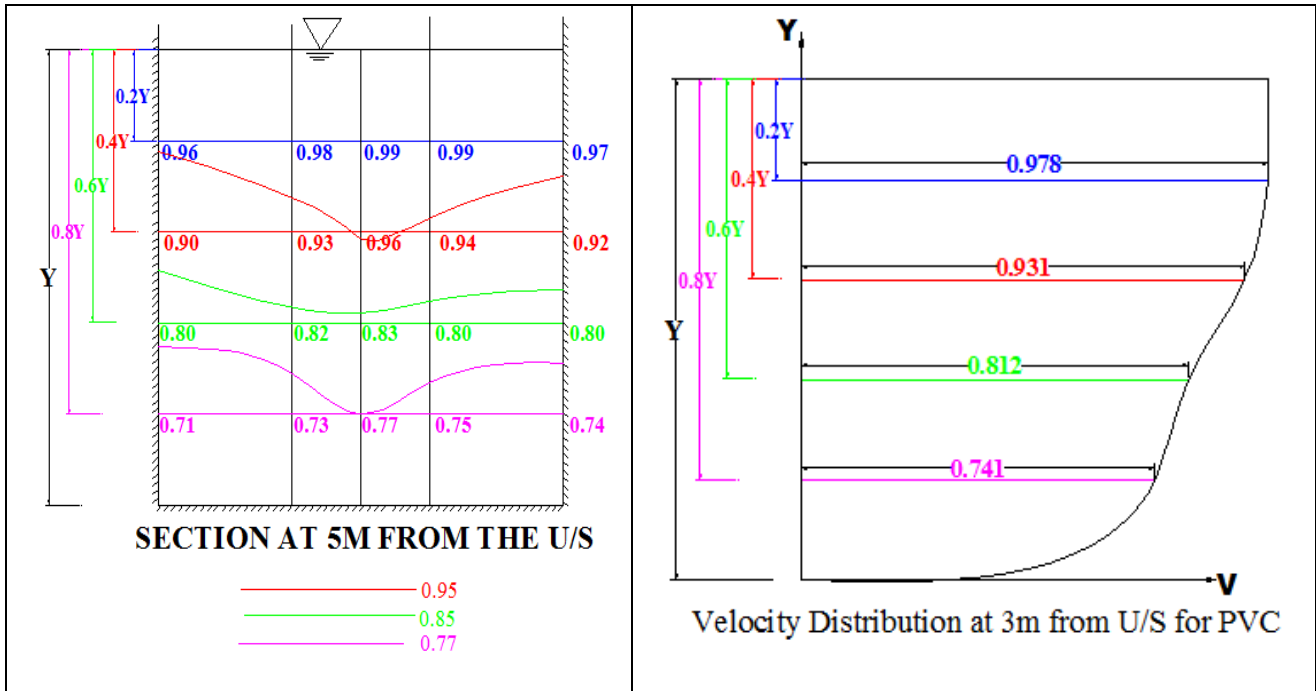


**Fig -13** Velocity distribution and effect of roughness in velocity distribution at section 4m from U/S for bed and side material PVC

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**Fig –14** Velocity distribution and effect of roughness in velocity distribution at section 5m from U/S for bed and side material PVC

UP STREAM					
0 M	0.1 M	0.15 M	0.2 M	0.3 M	
1 M	0.63	0.64	0.66	0.64	0.63
2 M	0.62	0.70	0.70	0.63	0.63
3 M	0.71	0.73	0.79	0.74	0.73
4 M	0.73	0.73	0.78	0.75	0.73
5 M	0.71	0.73	0.77	0.75	0.74
6 M					
DOWN STREAM					

**Fig –15** Velocities of water in the channel at a depth of 0.8m of the depth of water for bed and side material PVC

UP STREAM					
0 M	0.1 M	0.15 M	0.2 M	0.3 M	
1 M	0.83	0.85	0.86	0.85	0.84
2 M	0.84	0.86	0.87	0.86	0.84
3 M	0.80	0.82	0.83	0.82	0.79
4 M	0.79	0.82	0.84	0.80	0.80
5 M	0.80	0.82	0.83	0.80	0.80
6 M					
DOWN STREAM					

**Fig –16** Velocities of water in the channel at a depth of 0.6m of the depth of water for bed and side material PVC

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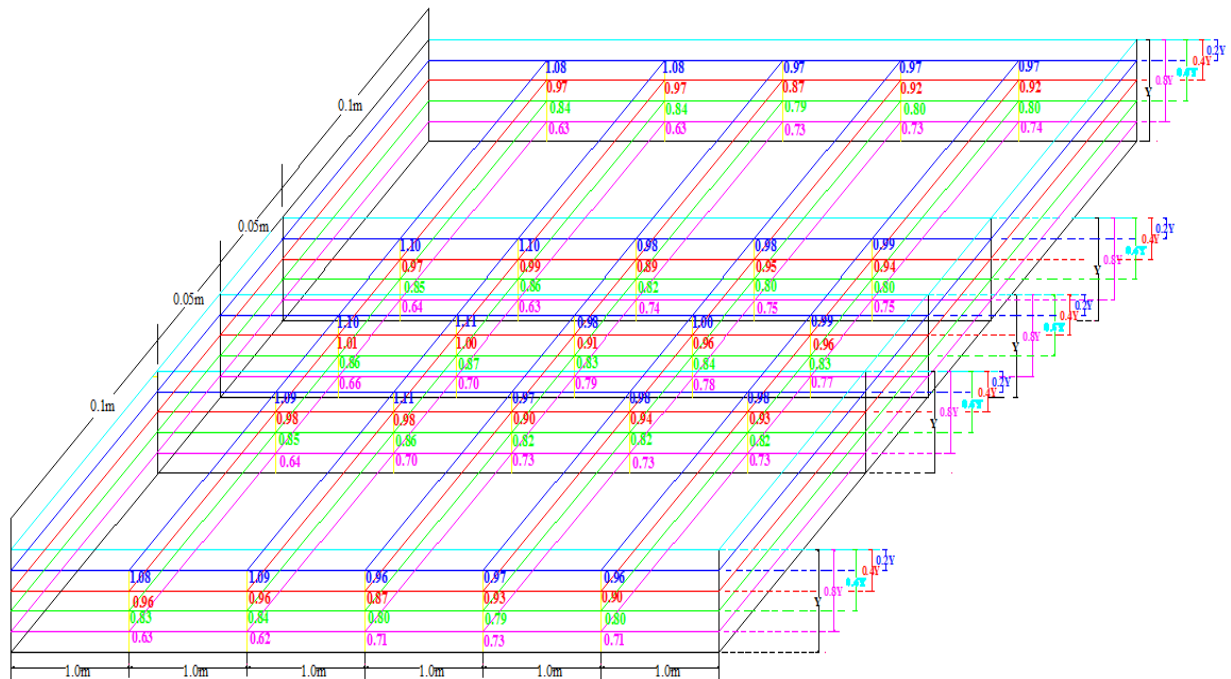
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UP STREAM					
0 M	0.1 M	0.15 M	0.2 M	0.3 M	0.3 M
1 M	0.96	0.98	1.01	0.97	0.97
2 M	0.96	0.98	1.00	0.99	0.97
3 M	0.87	0.90	0.91	0.89	0.87
4 M	0.93	0.94	0.96	0.95	0.92
5 M	0.90	0.93	0.96	0.94	0.92
6 M					
DOWN STREAM					

UP STREAM					
0 M	0.1 M	0.15 M	0.2 M	0.3 M	0.3 M
1 M	1.08	1.09	1.10	1.10	1.08
2 M	1.09	1.11	1.11	1.10	1.08
3 M	0.96	0.97	0.98	0.98	0.97
4 M	0.97	0.98	1.00	0.98	0.97
5 M	0.96	0.98	0.99	0.99	0.97
6 M					
DOWN STREAM					

**Fig –17** Velocities of water in the channel at a depth of 0.4m of the depth of water for bed and side material PVC

**Fig –18** Velocities of water in the channel at a depth of 0.2m of the depth of water for bed and side material PVC



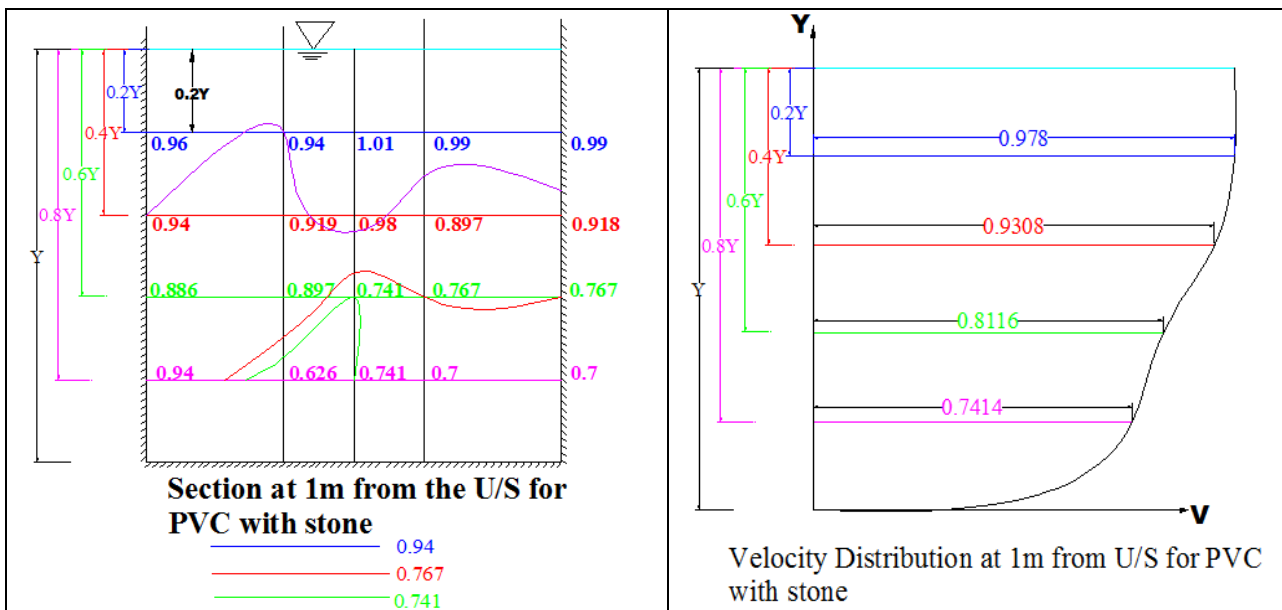
**Fig –19** A three dimensional view of the velocities both laterally and longitudinal for bed and side material PVC

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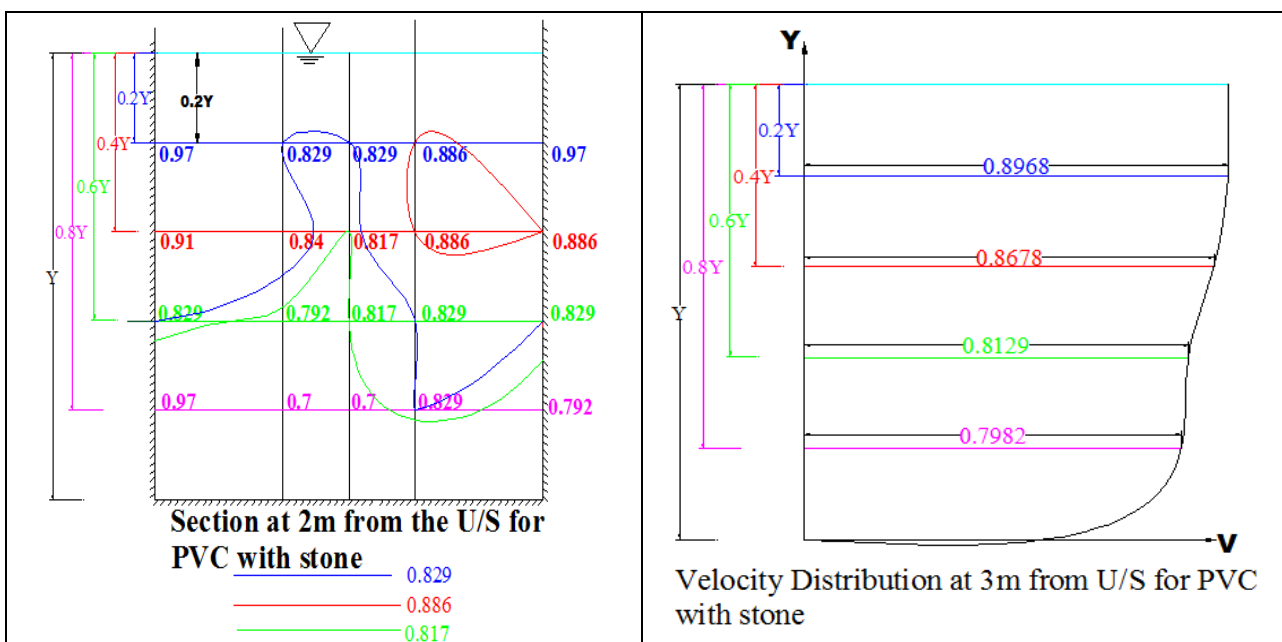
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The effect of roughness of bed and side material (PVC with stone) of channel on velocity distribution at different sections has been shown from Fig-20 to Fig-24 and the velocity at different depths of water throughout the channel has been shown from Fig-25 to Fig-28.



**Fig –20** Velocity distributions and effect of roughness in velocity distribution at section 1m from U/S for bed and side material PVC with stone



**Fig –21** Velocity distributions and effect of roughness in velocity distribution at section 2m from U/S for bed and side material PVC with stone



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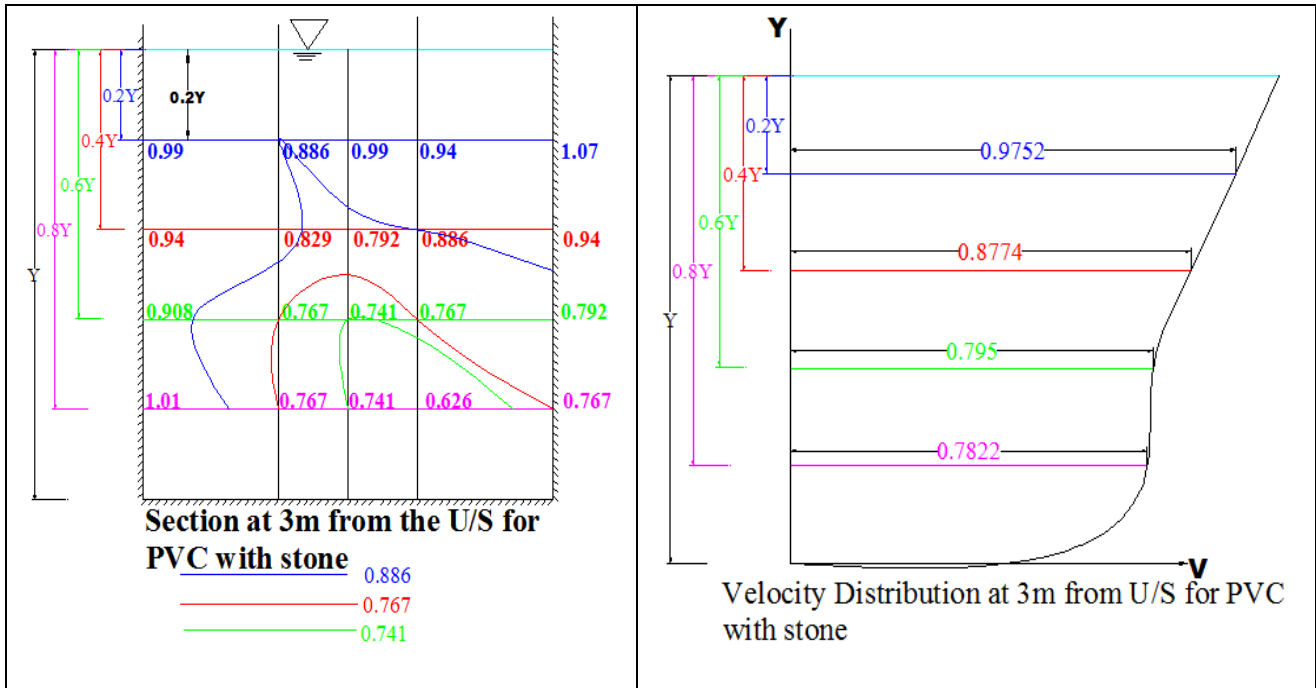


Fig –22 Velocity distributions and effect of roughness in velocity distribution at section 3m from U/S for bed and side material PVC with stone

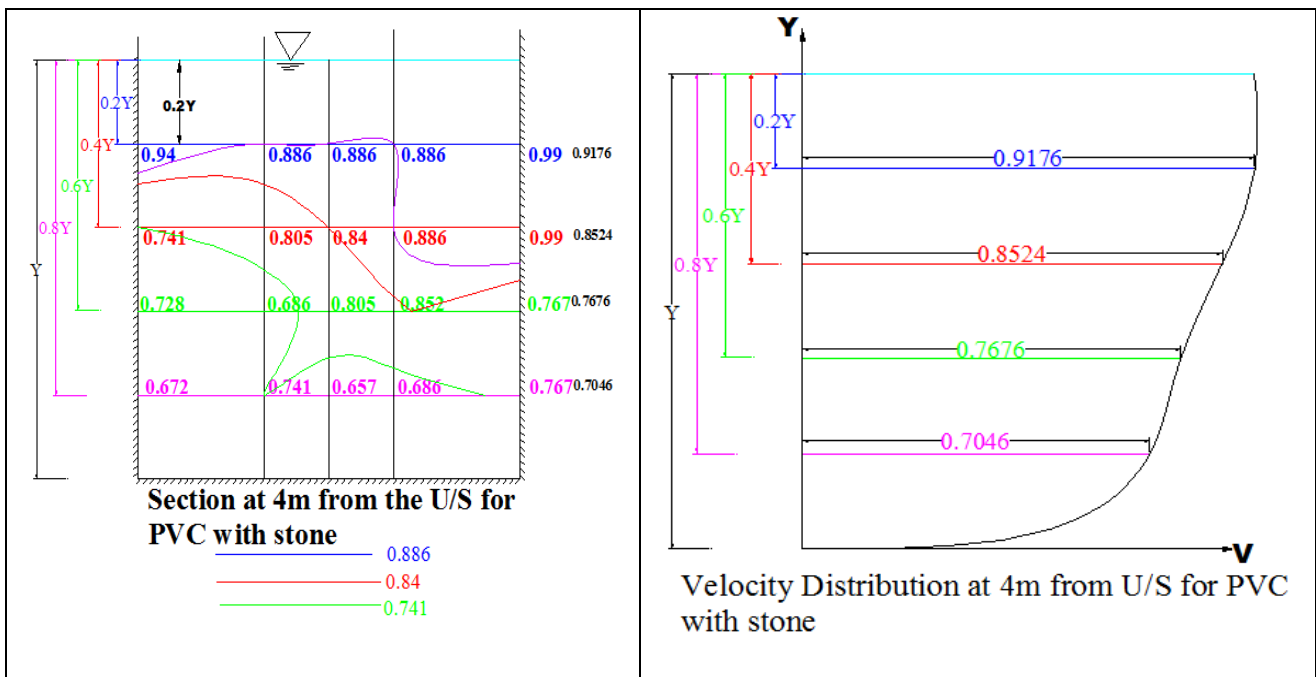
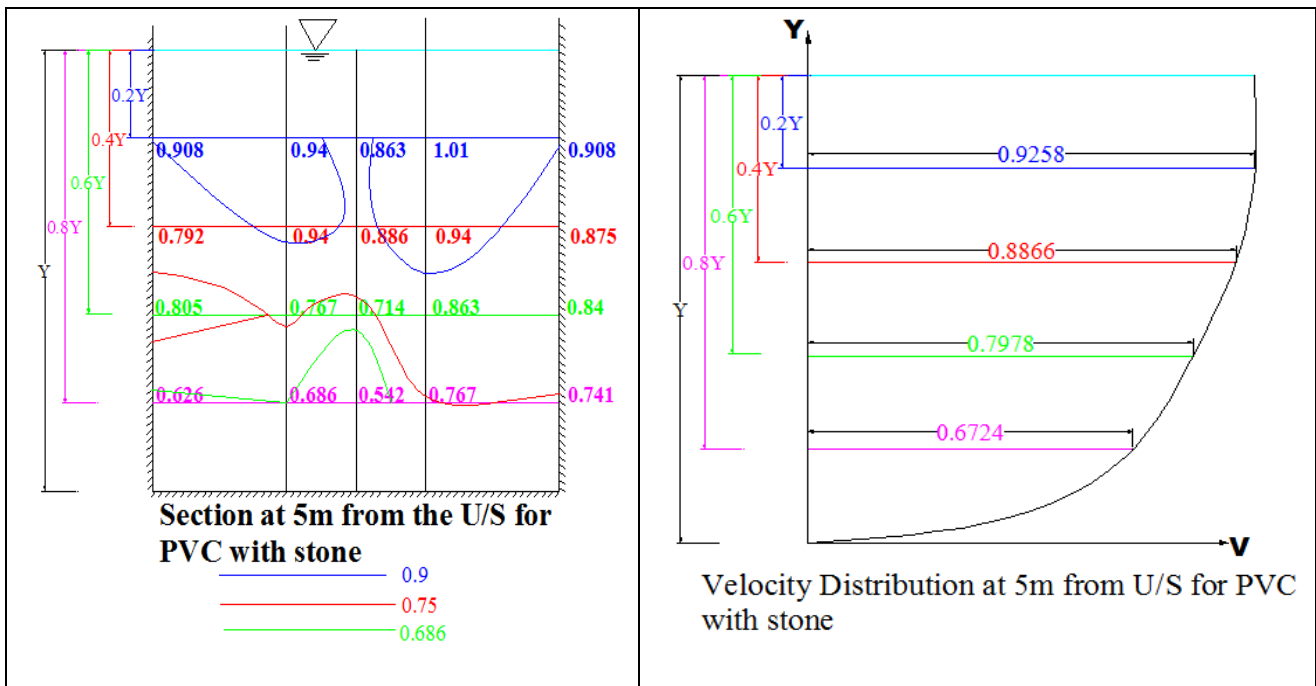


Fig –23 Velocity distributions and effect of roughness in velocity distribution at section 4m from U/S for bed and side material PVC with stone

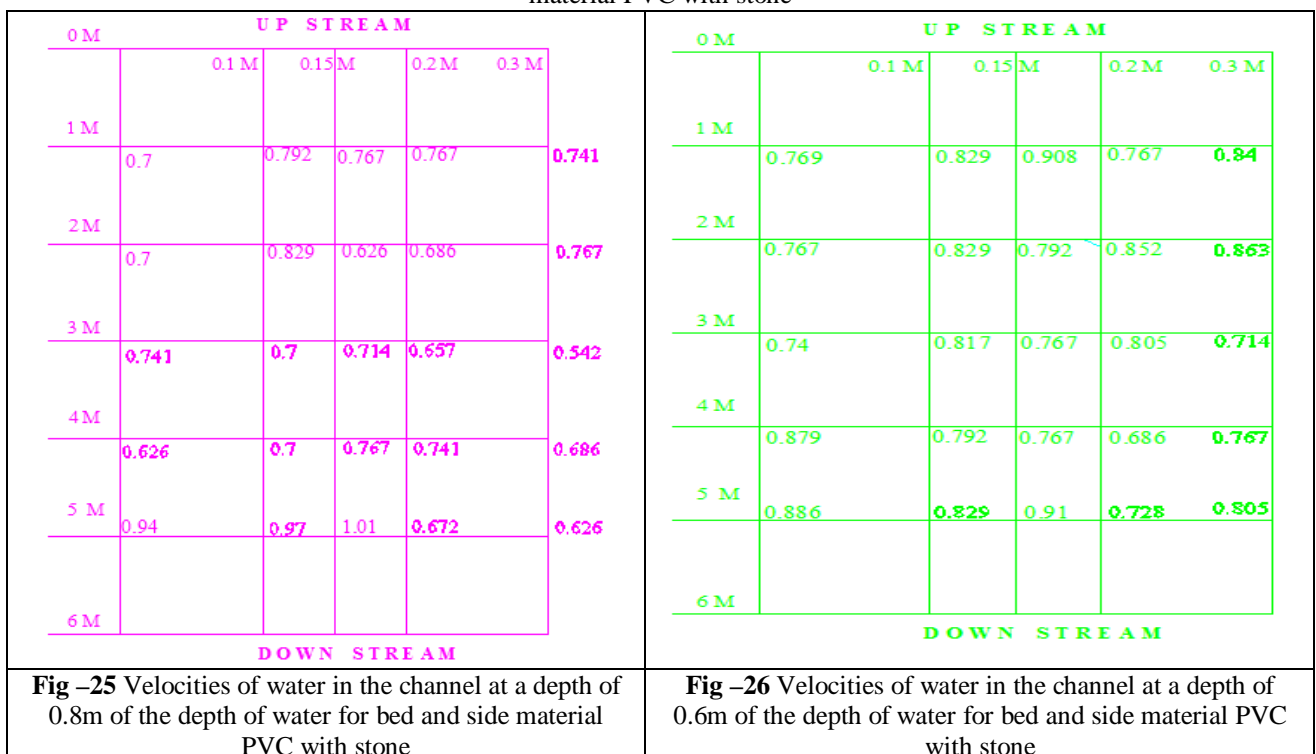
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**Fig –24** Velocity distributions and effect of roughness in velocity distribution at section 5m from U/S for bed and side material PVC with stone



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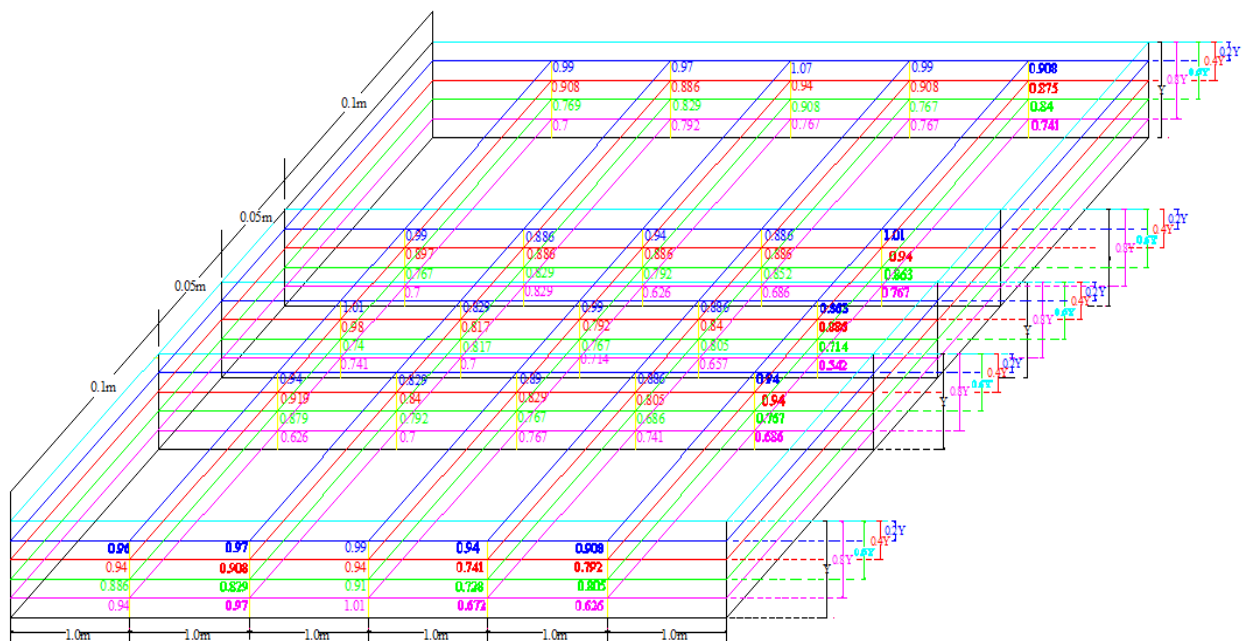
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UP STREAM					
0 M	0.1 M	0.15 M	0.2 M	0.3 M	
1 M	0.908	0.886	0.94	0.908	0.875
2 M	0.897	0.886	0.886	0.886	0.94
3 M	0.98	0.817	0.792	0.84	0.886
4 M	0.919	0.84	0.829	0.805	0.94
5 M	0.94	0.908	0.94	0.741	0.792
6 M					
DOWN STREAM					

**Fig –27** Velocities of water in the channel at a depth of 0.4m of the depth of water for bed and side material PVC with stone

UP STREAM					
0 M	0.1 M	0.15 M	0.2 M	0.3 M	
1 M	0.99	0.97	1.07	0.99	0.908
2 M	0.99	0.886	0.94	0.886	1.01
3 M	1.01	0.829	0.99	0.886	0.863
4 M	0.94	0.829	0.89	0.886	0.94
5 M	0.96	0.97	0.99	0.94	0.908
6 M					
DOWN STREAM					

**Fig –28** Velocities of water in the channel at a depth of 0.2m of the depth of water for bed and side material PVC with stone



**Fig –29** A three dimensional view of the velocities both laterally and longitudinal for bed and side material PVC with stone

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## IV. OBSERVATIONS AND DISCUSSION

For a channel of fixed slope the parameters of water and velocity distribution mainly depends upon the discharge and the bed material of the channel. When PVC is used as the bed material it acts as smooth bed and the variation in the velocity at different depths of water is almost negligible (Fig. 15 to Fig.18). When stone is used in PVC as bed material it is observed that the variation in velocity at a depth of 0.8, 0.6, 0.4 and 0.2 of the depth of water is about 46%, 21.5%, 15.7% and 17.9% respectively (Fig. 25 to Fig. 28) which shows that the stones have effect at the bottom layer of water and the effect get reduced at the upper layer. For both the cases the velocities is more near the surface of water and get reduced as the depth increases (Fig. 10 to Fig.15 and Fig. 20 to Fig. 24). Fig. 19 and Fig. 29 shows a three dimensional view of velocities both laterally and longitudinally for channel bed and side material PVC and for channel bed and side material PVC with stone respectively. In both the cases the state of flow is subcritical but in case of PVC with stone due to the effect of stone at a distance of 4m from upstream the state of flow becomes highly supercritical which results a jump in the channel (Fig.6, Fig 7 & Fig 8)and the coefficient of discharge also becomes two times at that point (Fig.9).

## V. CONCLUSION

From the experiment it is found that the parameters like depth of water, coefficient of roughness, Froude's no. etc of water in case of PVC is almost constant throughout the channel but it becomes very inconsistent when stones of different sizes are used. The velocity distribution curve of water at different section and the velocity at different depth of water is also drawn for both the cases and found that in case of PVC the velocity at the same depth from the surface remains constant throughout the channel and the velocity distribution curve also shows the bed as smooth bed whereas in case of PVC with stone the velocity at the same depth of water is not same and there is large variation in the velocity throughout the channel. The velocity distribution curve in case of PVC with stone also shows the bed material as rough bed.

## REFERENCES

- [1] Browski W. D and Polak U. "Flow Rate Measurements By Flumes" Fourteenth International Water Technology Conference, IWT C 14 2010, Cairo, Egypt, 2010
- [2] Bousmar D., Riviere N., Proust S., Paquier A., Morel R., Zech Y., "Upstream discharge distribution in compound-channel Flumes", HAL Id: hal-00842385, 2013.
- [3] Chow, Ven Te, Open Channel Hydraulics, McCraw-Hill, New York, 1973
- [4] Daboussi Olfa, Hafsia Zouhaier and Moussa Mahmoud, "Second Order Modelling Of Compound Open-Channel Flows"
- [5] Faruque M. A. Al et.al, "Open Channel Flow Velocity Profiles for Different Reynolds Numbers and Roughness Conditions", International Journal of Research in Engineering and Technology, Volume: 03 , 2014
- [6] Hooper Frank F. and Kohler Steven L., "Measurement of Stream Velocity and Discharge" Manual of Fisheries Survey Methods II, Chapter-19, 2000
- [7] Marjang Nat, "Calculated Surface Velocity Coefficients for Prismatic Open Channels by Three-Dimensional Hydraulic Modeling" DigitalCommons@USU, 2008
- [8] Patel Kaushal, "Mathematical Model of Open Channel Flow for Estimating Velocity Distribution through Different Surface Roughness and Discharge", International Journal of Advanced Engineering Technology, E-ISSN 0976-3945, IJAET/Vol.III/ Issue 1/January-March, 2012/252-253.
- [9] Patra K.C., et.al. Analysis of Depth Averaged Velocity in Meandering Compound Channels
- [10] Plant William J. et.al. , "Stream flow Properties from Time Series of Surface Velocity and Stage" , Journal of Hydraulic Engineering, 2003
- [11] Pu J. H., "Universal Velocity Distribution for Smooth and Rough Open Channel Flows" Journal of Applied Fluid Mechanics, Vol. 6, No. 3, pp. 413-423, 2013.
- [12] Rashmi Rekha Das et.al., "Velocity Distribution in Compound Channel Flows by Numerical Modeling", Journal of Mechanical and Civil Engineering, PP 14-19
- [13] Yen B. C., Uniform flow in a smooth open channel. Journal of Hydraulic Research, 27(5), 603-616, 1989
- [14] Yonesi H. A., Omid M. H., Ayyoubzadeh S. A., " The Hydraulics of Flow in Non-Prismatic Compound Channels" Journal of Civil Engineering and Urbanism , ISSN-2252-0430 , Volume 3, Issue 6: 342-356 (2013)
- [15] Yen, B.C.. "Open Channel Flow Resistance" J.Hydraulic Engineering, 2002 , vol. 1 Issue 2, ISSN 2320 – 4486, 2013