

# **Analysis of Flow Resistance for Different Bed Materials with Varying Discharge Experimentally in Open Channels**

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**ABSTRACT:** In an open channel flow, the rate of discharge, the bed material of the channel and the slope of the channel effects the flow parameters like depth of Flow, Velocity, Manning’s n, Darcy’s f, Froude’s no. Experiments are done with three bed materials, the original bed surface of the channel, PVC and grass carpet with three different discharges. The roughness coefficients Manning’s n and Darcy’s f is determined in various cases and the percentage of variation in “n” & “f” is compared in all the nine cases. Both the roughness coefficients Manning’s “n” & Darcy’s “f” are determined with constant slope and different discharges. Other parameters like depth, velocity and Froude’s no. is also compared for all the cases.

**KEYWORDS:** Open channel flow, bed slope, discharge, roughness coefficient, channel bed.

## **I. INTRODUCTION**

The proper prediction of flood i.e., to determine the water level during flood or for design of any hydraulic structure or open channel drainage system, the total discharge of flow, the bed slope and the roughness coefficient are very important parameters. Three roughness coefficients are generally used for open channel flow – Chezy’s coefficient, Manning’s coefficient and Darcy’s coefficient shown in Eq. (1), Eq. (2) and Eq. (3) respectively. Out of these three two coefficients Manning’s n and Darcy’s “f” is compared in this paper. Both Manning’s “n” and Darcy’s “f” depends upon slope of the channel, the bed and side material of the channel and the hydraulic radius i.e. the area of flow and the wetted perimeter of the channel. The state of flow and the velocity of flow also affect the state of flow. The main aim behind this paper is to study the effect of change of different flow parameters on the Manning’s “n” and Darcy’s “f”. An attempt has also been made to observe that which flow resistance parameter i.e., between the Manning’s “n” and Darcy’s “f” is affected more due to variations flow parameters.

**Chezy’s Equation**

$$V = C\sqrt{RS} \dots\dots\dots (1)$$

**Manning’s Equation**

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \dots\dots\dots (2)$$

**Darcy – Weisbsch Equation**

$$V = \sqrt{\frac{8g}{f} \sqrt{RS}} \dots\dots\dots (3)$$

**Where,**

V = magnitude of velocity, R = hydraulic radius = A/P where, A = Area, P= wetted perimeter  
S = slope, C= Chezy’s coefficient, n = Manning’s coefficient and f= Darcy’s coefficient

The relations among the different coefficient i.e. Manning’s “n”, Darcy’s “f” and Chezy’s “c” are represented by Eq. 4

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

$$C = \frac{1}{n} R^{\frac{1}{6}} = \sqrt{\frac{8g}{f}} \dots \dots \dots (4)$$

## II. RELATED WORK

In Ireland Limerinos Robert Manning in 1891 first introduced the Manning’s formula in his paper. In 1898, a paper was prepared in cooperation with the California Department of water resources for Geological Survey Water Supply for determination of Manning’s “n” for different bed roughness in open channel flow. Manning Coefficient was found by J. T in 1970 from measured bed roughness in natural channels. In 2002 Yen B. C. found that the flow in open channel is effected by the wall roughness of the channel, the cross sectional area as well as the roughness and viscosity of the bed material. In 2010, Francisco J.M. Simões did a lot of laboratory experiments and found that the total friction losses can be accurately predicted in natural channel with plane bed rather the sediments are transported in the channel. He introduced the resistance due to the flow viscous effects when the flow is turbulent and fully rough. Omid M. H. (2010) et al did a laboratory experiment and deduced some formula for friction factor in an alluvial channel. It is also shown in this paper that presence of bed load can reduce the friction factor as compared to the clear water flow. Ji-Sung KIM et.al in 2010, with the help of field measurements estimated Manning’s “n” for a gravel-bed river and also evaluated the various methods used for estimation of roughness coefficient. Ali1 Md Z. and Saib N. A. (2011) did a no. of laboratory experiments with different discharges and different bed materials to determine the affects of bed roughness in open channel flow. E. Retsinis et.al (2013) did a lot of laboratory experiment and concluded that the Manning’s “n” is not constant throughout the channel especially when the channel is having combined bed material.

## III. EXPERIMENTAL RESULTS

The experiments are conducted at water recourses laboratory of Assam downtown University in a channel with 6m length, 0.30m wide and 0.46m deep. Nine cases are considered (Table 1), three discharges 0.00384 m<sup>3</sup>/sec, 0.00367 m<sup>3</sup>/sec and 0.0012 m<sup>3</sup>/sec each with original bed material, grass carpet and PVC (fig 1, 2 & 3). The velocity is measured by pitot tube.

TABLE 1

No.	Material	Discharge(m <sup>3</sup> /sec)
Case-1	Original Bed Material	Q1=0.00384
Case-2	Grass Carpet	Q1=0.00384
Case-3	PVC	Q1=0.00384
Case-4	Original Bed Material	Q2=0.00367
Case-5	Grass Carpet	Q2=0.00367
Case-6	PVC	Q2=0.00367
Case-7	Original Bed Material	Q3=0.0012
Case-8	Grass Carpet	Q3=0.0012
Case-9	PVC	Q3=0.0012

Depth of water, Velocity, Variations of Manning’s n, percentage Variations of Manning’s n, Darcy’s “f”, percentage Variations of Darcy’s “f” and Froude’s no. along the total length of the channel have been plotted for the above mentioned nine cases from Fig 4 to Fig 10.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016



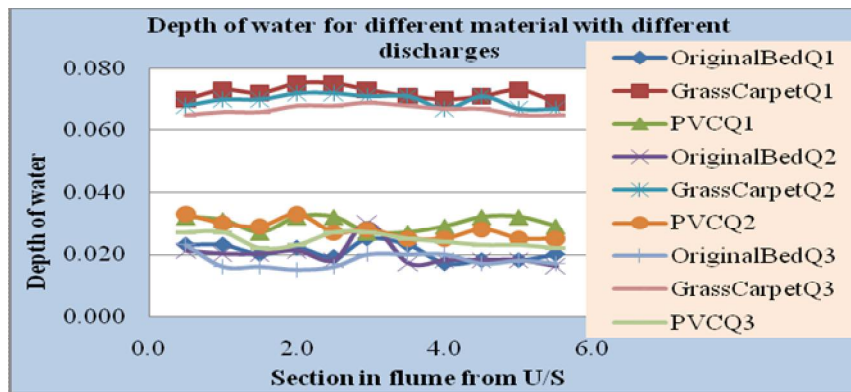
**Fig -1**  
Flow in the original bed material of the channel



**Fig -2**  
Flow through grass carpet

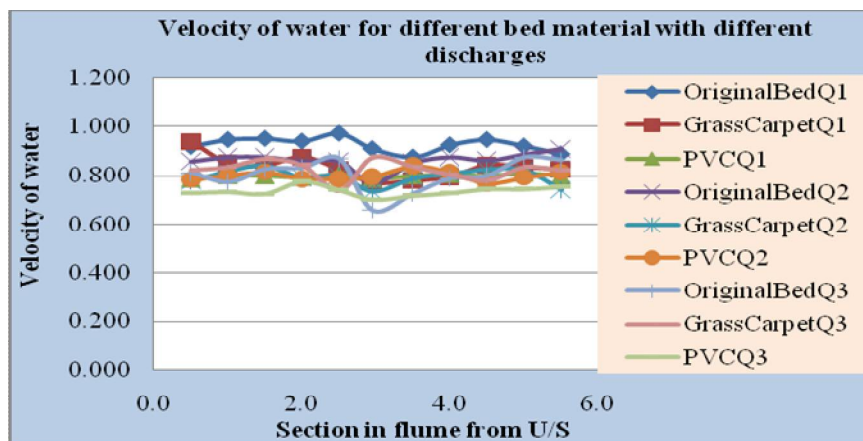


**Fig -3**  
Flow through PVC



**Fig No. 4** Depth of water for different discharges with different bed material

In Fig 4 the depth of water in the channel with different bed material with different discharge are presented. It is observed that the depth of water is more in original bed material and is minimum in grass carpet. It has been also observed that it decreases as the discharge decreases.



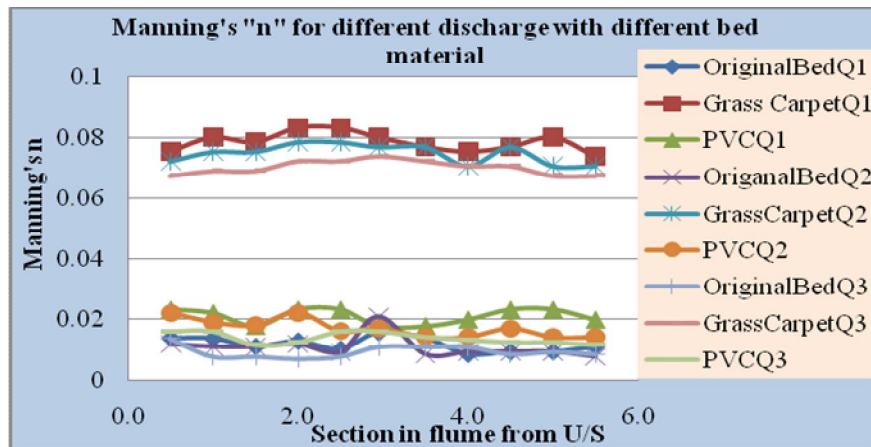
**Fig No. 5** Velocity of water for different discharges with different bed material

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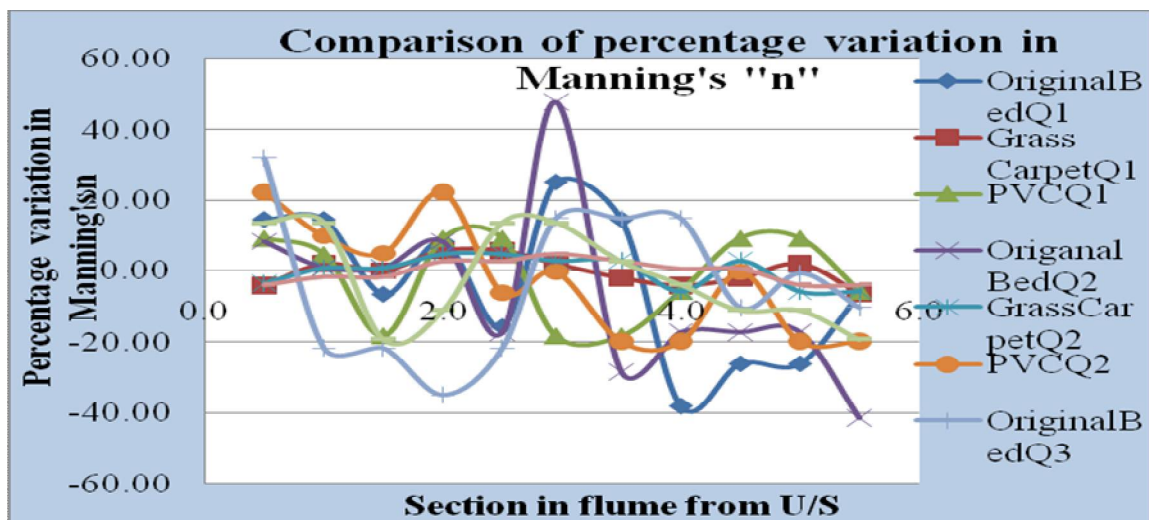
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In Fig 5 a graph between the section in flume from upstream and velocity of water in the channel with different bed materials with different discharges are represented. It is observed that the velocity of water is not constant throughout the channel in case of original bed material as the original bed material is not of the uniform material but in case of other bed material the velocity is almost uniform throughout the channel.



**Fig No. 6 Manning’s “n” for different discharges with different bed material**

In Fig 6 a graph between the section in flume from upstream and Manning’s “n” of different bed material with different discharge is taken. It is observed that the Manning’s “n” is not constant throughout the channel in case of original bed material but in case of other bed material the velocity is almost uniform throughout the channel. The difference in Manning’s “n” for the original bed material and for PVC is not much but the value of Manning’s “n” for grass carpet is very high with respect to the other two materials.



**Fig No. 7 Percentage Variation on Manning’s “n” for different discharges with different bed material**

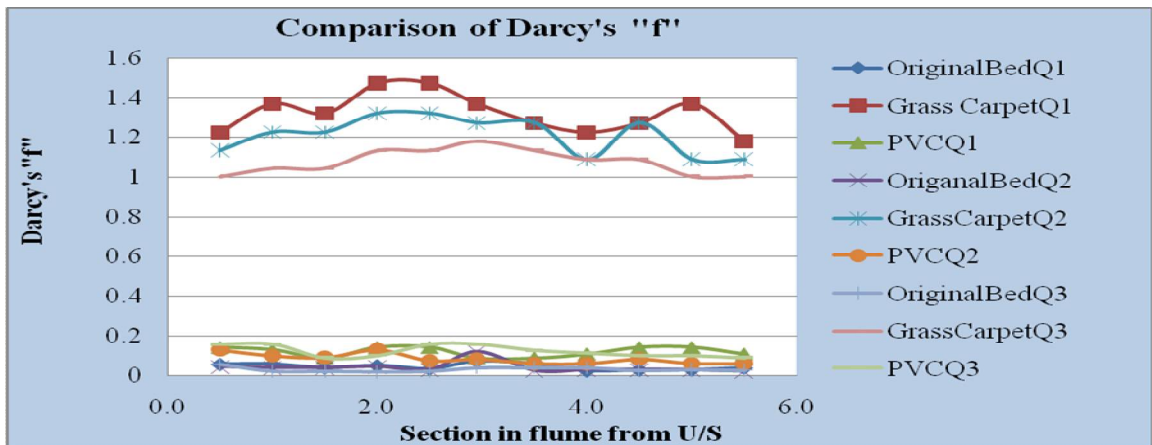
Fig 7 represents graph between the section in flume from upstream and the percentage variation in Manning’s “n” of different bed material with different discharges. It is observed that the percentage

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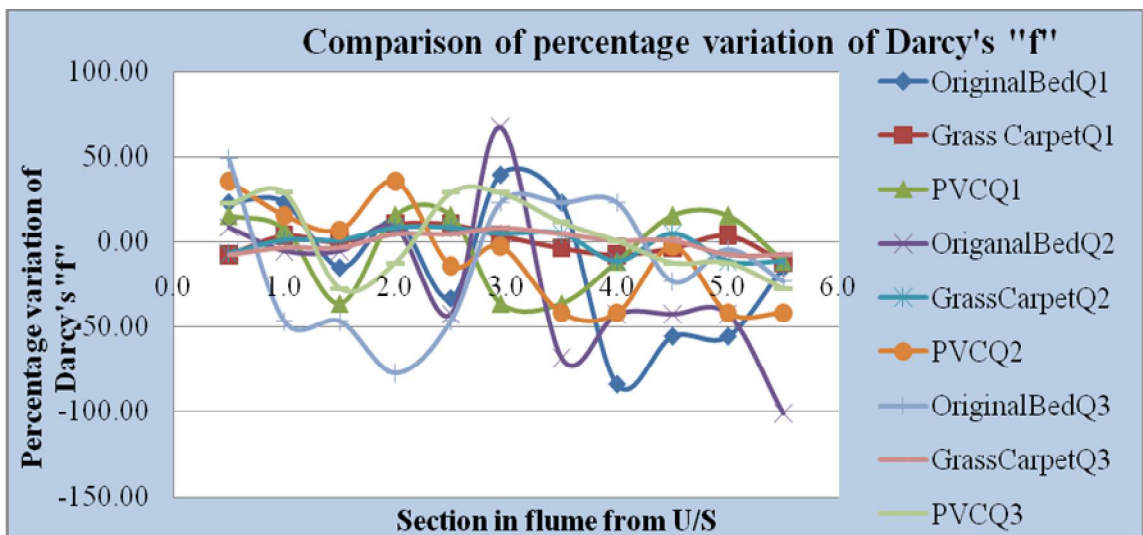
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variation in Manning's "n" in case of original bed material is very high, in case of PVC variations are there but in case of grass carpet it is almost uniform.



**Fig 8 No. of Darcy's "f" for different discharges with different bed material**

In Fig 8 a graph between the section in flume from upstream and Darcy's "f" of different bed material with different discharge is taken. It is observed that the Darcy's "f" is very high in case of carpet grass whereas it is almost same for both the original bed material and grass carpet. It decreases with the decrease in discharge for all the materials.



**Fig No. 9 Percentage Variation of Darcy's "f" for different discharges with different bed material**

In Fig 9 a graph between the section in flume from upstream and the percentage variation in Darcy's "f" of different bed material with different discharge is taken. It is observed that the percentage variation in Manning's "n" in case of original bed material is very high, in case of PVC also it is not uniform but in case of grass carpet it is almost uniform.



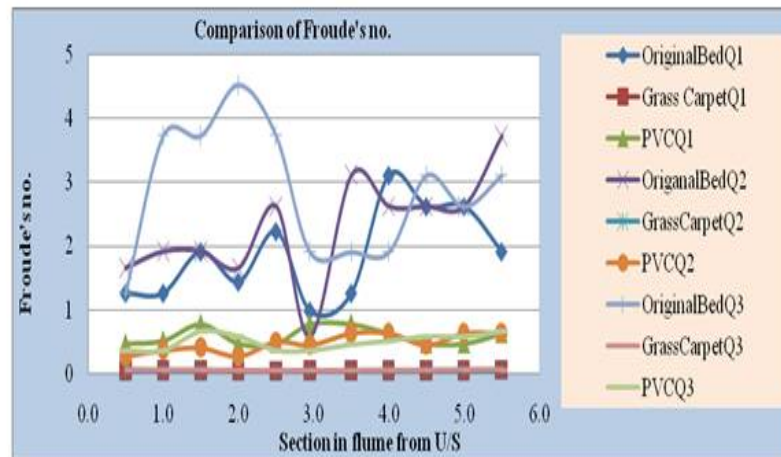


Fig No. 10 Froude's No. for different discharges with different bed material

In Fig 10 a graph between the section in flume from upstream and Froude's no. of different bed material with different discharge is taken. For the original bed material it is found that the state of flow varies from super critical to the sub critical state i.e. a jump is seen at a distance of 2m to 3m from the u/s. But in other two cases i.e. in case of grass carpet and PVC the state of flow is almost uniform and is in subcritical state.

#### IV. CONCLUSION

Manning roughness coefficient "n" and Darcy's roughness coefficient "f" are investigated for different bed material with different discharges, within rectangular open channels. It is found from the experiment that the Darcy's "f" is always greater than the Manning's n for the same flow parameters as presented in fig.6 and fig.8. Darcy's roughness coefficient "f" is almost 3 to 3.5 times of "n" for original bed material, for grass carpet "f" is almost 15 to 17 times of "n" and for PVC "f" is 4.5 to 8.5 times of "n". It is observed that this increase in "f" decreases with the decrease in discharge. The percentage variation in "f" and "n" for original bed channel is very high and less in PVC and minimum for grass carpet as presented in fig.7 and fig.9. From the experiment it is found that for the same discharge in original bed material, the state of flow is super critical whereas the state of flow is subcritical when the bed material is grass carpet or PVC as presented in fig.10. The original bed surface has a combination of different material which results a fluctuation in Manning's "n" as well as Darcy's "f" but the results are very uniform for grass carpet as well as PVC bed material. If the bed material of a channel is not uniform, the average "n" or "f" cannot be considered and it will be different for different cross section. The state of flow is also very much varying in each cross section of the channel for the original bed material but overall state of flow is supercritical. For grass carpet the state flow is coming highly subcritical because of the resistance whereas for PVC the state of flow is just in subcritical state as it has a smooth surface

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