

Unsteady Resistance Equations for Proper Prediction of High and Moderate Floods

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ABSTRACT: The values of Manning's roughness coefficient "n" generally have been considered for any point in channel bed as constant throughout the total time of prediction. But in real field the value of Manning's "n" varies not only depending on various factors such as channel irregularity, surface roughness, bed slope and vegetation cover but also it varies at the same point with effect of unsteadiness. In this study equations for unsteady resistance have been proposed using linear regression and spread sheet programming. Two unsteady resistance equations has been obtained here, one for high flood and another for moderate flood for a dam-break case in river Toce. The available data has been collected from the CADAM project (1999) and analysis has also been done in order to observe the variation of unsteadiness of water at various stations for both high flood and for moderate flood for the dam-break case.

KEY WORDS: Manning's roughness coefficient, bed slope, surface roughness, unsteady resistance.

I. INTRODUCTION

The objective of the present study is to carry out a detailed study of unsteady flow for high and moderate flood for dam-break case and the effect of unsteadiness in channel resistance for proper flood prediction and to propose some models to predict the unsteady flow resistance for different floods and its proper predictions. The roughness coefficient Manning's "n" depends on several factors including surface roughness, unsteadiness characteristics, land use around the section and channel irregularity, and the exact values are often uncertain. The unsteady characteristics i.e. its change with flood depth and time have been studied in details by Nguyen and Fenton (2004) (2005). Their study indicates that the main channel roughness values are almost constant while the floodplain roughness values change rather more with flood depth. But still an extensive study of affect of unsteadiness in the channel resistance or a proper model for its calculation for proper flood prediction is yet to be done. Hence here in this study an humble attempt has been made to propose unsteady resistance prediction model using the available data for high and moderate flood due to dam break condition in River Toce. Analysis and discussion of the proposed models is carried out in this study.

II. RELATED WORK

Bilgil, A., and Altun, H., (2008) made an efficient approach to estimate the friction co-efficient via an artificial neural network, which is a computational tool in civil engineering. The estimated value of friction co-efficient is used in Manning's equation to predict the open channel flows in order to carry out a comparison between the proposed neural networks base approach and the conventional ones. Results showed that the proposed approach is good agreement with the experimental results when compared to the conventional ones.

Ramesh, R., et.al. (2000) proposed a new approach to estimate roughness coefficients in a channel system by directly embedding the finite-difference approximations of the governing equations for flow into a non-linear optimization

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model as equality constraints. The SQP algorithm is used to minimize the nonlinear objective function based on least square error criterion. Potential applicability of the model is demonstrated by considering simulated observation data for hypothetical channels. Performance model is evaluated through a number of numerical experiments.

Hamimed, A., et.al., (2013) investigated the influence density and placement of emergent vegetation on flow resistance, water depth and velocity profile. Experiments using artificial vegetation were carried out in the laboratory flume instead of natural channel, and Manning's n is used to denote the resistance coefficient. The result showed large variations in the Manning resistance coefficient with depth of flow and vegetative density. The flow resistance increased with the increase in vegetation density and drag coefficient reduced.

Patel K.(2012) described the hydraulic model, testing of various important structure of open channel as well as river flow with analytical solution of the flow distribution along the open channel. Different roughness constant and different flow rate are considered to examine the flow pattern in channel. The modeling approach presented in the paper is motivated from the concept of open channel. This work also helps us to predict the velocity profile of open channel flow, this would be applicable for a wide range of Reynolds number by changing the discharge flow rate.

Greco M., et.al. (2013) investigated the direct dependence of Manning's roughness on the entropy parameter in the case of low depth and submergence. Using the available data obtained through laboratory campaigns, an explicit equation to assess the ratio y_0/y_{max} , knowing the local slope and the relative submergence, is proposed, enforcing the observed dependence of entropy parameter, M , for low depths on D/d (D = water depth; d = roughness dimension) and the local slope i .

Folorunso O.P. (2015) measured and quantified the hydraulic resistance of an idealized partly vegetated open channel. The channel bed roughness was realized with grass and gravel beds, alternately placed at the right and left side of the flume to form an elongated checkerboard. The stage-discharge curve is drawn which shows a breakpoint where there is a slight change between the lower discharge and high discharge. At low discharge, the stage rises fast, causing an increase in gradient, and approximately linear at higher discharge. The overall Manning's n value is found to be 0.025 which shows an average value of Manning's roughness coefficient n selected for both grass and gravel bed for the channel. The friction factor consistently decreased with increase in discharge. The grass vegetation bed exerts more friction on the flow, and the friction for gravel bed tending towards constant value as the flow depth increases. Minimal value of f is obtained for highest flow depth and the maximum hydraulic resistance found close to the channel bed. The stage-discharge curve provides a means of comparison with the theoretical Manning's model to independently reveal the retarding effects of the grass and gravel roughness respectively.

Priyadarshinee, K., and Mohanty L. (2015) analyzed computational results despite substantial research on the experimental data, to study the variation of roughness coefficients for both straight and meandering channel. This paper investigated a consistent trend of variation of roughness manifested by MATLAB. The study provides intended address of discharge properly so that it can predict the flood felicitously.

Yen, B.C. and Asce F.(2002) extended the study of Rouse (1956) which critically reviewed hydraulic resistance in open channels on the basis of fluid mechanics, by discussing the differences between momentum and energy resistances, between point, cross-sectional and reach resistance coefficients, as well as compound/composite channel resistance. Certain resistance phenomena is explained with the inner and outer laws of boundary layer theory. The issue of linear-separation approach versus nonlinear approach to alluvial channel resistances also is discussed. This review indicates the need for extensive further research on the subject.

III. MATHEMATICAL ILLUSTRATION

The most frequently used formulas relating open channel flow velocity, V , to resistance coefficients are -

Manning's equation is more frequently used and is expressed as:

$$V = \frac{K_n}{n} R^{2/3} S^{1/2}$$

i.e., $V = \frac{1}{n} R^{2/3} S^{1/2}$ (Manning's equation)

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The **Darcy-Weisbach equation** is a more rigorous relationship, written as: $V = \sqrt{\frac{8g}{f}} \sqrt{RS}$ (Darcy-Weisbach's equation)

Chezy developed the earliest velocity equation, expressed as: $V = C\sqrt{RS}$ in which n , f , and C are the Manning, Weisbach and Chezy's resistance coefficients respectively; R = hydraulic radius; S = slope; g = gravitational acceleration; and $K_n = 1 \text{ m}^{1/2}/\text{s}$ for V and R in SI units.

IV. EXPERIMENTAL TEST CASES FOR HIGH AND MODERATE FLOOD DUE TO DAM BREAK

In the present study an attempt have been made for a detailed study for highly unsteady flow i.e., for dam-break flood. Here we have considered two test cases – one for moderate flood another for high flood, that has occurred due to dam failure in river Toce, in the Northern Alps. The necessary data required have been collected from the project CADAM (1996-1999).. The model used is a 1:100 reproduction of the Italian alpine. Two different dam-break test cases are proposed - one with the flood wave overtopping the reservoir located in the middle of the model, and the other without overtopping.

It is observed that n_{unsteady} depends on y_{max} , y_{min} and y_{avg} . Hence an attempt is made to develop unsteady formula for both moderate flood and high flood using linear regression and spreadsheet programming. The linear regression equation is expressed as-

$$Y = A_0 + B \cdot X + C \cdot Z + D \cdot P$$

Where,

$$Y = n_{\text{unsteady}}, X = \frac{1}{y_{\text{max}}}, Z = Y_{\text{min}}, P = Y_{\text{avg}}$$

The channel resistance increases as depth of flow decreases and decreases as flow depth increases. Hence in the development of unsteady friction model it is assumed that it varies directly to the minimum depth in the river reach at that particular time step, to the average of flow depths along the river reach at that particular time step and varies inversely to the maximum/ peak depth of flow.

In all the cases Manning's n is assumed to be constant. But natural rivers or channels usually have sand beds in main deeper portion of the channel and flood plain on both sides may have vegetation as such 'n' values in different portion along the perimeter may be different. Linear multiple regression is used to find out the relationship between $n_{m, \text{unsteady}}$ and $n_{h, \text{unsteady}}$.

Where, $n_{m, \text{unsteady}}$ = calculated value for moderate flood and $n_{h, \text{unsteady}}$ = calculated value for high flood.

For moderate flood,

$$n_{m, \text{actual}} = n_0 \pm n_{m, \text{unsteady}}$$

$$n_{m, \text{unsteady}} = \frac{0.001 + (0.0229 \times y_1) + (0.00345 \times y_2) + (0.00804 \times y_3)}{y_1 + y_2 + y_3}$$

Where, $y_1 = \frac{1}{y_{\text{max}}}$, $y_2 = y_{\text{minimum}}$, $y_3 = y_{\text{average}}$

For high flood,

$$n_{h, \text{actual}} = n_0 \pm n_{h, \text{unsteady}}$$

$$n_{h, \text{unsteady}} = \frac{0.0168 + (0.010842 \times y_1) + (0.00002 \times y_2) + (0.00213 \times y_3)}{y_1 + y_2 + y_3}$$

Where, $y_1 = \frac{1}{y_{\text{max}}}$, $y_2 = y_{\text{minimum}}$, $y_3 = y_{\text{average}}$

The positive sign is used $y < y_{\text{avg}}$ and the negative sign is used $y > y_{\text{avg}}$.

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V. ANALYSIS AND DISCUSSIONS

Flood hydrographs for moderate flood, (depth of surface flow vs. time) have been plotted for different stations (Fig. 1, Fig. 2, Fig. 3 and Fig.4). It has been observed that there is much variation of depth of water with time (0 sec to 150 sec) in the stations except station P12. For station P12 the depth of water is found to be constant from 0 sec to 150 sec. The highest variation of depth of water with time was observed at station P10

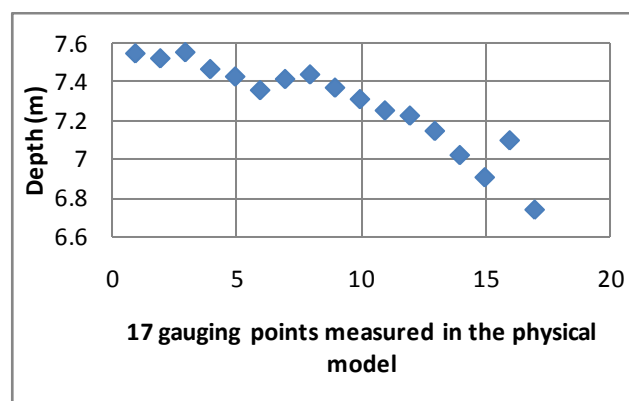


Fig.1: At time 20 sec water depth at 17 gauging points for moderate flood.

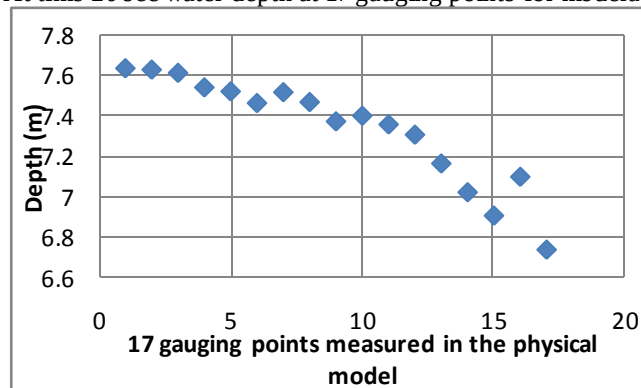


Fig.2: At time 50 sec water depth at 17 gauging points for moderate flood.

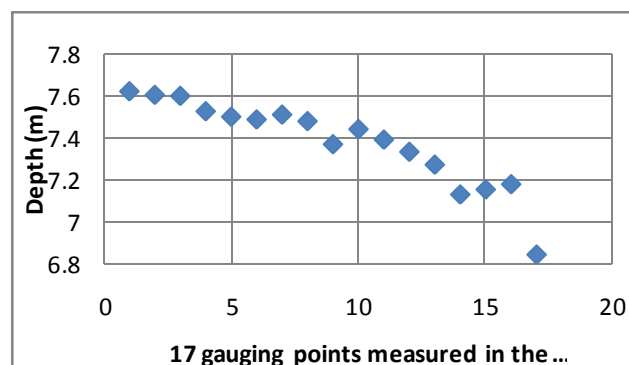


Fig.3: At time 100 sec water depth at 17 gauging points for moderate flood.

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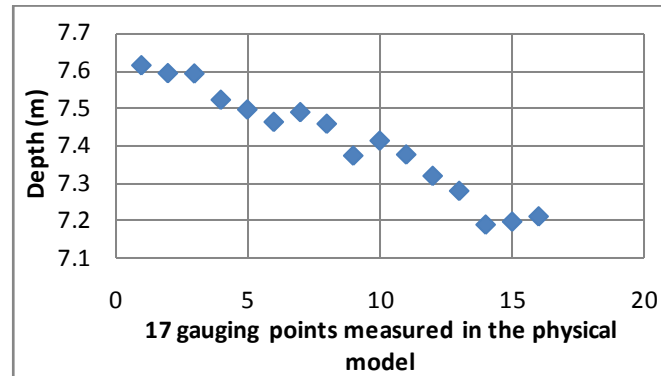


Fig.4: At time 150 sec water depth at 17 gauging points for moderate flood.

The flood hydrographs for minimum, maximum and average depth of water have been presented in fig.5, fig.6 and fig.7. It is observed that the highest unsteadiness has occurred at minimum depth of water. The unsteadiness is comparatively uniform in maximum depth of water than that of minimum depth of water and the unsteadiness is most uniform in average depth of water. Unsteadiness in the depth of water has also been noticed in the graphs plotted with depth of water vs. 17 gauging points for time 20, 50, 100 and 150 seconds (fig.1, fig.2, fig.3 and fig. 4).

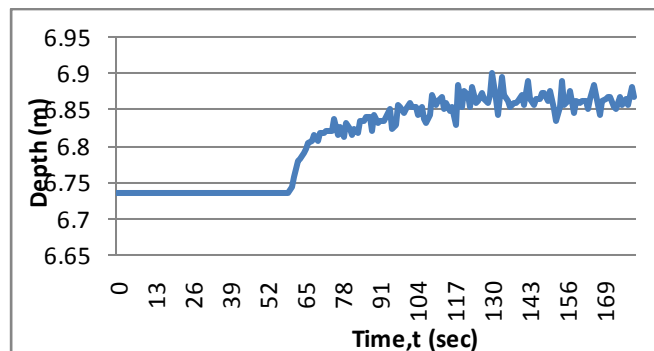


Fig.5: Depth vs. time for minimum depth for moderate flood.

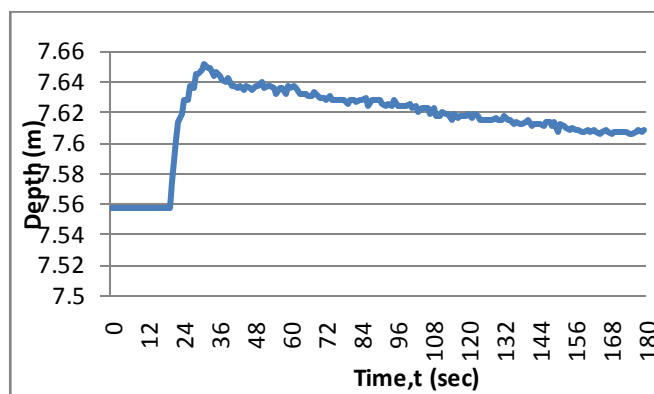


Fig.6: Depth vs. time for maximum depth for moderate flood.

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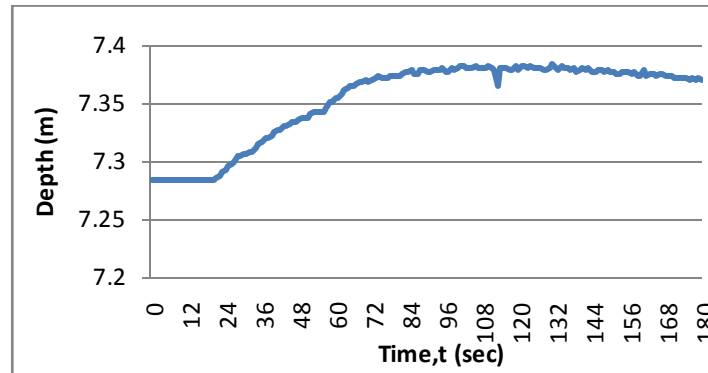


Fig.7: Depth vs. time for average depth for moderate flood.

Flood hydrographs for high flood at various stations are plotted for high flood, flood hydrographs (depth of surface flow vs. time) have been plotted for various stations (fig.8, fig.9, fig.10 and fig. 11). It has been observed that there is much variation of depth of water with time (0 sec to 180 sec) in the stations. The flood hydrographs for minimum, maximum and average depth of water have also been plotted (fig.12, fig.13, and fig. 14). and it is observed that the highest unsteadiness has occurred at minimum depth of water. The unsteadiness is comparatively uniform in maximum depth of water than that of minimum depth of water and the unsteadiness is most uniform in average depth of water.

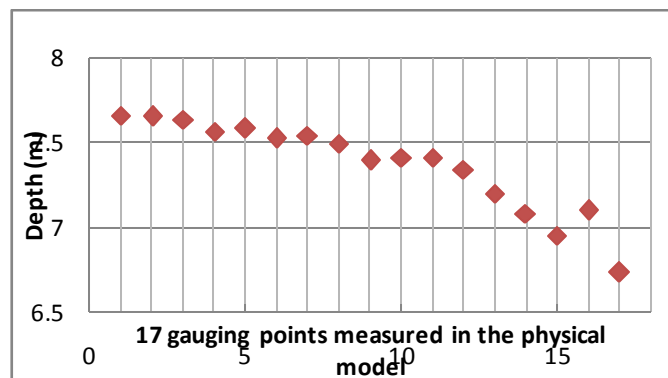


Fig.8: At time 50 sec Water Depths at 17 Gauging points for high flood.

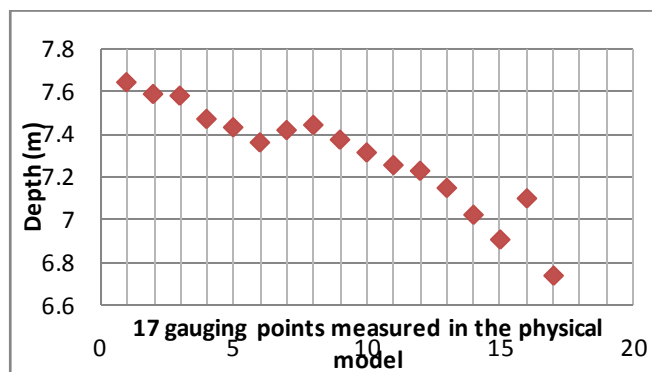


Fig.9: At time 20 sec Water Depths at 17 Gauging points for high flood.

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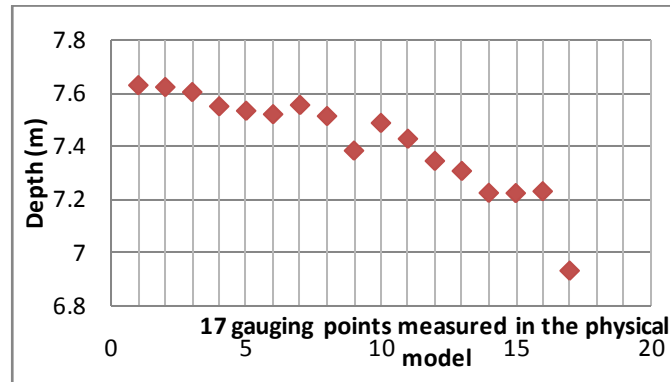


Fig.10: At time 100 sec Water Depths at 17 Gauging points for high flood.

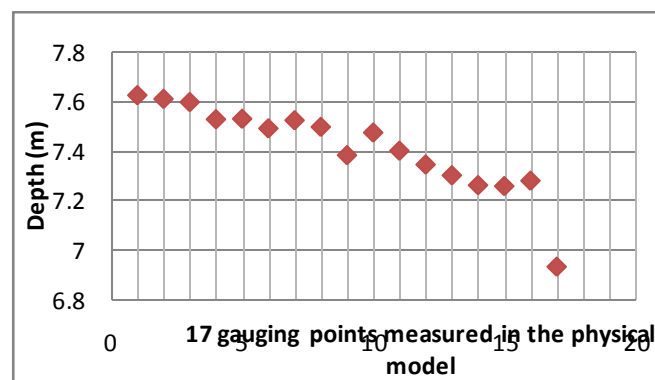


Fig.11: At time 150 sec Water Depths at 17 Gauging points for high flood.

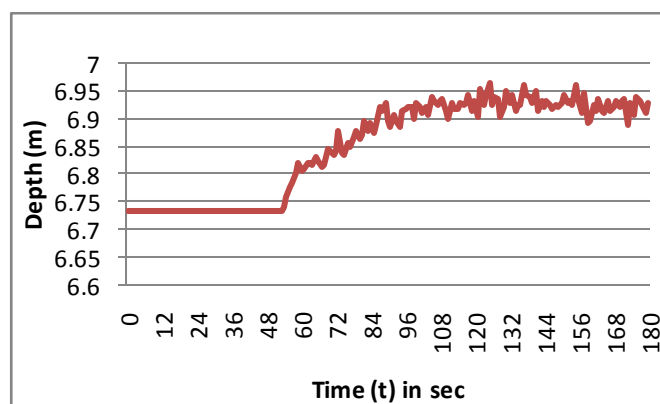


Fig.12: Depth vs. time for minimum depth for high flood.

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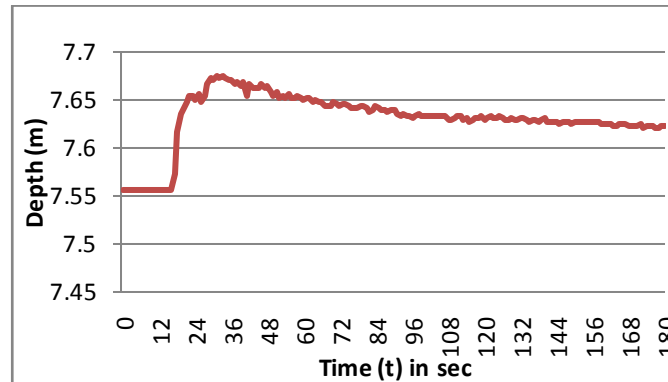


Fig.13: Depth vs. time for maximum depth for high flood.

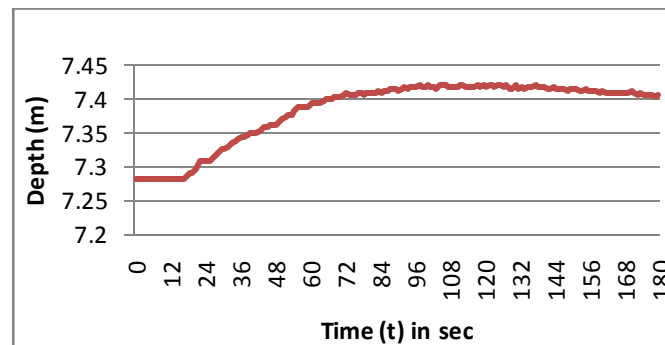


Fig.14: Depth vs. time for average depth for high flood.

VI. CONCLUSION

In this present study an attempt has been made to propose unsteady resistance prediction model using available data from the CADAM project for high and moderate flood due to dam break condition in river Toce. The unsteady resistance equations have been proposed for both high and moderate flood, using linear regression. After analysis it is observed that the highest unsteadiness occurs at minimum depth of water for both high and moderate flood cases.

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