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DESIGN AND PROBABLE IMPROVEMENT OF FIBER-REINFORCED CONCRETE CANAL-LINING BY ROLE OF ROUGHNESS COEFFICIENT

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Abstract- Flow resistance in channels carries prime importance for different purposes like evaluation of stage-discharge relationship. All relationships among Manning's Roughness Coefficient (N) and Froude Number (Fr) result in obtaining valuable information concerning design of an economical section, implementation and reducing the cost of construction. Fiber Reinforced Concrete (FRC) is strongly gaining attention of researchers which is credited to its improved properties. The necessity for optimal design of water-conveyance structures offers a wide range of research in the field of Water Resource Engineering. A review carried-out on optimal channels design specifies that alteration of Manning's Roughness Coefficient (N) with water depth has not been considered. This study primarily focusses on this variation of roughness coefficient in design of lined canal with the fiber-reinforced composites. So, the substantial difference regarding the results achieved for both scenarios, roughness coefficient of FRC compared with the conventional roughness coefficients of materials validates the need for considering variation of (N) with water depth. Moreover, when dealing with a distinctive design problem by means of the proposed equation it indicated the adequacy and the need for considering variable roughness while designing an economical section.

Keywords- Alternative, Canal, Concrete-Lining, Fibers, Manning's Roughness Coefficient.

1 INTRODUCTION

Design of open channels is conducted for transporting water at atmospheric pressure and may well be constructed in many shapes. When water flows in an open channel, it must have a free surface which is subjected to atmospheric pressure. So, the flow conditions in an open channels are complex as the position of the free surface will probably change with respect to time and space, and also by the fact that the discharge, depth of flow and the slope of the free surfaces and of the channel bottom are independent [1]. Flow resistance in channels is of key importance for different purposes like evaluation of stage-discharge relationship, and the assessment of sediment transport from the hydraulic properties of the channel by utilizing transport formulas. All relationships among Manning's Roughness Coefficient (N) and Froude Number (Fr) result in obtaining valuable information concerning design of an economical section, implementation and reducing the cost of construction [2].

The cross-section having maximum velocity or minimum area is in general, considered for lined canals. Such section is supremely effective (based on economy) as it includes least amount of earthwork. Design of irrigation canals for uniform flow includes optimization of cost by minimizing the flow perimeter and flow area to a minimum. Moreover, assessing the velocity and depth of flow are substantial for selecting adequate lining material. Special liners which do not get affected by erosion (such as concrete) are used where high velocity is permitted. For designing an economical section, the Manning's equation is most widely accepted as adequate design equation [3]. Seepage and erosion to the bottom of channel and banks can be controlled by irrigation lining. Moreover, as the roughness is reduced in lined channels hence it permits channels to transport greater flow as compared to larger un-lined channels. This efficiency means that channel can be constructed in less land. In hydraulics engineering, to design water structures, frictional coefficient (f) serves as the critical parameter while velocity, discharge and flow profile calculation plays a vital role in flood management, water resource projects and the determination of hydraulic effects for river conservation [4]. Moreover, broad knowledge of the resistance characteristics of alluvial streams is of great importance when studying different applications of water resources. The contribution of the factors like silting, scouring, location of bridges, flood forecasting, prediction of aggradation and degradation due to the presence of hydraulic structures and so on are key contributor in design of canals [5].

The aim of this research is to investigate the effect of fibre reinforced concrete lining in Manning's roughness coefficient on Froude number in open channel and resistance to flow through channel. In recent years, various researchers have been conducted regarding the roughness coefficient using Manning's equation. However, there are still uncertainties remaining regarding the precise value and effect of roughness coefficient by using fiber-reinforced concrete on discharge in channels. Moreover, to develop relationship between different parameters, especially Froude number with Manning roughness coefficient (N), and other factors velocity (V) and head (H), is considered in order to find useful relations.

2 SIGNIFICANCE OF THE STUDY

Roughness coefficient is widely adopted by the Manning's equation for lined-canal sections. The discharge of canal-sections are dependent on channel slope and roughness coefficient. Significantly, the design slope and depth of flow for channel can be increased in accordance with the roughness coefficient to achieve non-silting and non-scouring channels. Engineers should adopt the viable parameters of FRC in design for the improved characteristics of hydraulic structures.

3 LINED CANAL DESIGN PARAMETERS

The Manning Equation is the most commonly used equation to analyze open channel flows. The Manning Equation is utilized in lined canal channel designs calculation as in (1) and (2).

$$Q = A\, x\, V \tag{1}$$

$$Q = \frac{A}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \tag{2}$$

The Manning Equation was developed for prismatic channels. Prismatic channels have constant dimensions along its length including depth with the steady state of flow.

3.1 Design Cross-Section

The equation (2) is stated in terms of flow, as flow area (A) is multiplied on both sides of the equation. In (2), left hand side can be stated as A*V as it is equivalent to flow (Q) in the continuity equation. Moreover, this equation can be effectively utilized to assess the velocity (V) by eradicating the area (A).

3.2 Hydraulic Radius

The hydraulic radius (R) is the ratio of cross-sectional area to wetted perimeter. It is one of the most important property of a channel as it controls the discharge of water. Moreover, hydraulic radius and volume of water that a channel can carry are directly related i.e. a river having greater (R) will have greater flow velocity, and it will also have greater cross-sectional area through which water can travel quickly. Also, it accounts for geometry of the channel.

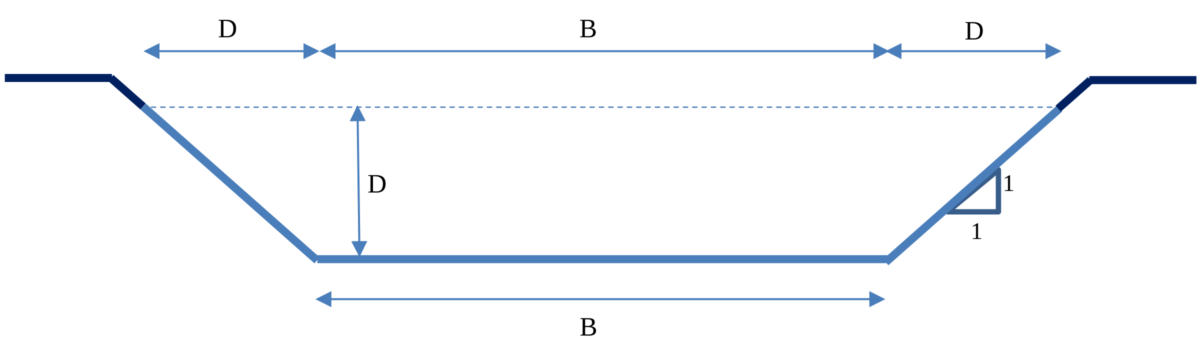

Figure 1: Schematic diagram of canal section for design

3.3 Slope of energy gradient

Generally, energy gradient slope is utilized, which signifies that due to friction, energy is released at a certain rate from the conduit. This form of equation permits it to be utilized in order to carry-out an analysis on conduits that do not only flow under uniform conditions but also flows under different conditions.

3.4 Roughness coefficient (Manning's Coefficient)

The Manning's coefficient (N) is a unit less quantity which signifies the frictional factor (*f*) or the roughness of the conduit. Moreover, (N) is higher in case of rougher conduits having high friction whereas (N) is lower in case of smoother conduits having less friction. Manning's coefficient (N) is an empirically derived coefficient and depends upon various factors including sinuosity and surface roughness.

4 ROLE OF ROUGHNESS COEFFICIENT

Flow resistance explicates the influence of friction on flow due to channel characteristics. Also, roughness equation is used for its estimation. Moreover, resistance coefficient can be stated as magnitude of resistance. In an open channel, the study of flow resistance is a delicate concept and there is no ideal approach to assess it (Järvelä, 1998). The factors that affect the flow resistance to a great extent are described below and it shall be observed that all of these factors are interdependent to a certain extent (Chow, 1959, 1973; French, 1986; and Bin Abrahim, 2011). Among the top of the factors surface roughness is indicated by the size and shape of the roughness particles of the material forming the wetted perimeter and producing the effect of retardness on flow. Retarding effect is greatly influenced by the bottom irregularities including the material roughness. Vegetation evidently decreases the capacity of flow for the channel and hinders the movement of flow. This effect depends primarily on stiffness, height, density, spreading and type of vegetation. Seasonal change influences the growth of weeds, willow and trees, aquatic plants and grass on the banks of channel or within the channel. On the other hand, channel shape, size and irregularity principally refers to shape dissimilarities in the channel, X-section and wetted perimeter along the gradient and slope of the channel. Erosion and sedimentation can alter the flow movement either to move un regular form or to divert and make irregular form. The factors mainly depend upon roughness characteristics and soil material type. Obstructions, for instance, debris flows, fallen trees, bridges, log jams and stones can have a noteworthy influence on the flow resistance. Stage-Discharge generally effect flow resistance in such a way that when stage-discharge increases, it leads to decrease in roughness coefficient.

5 PROBABLE IMPROVEMENT IN DESIGN

Concrete linings carry number of benefits and are used widely despite of their relatively higher cost. Cement concrete lining made from selected aggregate provides very satisfactory service. Cement concrete linings are optimal for main canals that carry a greater flow at high velocities. The conveyance of the channel is increased by smooth surface of the concrete lining.

Table 1- Roughness coefficient of different materials [20]

Sr. No.	Type	Material/ Type	Coefficient
1	Paved	Watertight roofs	0.70-0.85
2		Asphaltic cement streets	0.85-0.95
3		Portland cement streets	0.80-0.95
4		Paved driveways and walks	0.75-0.85
5		Gravel driveways and walks	0.15-0.30
6	Clayey soil lawns	2% slope	0.05-0.10
7		2-7% slope	0.10-0.15
8		>7% slope	0.15-0.20
9	Sandy soil lawns	2% slope	0.13-0.17
10		2-7% slope	0.18-0.32
11		>7% slope	0.25-0.35

Channel banks are kept at self-supporting slope 1.5H: 1V to 1.25 H : 1V, so that as a result lining is not needed to bear earth pressures and its thickness do not increase. They are durable, tough, hydraulic efficient and relatively impermeable

(Pencol, 1983). Lined irrigation canals serve for many purposes, out of which some are to minimize seepage, stabilize channel bed and channel banks, avoid piping through and under channel banks, reduce hydraulic roughness (flow resistance), promote movement rather than deposition of sediments, evade water logging of adjacent land, regulate weeds growth, lessen maintenance costs, assists cleaning and decrease movement of polluted groundwater plumes (Özcan, A., (2005).

There are a number of reasons to make relationship like this because channel irregularity includes irregularities in wetted perimeter and disparity in cross-section, shape, size along the length of channel and ripples, meandering, which leads to small pitches or grooves unsettled in the bottom of the channel. These irregularities certainly provoke roughness in addition to that caused by the surface roughness and other factors (Abdul Ameer, 1989). Also, vegetation can be look upon as a kind of surface roughness, and evidently decreases the channel capacity and impedes the flow. Ebrahimi et al., (2008) discovered direct relation between (N) and vegetation density which means increase in (N) results in an increase in vegetation density [22]. Likewise, the erosion of particles and presence of sediments effects the Manning's roughness coefficient.

Contrarily, silting can vary an irregular channel into a relatively uniform channel and reduce Manning's roughness coefficient (N), whereas scouring may result in an increase in (N) (Al Jawad, 1994). Side slope of the banks triggered an excessive effect on velocity, and plant growth also led to acquire the different values for (N). In lined irrigation canal, decrease in flow depth will result in decrease in velocity, Froude Number and increase in (N) [21].

Thus, from all those influencing parameters, the multi-regression analysis does not give a good understanding for the relation between (N) and stage-discharge and needs more detailed study for the concrete irrigation canals. The roughness coefficients of few materials are obtained empirically after the research work are presented in Table 1.

6 CONCLUSION

Based on the literature based experiments which was investigated by many researchers in experimental tests on open channel, a summarized form of the findings and conclusions drawn from the studies are as follows:

- The relation between Froude number and Manning's roughness coefficient n in subcritical flow was appeared inverse relation having a good agreement with the observed value.
- The relation between Froude number and Manning's n in concrete lining irrigation canal is inverse relation with polynomial of fourth degree and showed moderate relation.
- The relationships between Fr and n in the natural are inverse relations. The causes of the inverse relation are due to the presence of many variables belong to the hydraulic conditions, and river morphology which affecting the measurements and relationships.
- The use of fibres provide the roughness which can be incorporated by increasing the depth of flow.
- The roughness coefficient is material characteristics, properties and roughness of each fiber varies and the design parameter of the canal design will be varied accordingly.

On the other hand, role of roughness coefficient plays a vital role in design of the non-silting and non-scouring channels, by the use of the fiber in concrete canal lining we can increase the depth of flow, by reducing the effective surface area which is more likely to reduce the losses as well. The use of fibres in canal lining can be more cost effective and more sustainable material leading to green infrastructures.

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