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VARIATION OF MANNING'S ROUGHNESS COEFFICIENT WITH SEEPAGE IN SAND-BED CHANNEL

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Abstract: Manning's roughness coefficient affected by seepage in alluvial channel was experimentally investigated. In this paper, the experimental observations were carried out in a 20 m long tilting flume, 1 m wide and 0.72 m deep with glass class sided rectangular crass section on one median sand size 1.1mm and two different types of slope uses: without seepage condition to observed the incipient motion of sand bed channel with different top widths. In the presence of downward seepage flow through in alluvial channel bed get affected the water surface depth, energy slope, velocity, scour, sediment transport and roughness coefficient with compare of no seepage condition. The Manning's roughness coefficient *n* decreases with increase in downward seepage (suction) but the velocity increases with increase in downward seepage flow through the alluvial channel bed. In this study, such variations of velocity and Manning's coefficient are quantified with and without seepage conditions. So, it has been concluded that seepage condition should be considered as parameter for design of channels.
Keywords: Alluvial channel, Manning's Coefficient, Incipient motion, Seepage.

Introduction

A study of the effect of seepage on manning's roughness coefficient is of great interest, since this problem is one of the most difficult problems in river engineering to carried out equally for all natural channels. Alluvial channel are the man-made or natural channels, it is a free to change their dimensions, either through erosion or deposition under present of flow conditions. The occurring of vertical downward flow of water from an alluvial channel leads to a process of change in the bed conditions. The amount of water losses in alluvial channel in form of seepage is many researchers are investigated. An analysis of seepage from the New York Channel (NYC) estimates that cumulative seepage rates range between 12% and 20% at channel flows of 439 to 980 cubic feet per second (cfs) (Berenbrock, 2 1999; Carlson and Petrich, 1999). Seepage losses from alluvial channels have been estimated to range from 15 to 45% of total inflow (Van der Leen 1990). Recently, Australian National Committee on Irrigation and Drainage (ANCID, 2006) has indicated that a significant amount of water (10

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to 30 percent) is lost in the form of seepage from alluvial channel. The The Manning roughness coefficient is also not constant, it is depending on depth and slope i.e., the greater the depth, the smaller the coefficient; this is due to the minimization of the relative roughness, with the effect being similar to a slope increase.

According to Nakagawa and Tsuimoto (1984), the hydraulic resistance coefficient gets affected with the presence of seepage. The Manning's *n* is a greatly significant variable and widely used empirical resistance equation in the open channel flow computations. Willets and Drossos (1975), Maclean (1991), Rao and Sitaram (1999) and Rao and Sreenivasulu (2009) suggest that suction increases bed material transport, whereas injection reduces sediment transport and increases particle stability, or does not aid in initiating their movement. Sitaram and Rao (2005) has ascertained that Manning's *n* values significantly affected from the seepage, thus there is a need to have a different kinds of equation. Thus, Manning's n will be affected by flow rate of seepage through the boundaries of alluvial channels.

The aim of the present work is to observe the variation of Mannings' coefficient with seepage through experimentation and also aims in quantifying the changes in Mannings' coefficient with seepage in alluvial channel.

Methods

In this study a set of laboratory experiments conducted in IIT Guwahati to quantify the variation of manning's roughness coefficient with seepage in sand-bed channel, experiments were conducted in a glass-sided tilting flume. Mechanical arrangement has been provided beneath the flume which is used to change the bed slope either in positive or even negative direction if need be. A schematic view of the tilting flume is show in Fig. Dimensions of flume are 20 m in long, 1m wide, and 0.72m deep. The upstream tank of dimensions 2.8 m long, 1.5 m wide and 1.5 m deep is provided at the upstream of the flume which serves to straighten the flow prior to its introduction in to the flume. A tank is provided at the downstream of the flume to collect the water from channel as well as a measuring tank for the water flowing through flume and release it to the underground trench, which delivers it to an underground tank from where the water is pumped into the overhead tank. A control valve is located at the overhead tank and is used to regulate the flow in the main channel. The flume consists of a seepage chamber; length of 16 m was facilitated from the downstream end towards the upstream end of the flume. It is 1 m wide and 0.22 m deep, which collects and allows the free passage of flow through the sand bed. A uniform sand bed of particle size 1.1 mm was placed on perforated sheet at an elevated level from the channel bottom and covered with a fine wire mesh to facilitate the seepage flow through the sand bed. The space between the bottom of the channel and the perforated sheet act as a pressure chamber.

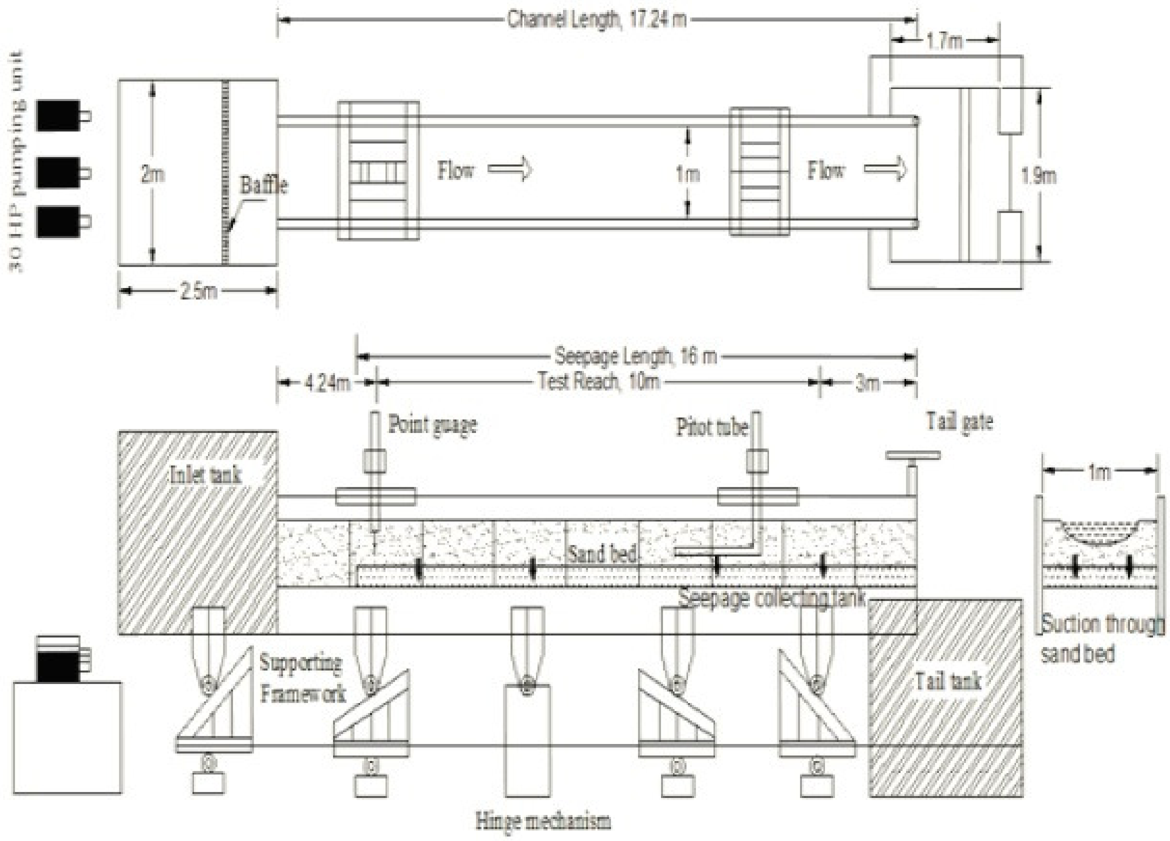

Figure 1: Schematic diagram of experimental setup

The fine mesh prevents the bed material entering into the chamber. This pressure chamber is used to remove the water from the main channel through the sand bed (uniformly) in perpendicular direction. A couple of valves located at the downstream end of the chamber that used to allow uniform and controlled amounts of seepage in the form of suction. A tail gate is provided at the downstream end of the main channel which can be raised or lowered to control the flow depth. The tail gate is operated manually by a geared mechanism with edges, which allows precise positioning of the gate. A magnetic flow meter installed for measure the seepage discharge.

Initially, the required size Lane's shape (Top width of Lane's shape 70 cm, 60 cm, and 50 cm) of the sand bed was made for all of the experiments run with a required bed slope, S_0. Two different bed slopes (0.00249 and 0.00116) were used. Then inflow discharge, Q, is allowed. The experiments run were continued for several hours (4 to 8 h) i.e. the channel geometry and the longitudinal slope adjusted to the point where there is no visible sediment movement in the channel. After that the sand bed channel achieve stable condition, downward flow of water, q (suction), was slowly allowed. Before and after the application of seepage, the water surface slope, flow depth was obtained along the central line of the channel at the regular intervals by using a point gauge. The point gauge was attached to a trolley; by moving the trolley.

The amount of Q was measured volumetrically and q (seepage flow) was measured with calibrated magnetic flow meter.The amount of downward flow of water (seepage) was varied from 30% to 50% of the total inflow discharge.

Table 1 Experiment Ranges

Top width, B m	Bed Slope S_o	Flow Depth Y m	Discharge Q_o m^3/s	Seepage Discharge (q_s) %
0.5	0.00116-0.00249	0.0962	0.010	50
0.6		0.1155	0.017	40
0.7		0.1347	0.025	30

Result and Discussion

In the alluvial channel, the sediment transport is only dependent on rate of flow of water in the channel and the presence of seepage flow through the channel. Thus, the describing 'Manning roughness concept' is more appropriate for influences of seepage flow in an alluvial channel. Manning's n with seepage and without seepage can be expressed by the following two equations as:

$$n_s = S_{fs}^{1/2} R_{bs}^{2/3} / u_s \quad (1)$$

$$n_o = S_{fo}^{1/2} R_{bo}^{2/3} / u_o \quad (2)$$

Where, u_s and u_o are average velocities in the channel with seepage and without seepage respectively. The variation of Manning's n with seepage and without seepage can be expressed by using Eq. (1) and (2) as,

$$n_s / n_o = \left(S_{fs} / S_{fo}\right)^{1/2} \left(R_{bs} / R_{bo}\right)^{2/3} \left(u_o / u_s\right) \quad (3)$$

The gradually varied flow equation (Chow, 1959), with energy/ momentum correction factor as unity, is used in computing the S_{fo}as follows:

$$S_{fo} = S_{wo}\left(1 - F_o^2\right) + S_o F_o^2 \quad (4)$$

Momentum equation for seepage can be expressed the S_{fs} as follows:

$$S_{fs} = S_{ws}\left(1-F_s^2\right)+S_oF_s^2 \pm 2\rho u_s v_s/\left(\gamma_w y_s\right) \quad (5)$$

The ratio of the bed shear with and without seepage can be expressed as,

$$\tau_{bs}/\tau_{bo} = \gamma_w R_{bs}\left[S_{ws}(1-F_s^2)+S_oF_s^2\right]/\tau_{bo} \pm N \quad (6)$$

$$\frac{\tau_{bs}}{\tau_{bo}} = \left[\frac{S_{ws}(1-F_s^2)+S_oF_s^2}{S_{wo}(1-F_o^2)+S_oF_o^2}\right]\frac{R_{bs}}{R_{bo}} \pm N \quad (7)$$

$$\frac{\tau_{bs}}{\tau_{bo}} = M + N \quad (8)$$

Where, N called as the seepage intensity parameter expressed as:

$$N = \left(2\rho u_s v_s/\tau_{bo}\right)$$

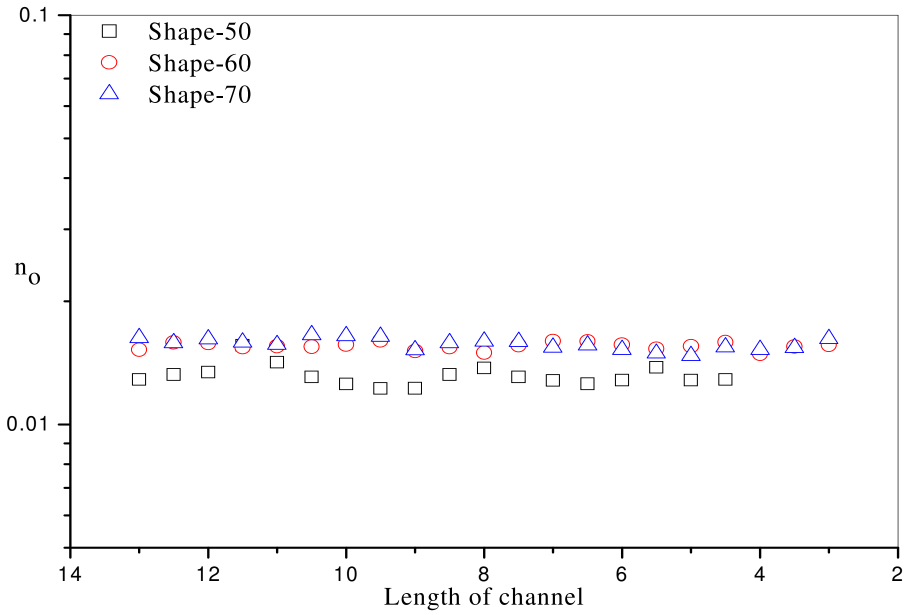

Figure 2: Variation of Manning's roughness coefficient without seepage (slope-0.00116)

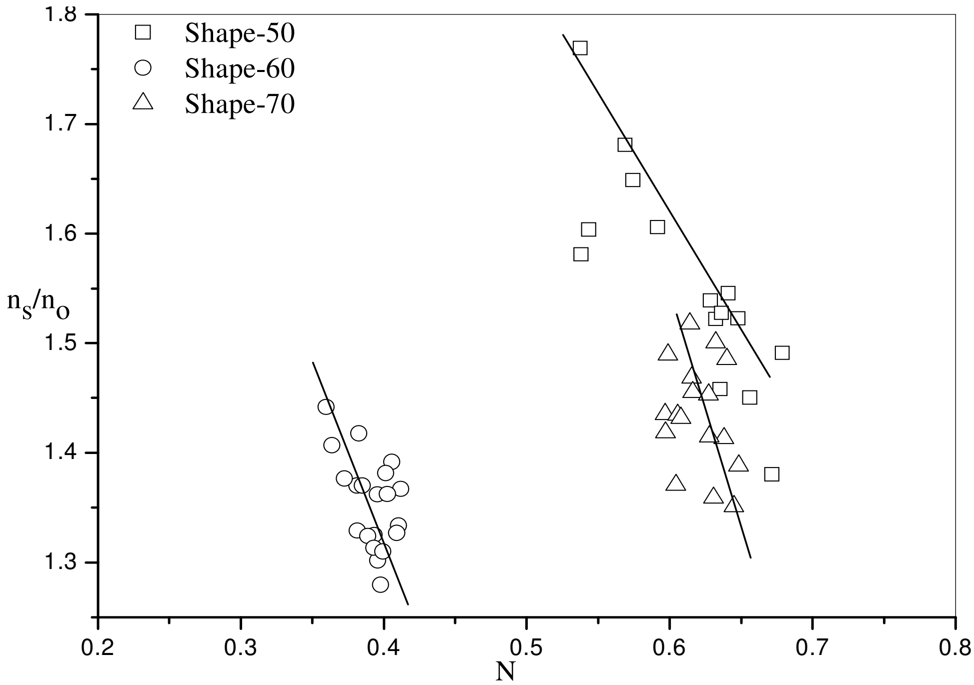

Figure 3: Variation of Manning's roughness coefficient with N (slope-0.00116)

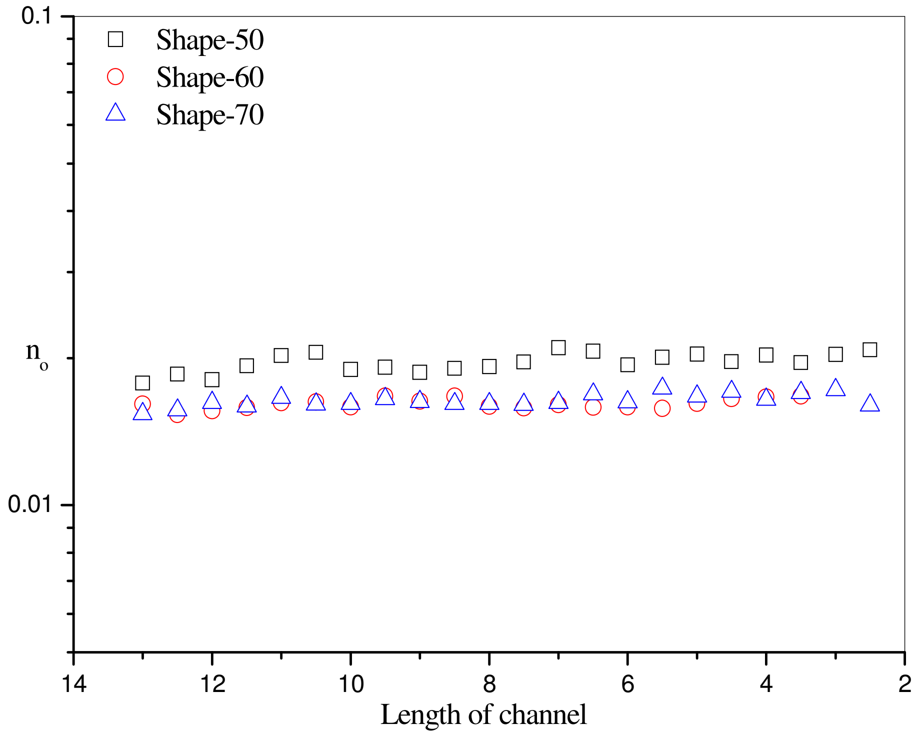

Figure 4: Variation of Manning's roughness coefficient without seepage (slope-0.00249

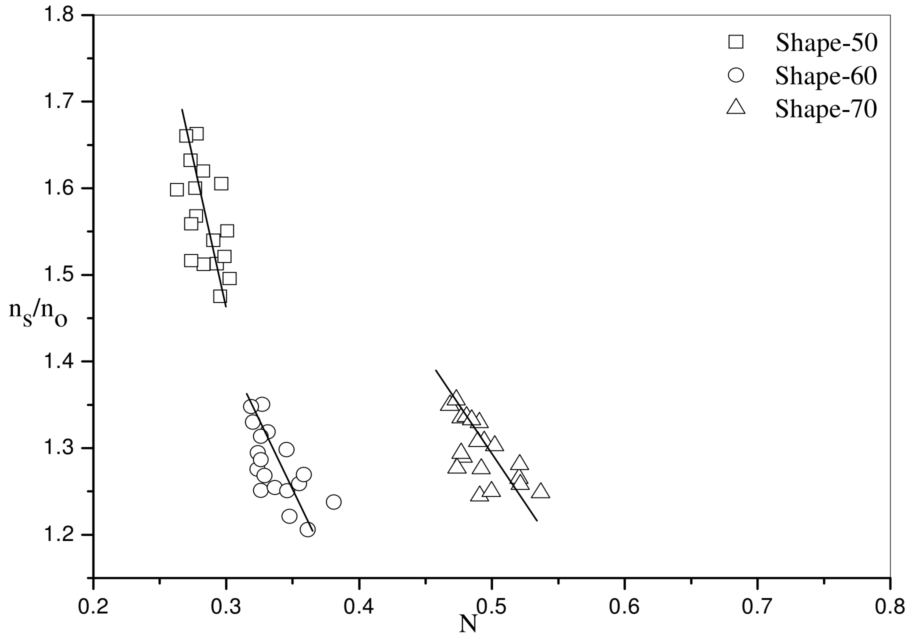

Figure 5: Variation of Manning's roughness coefficient with N (slope-0.00249)

As shown in Fig. 2 and Fig. 4, when the water flow in sand bed channel without downward flow of water (seepage), it is found that the manning's roughness coefficient does not change along the length of channel. The experimental results of variation of Manning's coefficient n_s/n_0 with seepage intensity parameter *N* are plotted in Fig.3 and Fig.5, Using of Eq.3. It can be observed that seepage change the value of Manning's *n*. Also observe that the suction decrease the value of manning's coefficient *n i.e.* n_s/n_0 can be greater than unity. Thus, the seepage should be considered as parameter to determine the resistance coefficient of the channel.

Conclusions

The following results can be concluded from the experiments were carried out the effect of seepage on manning's roughness coefficient in an alluvial channel.

The Manning's coefficient is get affected by the present of seepage and it is higher than the value from no seepage. So, seepage should be considered as parameter to determine the resistance coefficient of the channel. The Manning's coefficient decreases with increasing rate of suction.

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