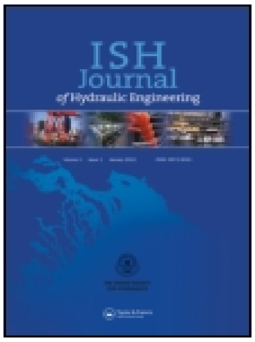
Use of inclined compound triangular notch-weir to improve discharge range

Article *in* ISH Journal of Hydraulic Engineering · June 2012

DOI: 10.1080/09715010.2009.10514962

Raviraj Mulangi
National Institute of Technology Karnataka



ISH Journal of Hydraulic Engineering

ISSN: 0971-5010 (Print) 2164-3040 (Online) Journal homepage: http://www.tandfonline.com/loi/tish20

USE OF INCLINED COMPOUND TRIANGULAR NOTCH-WEIR TO IMPROVE DISCHARGE RANGE

Anand V. Shivapur M.ISH , Raviraj H. Mulangi & H. S. Govardhan Swamy

To cite this article: Anand V. Shivapur M.ISH , Raviraj H. Mulangi & H. S. Govardhan Swamy (2009) USE OF INCLINED COMPOUND TRIANGULAR NOTCH-WEIR TO IMPROVE DISCHARGE RANGE, ISH Journal of Hydraulic Engineering, 15:3, 87-96, DOI: 10.1080/09715010.2009.10514962

To link to this article: http://dx.doi.org/10.1080/09715010.2009.10514962

Published online: 07 Jun 2012.

THE INDIAN SOCIETY FOR HYDRAULICS
JOURNAL OF HYDRAULIC ENGINEERING

USE OF INCLINED COMPOUND TRIANGULAR NOTCH-WEIR TO IMPROVE DISCHARGE RANGE

by

Anand V. Shivapur[1], M.ISH **Raviraj H. Mulangi**[2] and **H. S. Govardhan Swamy**[3]

ABSTRACT

The notch–weir having simple geometric shapes is unable to measure small as well as occasional large flows. In such situation compound weirs find application. In the present paper authors have reported their study on the use inclined compound notch-weir consisting of two triangular sections with different vertex angles. The notch plane is placed inclined to the general flow surface in the channel. The general discharge equation has been evolved through the semi analytical cum experimental procedure. Results show a significant improvement in discharging rate compared to normal weir. The lower triangular portion of the notch-weir handles the smaller flow whereas the upper part helps to measures the occasional high flows. Further advantages of the inclined compound weir in reducing afflux near the structure are also discussed.

KEY WORDS : Compound notch-weir, Inclined notch-weir, Discharge coefficient, Discharge equation.

INTRODUCTION

The demand for water is increasing with the time from all facets of life. Hence the issue of water measurement is particularly attains importance in the present scenario. The sharp-crested notch-weirs (USBR., 1997; Bos, M.G., 1976) are the oldest among the measuring devices known to mankind. These devices are usually placed normal to the general direction of flow in the channels. Sometimes depending on the purpose and the site condition they are also placed as oblique or side weir in view of the advantages they have in a particular situation.

Many researchers have expressed weir discharge coefficient in terms of the fluid

1. Professor, Civil Engg. Dept., and Dean (IPD), S. D. M. College of Engg. & Tech. Dharwad -580 002 Karnataka email:av_shivapur@rediffmail.com
2. Assistant Professor, Dept. of Civil Engineering, National Institute of Technology-Karnataka, Surathkal. email : ravirajmh@rediffmail.com
3. Senior Lecturer, Civil Engineering Department, M.S.R. Institute of Technology, Bangalore, Karnataka. email:hsgswamy@yahoo.com

Note : Written discussion of this paper will be open until 31st December 2009.

and flow properties. But an effort on improving discharge capacity of weirs has attained a very little importance. The effort of Lakshamana Rao and Jagannadha Rao, 1973 by modifying the profile of weir crest is one such example. However results were not very encouraging.

In the present paper authors have proposed to install the compound weir inclined to the general flow surface in the channel to improve the discharge capacity.

LITERATURE REVIEW

Many investigators have expressed weir discharge coefficient in terms of flow and fluid properties. The available literature mainly pertains to normal, side or oblique weir. Few of the researchers have attempted to improve the discharge capacity of these weirs by modifying their crest profile etc. Therefore there is a need to develop notch-weir which is simple in design and fabrication and can measure a reasonably large flow rates with accuracy. Not many studies were reported on inclined sharp crested notch-weirs.

An analysis of flow over inclined triangular weir has been reported by Shesha Prakash and A.V. Shivapur (2003) expressing discharge coefficient in terms of head to crest height ratio for all inclinations studied. The same authors have also reported that the discharge capacity of Inclined Inverted V-notch, Inclined Rectangular Weirs (2002a, 2002b) improves with the inclination.

Shesha Prakash and A. V. Shivapur (2004a, 2004b, 2004c) have reported their study on inclined rectangular weir, triangular weir and inverted triangular weir (IIVN) and expressed discharge as a function of weir plane inclination to the general surface of flow in the channel. Through the semi theoretical cum experimental approach Shivapur, A. V. and Shesha Prakash, M. N. (2006) have reported the general discharge equation for inclined trapezoidal notch. Ismail Aydin et al., (2002) have shown that small discharge can be measured with accuracy using a slit weir. Martinez, J. et al., (2005) have reported the advantages of using compound weirs consisting of upper and lower triangular portion with different vertex angle. Though the literature review reveals that the some work has been carried on simple compound notch-weirs which are easy to fabricate using unskilled labour, work the inclined compound weir has not been attempted yet.

In the present study it has been shown that there is improvement in discharge with the inclination for the compound weir consisting of two triangular portions with different vertex angle. An expression for the discharge as a function of weir inclination to the general flow surface in the channel has been established.

COMPOUND WEIR

In certain case compound sharp crested weirs are used in place of single sharp crested weir (Martinez, J. et al., 2005) to improve the performance. The compound weirs chosen in the present study consists of two triangular weir with vertex angles ϕ and θ (Fig.1). The lower triangular notch-weir helps in handling the normal range of discharges and the upper triangular notch-weir having vertex angle ϕ helps is discharging occasional high flows efficiently. The major inconvenience of this weir in its normal position is that there is a discontinuity in the transition between the two parts. The effort of the present work i.e. the study on inclined compound weir is to explore the possibility of overcoming the above difficulty.

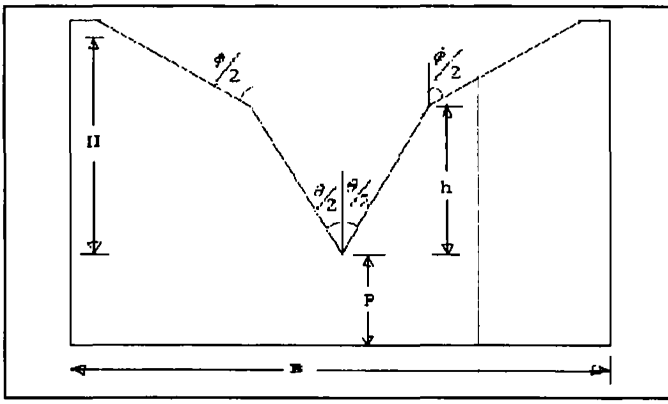


FIG. 1 WEIR CROSS SECTION

DESIGN OF WEIR WITH DIFFERENT VERTEX ANGLE

Figure 2 illustrates the proposed sharp crested compound notch-weir. The cross section of the proposed compound weir results from the composition of three triangular weir area (see Fig. 2).

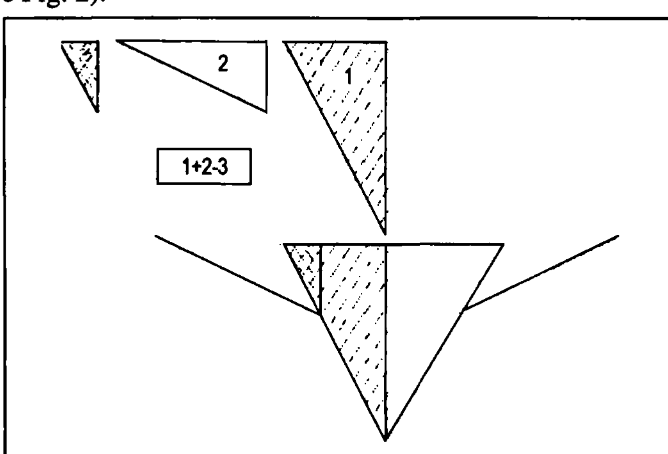


FIG. 2 DEFINITION SKETCH OF COMPOUND NOTCH-WEIR

Therefore, the total discharge can be expressed as the sum of discharge through 1 and 2 minus the discharge through area 3.

When the head over the crest 'H' is less than the height of lower triangular cut 'h' it behaves as a simple triangular notch-weir. On the other hand when the head 'H' is more than 'h', the weir will act as compound weir.

The discharge for the compound weir placed normal to the flow in a channel can be written as

$$q_t = \frac{8}{15}\sqrt{2g}\left\{\tan\left(\frac{\theta}{2}\right)\left[H^{5/2} - \left(H-h\right)^{5/2}\right] + \tan\left(\frac{\phi}{2}\right)\left[H-h\right]^{5/2}\right\} \tag{1}$$

DISCHARGE EQUATION FOR INCLINED COMPOUND NOTCH-WEIR

Let the plane of notch-weir be fixed at an angle 'a' degrees inclined to the plane normal to the flow axis as shown in Fig. 3.

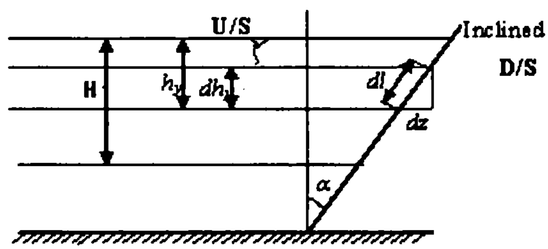


FIG. 3 INCLINED NOTCH-WEIR

The discharge through the compound notch-weir can be considered as the sum of discharges through the normal weir and the flow through the orifice formed by the horizontal projection of inclined compound notch-weir.

Therefore, for any length 'dl' considered along the weir plane can be resolved into two components *viz.* one along the general direction of flow in channel, i.e. in x-axis and other in vertical direction, i.e. y-axis.

The discharge through the inclined sharp crested notch-weir can be considered to be

$$q_i = q_x + q_y \tag{2}$$

where q_x= discharge through the vertical projection of inclined compound weir, i.e. x-axis q_y= discharge through the horizontal projection of inclined compound notch-weir (considering as an orifice), i.e. y-axis.

The discharge through the vertical projection of the inclined compound notch-weir, i.e. x-axis is given by

$$q_x = \frac{8}{15}\sqrt{2g}\left\{\tan\left(\frac{\theta}{2}\right)\left[H^{5/2} - \left(H-h\right)^{5/2}\right] + \tan\left(\frac{\phi}{2}\right)\left[H-h\right]^{5/2}\right\} \quad (3)$$

The discharge through the horizontal projected area of the compound weir (treated as sharp-edged orifice) in the vertical direction i.e. y-axis is given by

$$q_y = \frac{8}{15}\sqrt{2g}\tan\alpha\left\{\tan\left(\frac{\theta}{2}\right)\left[H^{5/2} - \left(H-h\right)^{5/2}\right] + \tan\left(\frac{\phi}{2}\right)\left[H-h\right]^{5/2}\right\} \quad (4)$$

From Eqs. (2), (3), and (4) we get

$$q_i = q_n(1+\tan\alpha) \quad (5)$$

where, $q_n = \frac{8}{15}\sqrt{2g}\left\{\tan\left(\frac{\theta}{2}\right)\left[H^{5/2} - \left(H-h\right)^{5/2}\right] + \tan\left(\frac{\phi}{2}\right)\left[H-h\right]^{5/2}\right\}$

where q_n is the discharge through the normal compound notch-weir.

Actual discharge, $q_a = C_d q_i$ where C_d is the coefficient of discharge of notch-weir.

EXPERIMENTATION

Compound notch-weir was fabricated in 6 mm thick acrylic sheet. The vertex angle for the lower triangle 45^0 and upper triangular portion has a vertex angle of 90^0. The height of the lower triangular weir is 80 mm. The downstream edge of compound notch-weir is chamfered to 45^0 with 1 mm crest thickness. Figure 4 shows the experimental set up for the inclined compound weir.

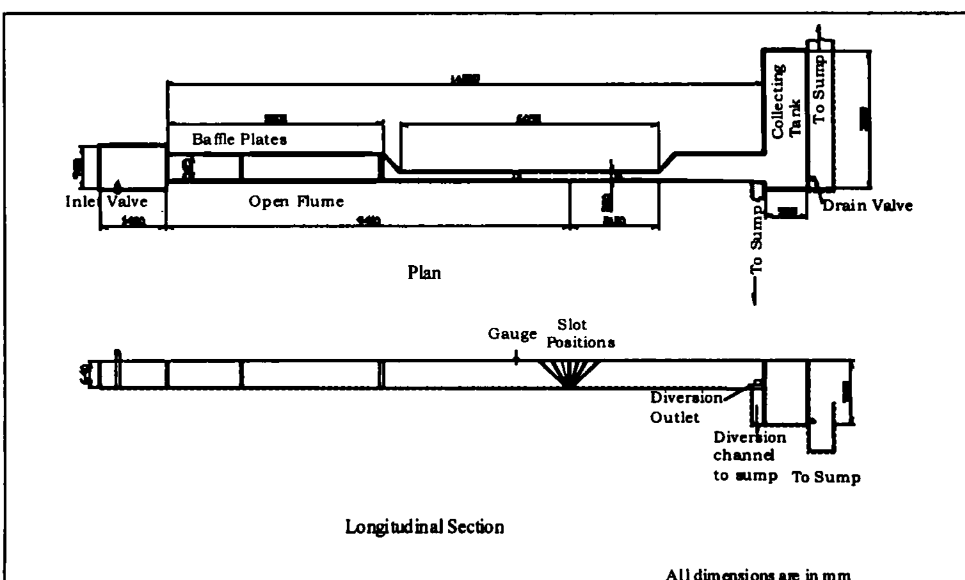


FIG. 4 EXPERIMENTAL SETUP

The experiments were carried on compound notch-weirs in its normal, 15°, 30°, 45°, and 60° inclinations with the general surface of flow in the channel. The volumetric method of discharge measurement is used for better accuracy instead of using calibrated notch-weir as followed by many researchers. To minimize the human error, time required for 100 mm, 200 mm, 300 mm and 400 mm rise of water level in collecting tank was recorded and average was calculated.

ANALYSIS, RESULTS AND DISCUSSION

The variation of actual discharge with head for various inclinations of compound notch-weir as obtained through the experiments is as shown in Fig. 5. It shows that as the inclination increases, discharge rate increases for the same head. It is observed that as the inclination increases, the lower nappe length decreases. This property may probably influence the notch to improve the discharge capacity. The additional weight of water on the inclined weirs draws the suspended silt and hence reduces silt accumulation on upstream of the weir. It can also be observed from Fig. 5 (head Vs. discharge curve) that the kink formed corresponding to lower triangular weir and upper triangular weir portion gets eliminated with 30⁰ inclination for the compound weir.

The average discharge coefficient for the lower triangular notch-weir and compound notch-weir in its normal position of the weir are 0.63 and 0.60 respectively. Using the Eq. 5 the discharge values were estimated corresponding to the measured heads for all the inclinations studied. One such graph for 30^0 inclination is shown in Fig. 6. It can be seen that the measured discharge values deviates from the estimated values of discharges. This necessitates the introduction of new parameter 'β' as a function of weir plane inclination 'α' in the Eq. 5 as shown below.

$$q_i = q_n(1+\beta\tan\alpha) \qquad (6)$$

By regression an expression for β is obtained as a function of α (in radians) for all the inclinations studied as

$$\beta = 1.3072\,\alpha^{0.6693} \qquad (7)$$

The Fig. 7 shows a variation of β with α. The regression coefficient obtained is 0.988.

Then discharge values are estimated for various heads for all the inclinations using Eq. 7 in Eq. 6. The estimated discharge values are plotted against actual discharge values (Fig. 8). The percentage error in estimating discharge is found to be within ±10% when compared with actual discharges values. The percentage increase in discharge capacity of compound notch-weir with the inclination are shown in Table-1.

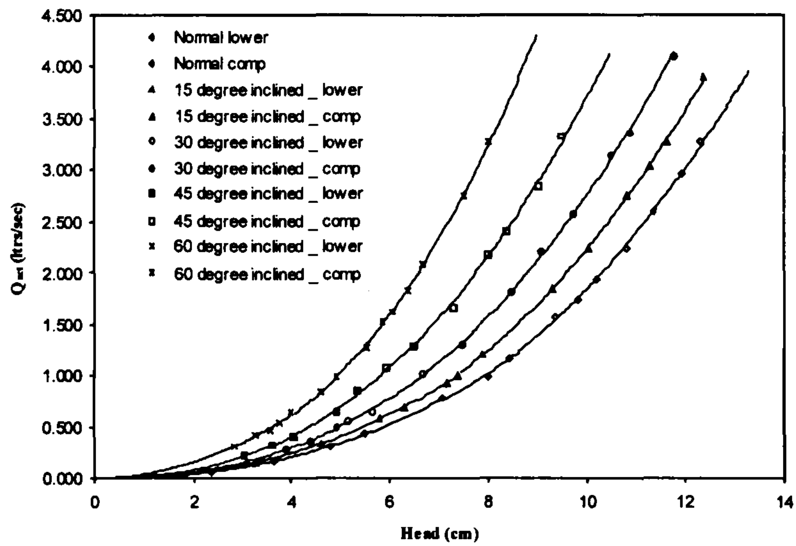


FIG. 5 Q_{act} Vs HEAD

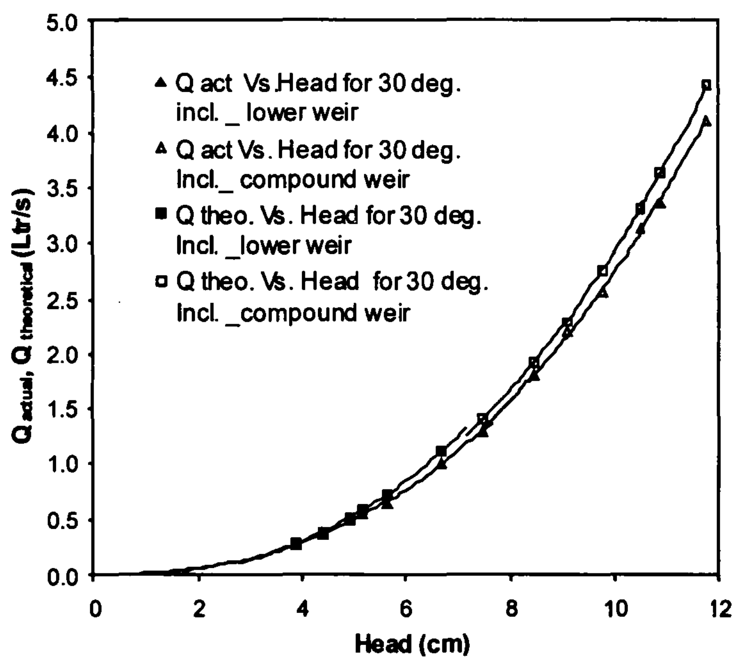


FIG. 6 Q_{actual} AND $Q_{theoretical}$ Vs HEAD (FOR 30° INCLINED WEIR)

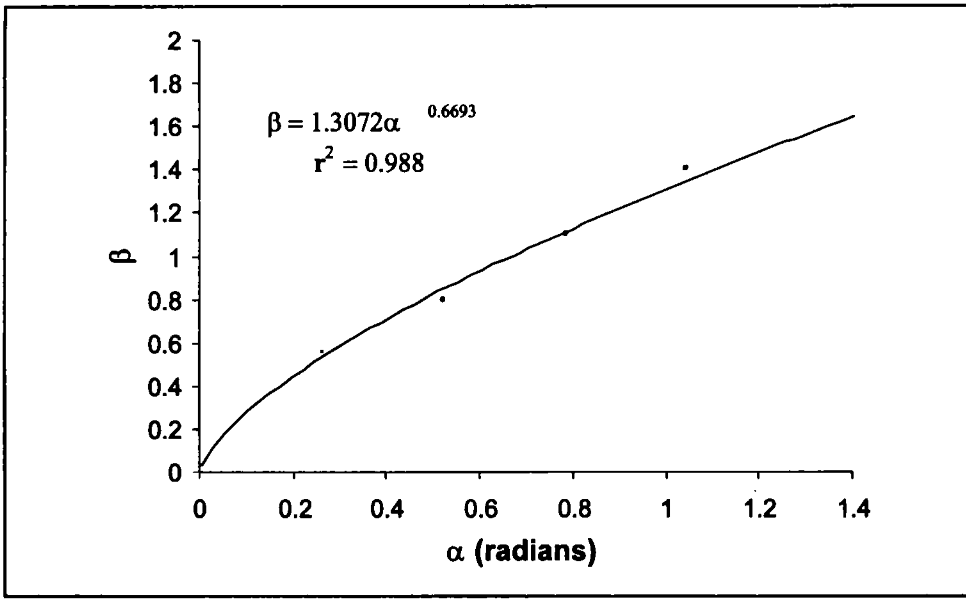


FIG. 7 α Vs β

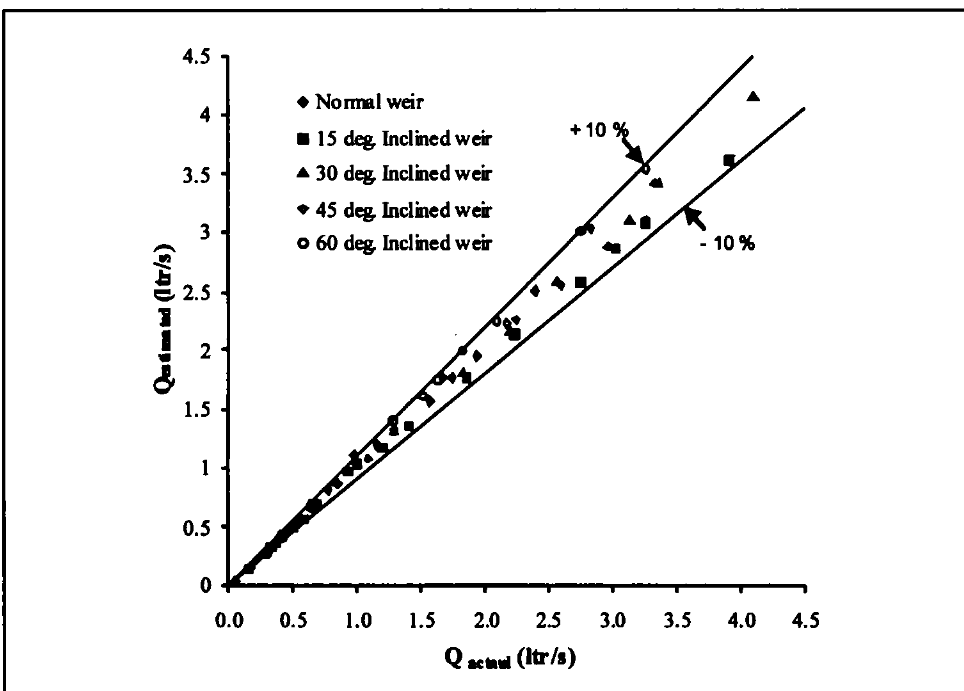


FIG. 8 $Q_{estimated}$ Vs Q_{actual}

TABLE-1

PERCENTAGE INCREASE IN DISCHARGE WITH RESPECT TO NORMAL WEIR

Inclination with the normal (vertical)	$\alpha = 15^0$	$\alpha = 30^0$	$\alpha = 45^0$	$\alpha = 60^0$
Percentage increase in discharge with respect to its corresponding value at normal position	14.29	48.96	111.24	233.60

CONCLUSIONS

Conclusions derived from the semi theoretical cum experimental approach are as follows:

1 A compound sharp crested weir composed of two triangular portions with different vertex angles helps us in measuring wide range of flows. The lower triangular notch-weir having smaller vertex angle measures discharge more accurately while the compound notch-weir helps in measuring the occasional large flows.

2 The equation derived through semi theoretical cum experimental procedure can estimate discharge within ± 10 error.

3 The discharge capacity of such an inclined notch-weir is much higher (233.60 % for 60^0 inclination) when compared to normal weir for the same head and is evident from Fig. 5 and Table 1.

4 The major hurdle in the measurement of discharge in compound notch-weir at the junction between the two weir sections is eliminated as the kink formed in the Fig. 5 disappears at 30^0 inclination of the notch-weir.

5 Since the flow area for compound notch-weir is larger for the same head relative to the conventional normal weir, the afflux on upstream of the weir gets reduced.

6 As the discharge capacity increases with the inclination, the free board requirement for the channel reduces thereby sections can be designed economically.

7 The property of increase in discharge of compound notch-weir can be best used to discharge fluid more quickly without increasing afflux on upstream side in the existing channels.

8 The compound notch-weir can help in drawing suspended silt and reduce silting on upstream of notch-weir position when compared to the normal notch-weir especially in unlined channels.

REFERENCES

Shesha Prakash, M. N. and Shivapur, A. V. (2002a). *Design and Experimentation on an Inclined Inverted V-notch.* Proceedings of the 2nd International Conference on "Fluid Mechanics and Fluid Power" IIT, Roorkee-67, 12-14 Dec, Vol. II, pp. 65-72.

Shesha Prakash, M. N. and Shivapur, A. V. (2002b). *Study on Inclined Rectangular Weirs - A New Approach.* Proceedings of the Conference on "Hydro – 2002", IIT, Mumbai-76, 6-17 Dec, pp. 70-74.

Shesha Prakash, M. N. and Shivapur, A. V. (2003). *Study on Flow Characteristic of Inclined Triangular Weir.* ISH Jl of Hydraulic Engineering. Vol. 9, No. 2, pp. 80-88.

Shesha Prakash, M. N. and Shivapur, A. V. (2004a). *Use of Inclined Rectangular Notch-Weir for Flow Measurement with Lesser Afflux.* Jl. of Hydrology, Vol. XVII, No. 1, pp. 43-53.

Shesha Prakash, M. N. and Shivapur, A. V. (2004b). *Discharge Characteristics for Flow Through Inclined Triangular Notch-Weir.* Jl of Hydrology, Vol. 27, No.1-2, pp. 43-53.

Shesha Prakash, M. N. and Shivapur, A. V. (2004c). *Generalized Head-Discharge Equation for Flow Over Sharp Crested Inclined Inverted Triangular Notch-Weir.* Jl. of Irrigation and Drainage, Vol. 130 (4), pp. 325-330.

Shivapur, A. V. and Shesha Prakash, M. N. (2006). *Study on Discharge Characteristics of Sharp Crest Inclined Trapezoidal Notch-Weir.* ISH Jl. of Hydraulic Engineering. Vol. 12, No. 2, pp. 118-129.

Martinez, J. et al., (2005). *Design and Calibration of a Compound Sharp-Crested Weir.* Jl. of Hydraulic Engineering, Vol. 131, No. 2.

United States Department of the Interior, Bureau of Reclamation (USBR) (1997). *Water Measurement Manual.* 3rd Ed., Denver.

Ismail Aydin, et al., (2002). *Measurement of Small Discharges in Open Channels by Slit Weir.* Jl. of Hydraulic Engineering, Vol. 128, No. 2.

Bos, M. G. (1976). *Discharge Measurement Structures.* Oxford and IBH Publishing Company, New Delhi, pp. 426-428.

Lakshana Rao, N. S. and Jagannadha Rao, M. V. (1973). *Characteristics of Hydrofoil Weirs.* Jl. of Hydraulic Div., Am. Soc. Civ. Eng., 99(2), pp. 259-283.