Scour Investigations Behind a Vertical Sluice Gate without Apron.

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ABSTRACT

The results of an experimental study on scour of a cohesionless bed downstream of an apron due to submerged jet issuing completely over, and completely below, a vertical gate are presented. The maximum depth and location of scour, volume of scour, volume of dune, and scour profiles are drawn under two situations at different discharges. Several graphical relationships have been found on the basis of experimental results.

The results show that the maximum depth increases with increase in discharge and volume of scour increases with increase in discharge per unit width of channel in each situation. However, the depth of scour hole, dune height, volume of scour, extent of scour, and dune are maximum, when flow is completely above the gate and minimum when completely below the gate.

(Keywords: submerged jets, hydraulics, scour, vertical gate, discharge)

INTRODUCTION

A vertical gate is one of the most commonly provided hydraulic structures for controlling discharge (Ranga Raju, 1993). Water surface is typically smooth for a freely issuing jet of water from the gate. For a submerged flow, the surface profile is quite rough. In the submerged flow, in addition to upstream depth and gate opening, the downstream depth is also taken into consideration as a third parameter for discharge calculation. Scour created downstream of the apron has been investigated by many researchers like Breusers (1965); Chatterjee and Ghosh (1980); Farhoudi and Smith (1982,1985); Hassan and Narayanan (1985); Chatterjeee et al. (1994); Balchander and Kells (1997,1998); Balchander et al. (2000); Kells et al. (2001); Dey and Westrich (2003); Sarkar & Dey (2005); Goel and Verma (2005); and Dey and Sarkar (2006).

Breusers (1965) investigated the time variation of scour due to flow over and under an estuary. Chatterjee and Ghosh (1980) proposed empirical relations to evaluate bed shear stress for the scour hole development. Farhoudi and Smith (1982) studied time scale of scour downstream of a spillway apron. Hassan and Narayanan (1985) studied flow characteristics of scour profile downstream of an apron. Chatterjeee et al. (1994) measured time variation of scour downstream of apron due to jet and developed empirical relationships. Balchander and Kells (1997, 1998) studied scour downstream of sluice gate and Balchander et al. (2000) studied experimentally the effect of tail water on scour downstream of a sluice gate. Dey and Westrich (2003); Sarkar and Dey (2005); Goel and Verma (2005); Goel (2006, 2007); and Dey and Sarkar (2006) have studied development of scour hole downstream of an apron for a submerged jet.

The literature review indicates that none of them have considered the flow simultaneously above and below the vertical gate. Uyumaz (1998) has studied scour under these three conditions without any apron downstream of the vertical gate without changing tail water depth. He suggested some equations to predict maximum depth scour for two different materials for simultaneously flow over and below the vertical gate as well. The present model study aims to investigate the scour characteristics without any apron under two flow situations like flow falling over an below a vertical gate under different tail water depth conditions.

DETAILS OF EXPERIMENTAL SETUP

Experiments were performed in the Fluid Mechanics Laboratory of National Institute of Technology, Kurukshetra, India. A flume of width 40cm, height 56 cm, and length 1220 cm with a recirculation arrangement of water was used for the experimentation. It was provided partially with glass panels on either side for visual observations. The water from a sump channel was allowed to flow in the flume by opening an inlet valve. A wire mesh, along with floating wooden planks, were used to dampen the waves on the water surface upstream of the gate. A 3 mm thick mild steel plate of width 40 cm and height 18.1 cm, chamfered at 45° on top and bottom was placed in the flume in thin slits made in the sidewalls for the movement of a model sluice gate.

A bolt was welded at the top of the gate, which was provided with a nut to facilitate the movement of the sluice gate. A wooden apron of length 83.1 cm, width 40 cm and thickness 2.5 cm was provided upstream of the sluice gate. An erodible bed consisting of fine local sand (median size of sediment, d_{50} = 0.37 mm, geometric standard deviation = 2.30, uniformity co-efficient of general sediment C_{ug} = 2.16, specific gravity = 2.65) was provided after the wooden apron. A trap basin was also constructed after the end of erodible bed to avoid further movement of eroded sand in the downstream channel. A pre calibrated sharp crested weir was used for discharge measurement. The water levels and distances were measured by a pointer gauge and a meter scale. The experimental set up with details is illustrated in Figure 1.

EXPERIMENTAL PROCEDURE

Initially the motor was started and inlet valve was opened slightly. Flow to the flume was gradually increased to the desired flow is achieved by measuring the actual discharge with a pre-calibrated weir provided on the downstream end of 60 cm wide flume. The tailgate was used to control the tail water depth during experimentation. As the erodible bed was disturbed due to flow, the erodible bed was leveled again by a plank and this flow continued for one hour. After one hour, motor was switched off and the tailgate was lowered completely so that the scour pattern developed is not changed.

The water in the flume was allowed to drain off gradually. The scour parameters, namely (d_1 = maximum depth of scour, x_1 = distance of point of maximum scour from the end of apron, x_2 = distance of the point where the scour profile meets the original bed level from the end of apron, d_2 = height of peak of dune above original bed level, x_3 = distance of peak of dune from the end of rigid pavement, and x_4 = distance of the point where the dune ends and the scour profile meets the original bed level) as shown in Figure 2, were measured by a graduated scale and a pointer gauge mounted on the flume. The whole procedure was repeated again for the next run. For each flow, seven runs were taken by varying the tail water depth.

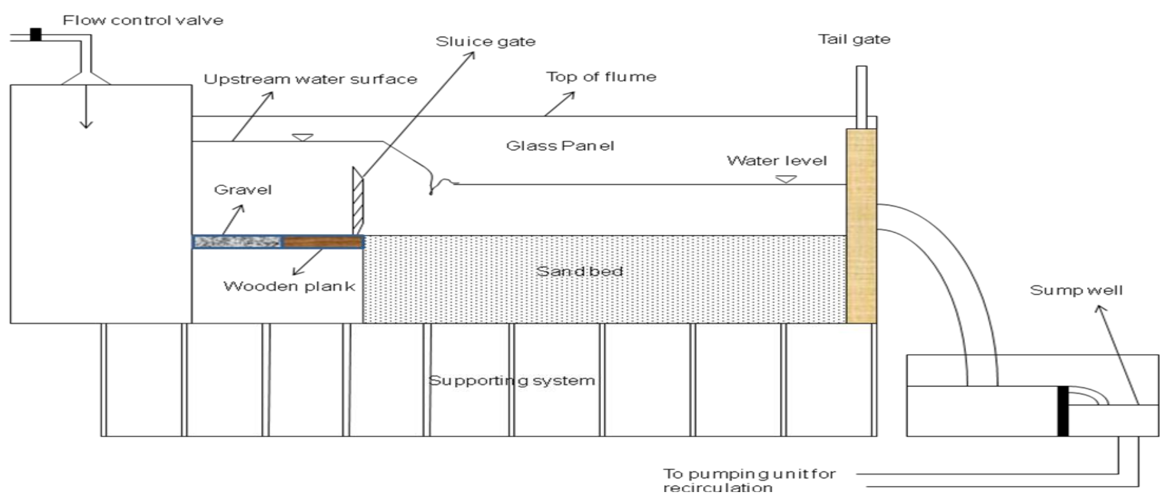

Figure 1: Experimental Set Up.

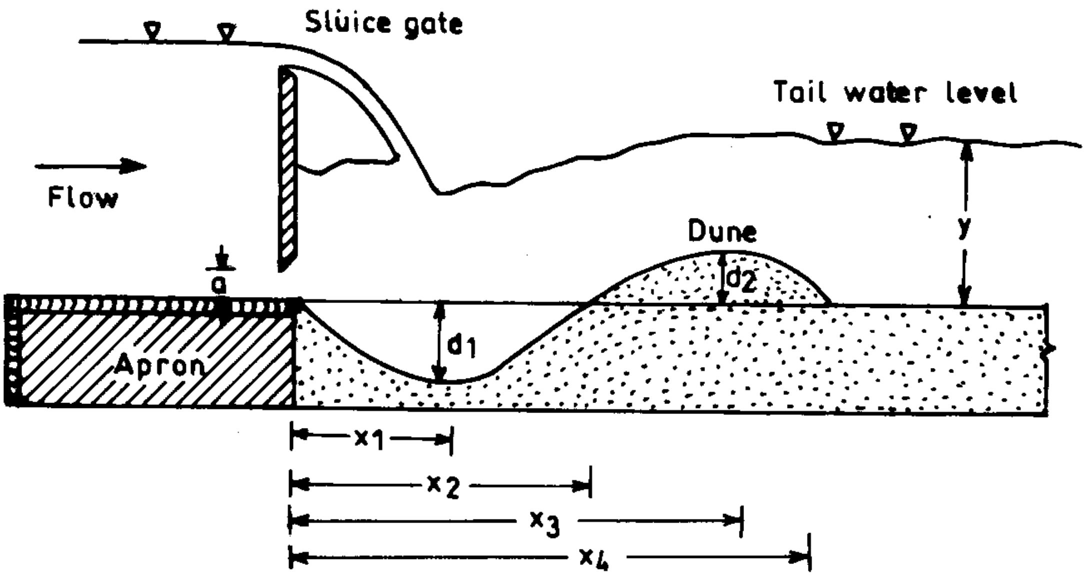

Figure 2: Typical Scour Profile with Scour Parameters.

SCHEME OF EXPERIMENTATION

Experimental data was collected for two flow conditions such as flow over and flow under the sluice gate. The discharge rate was kept in the range of 3 l/sec to 10 l/sec. The sluice gate openings were kept equal to 2 cm under the gate as constant at all discharges. The experimental details are given in Table 1.

ANALYSIS OF EXPERIMENTAL DATA

Graphical relationships for maximum depth of scour (d_1) and volume of scour (Vs), height of dune (d_2), volume of dune (V_d) are developed as shown in Figures 3 to 6. The volume of scour per unit width of channel (Vs) is calculated by assuming scour hole as a triangle and given by volume of scour $V_s = 0.5 x_2 d_1$.

Figures 3 and 4 have been plotted for maximum depth of scour (d_1) and discharge (Q) considering tail water depth for making the parameters non dimensional. The examination of both figures show that as for lower values of Q/y^3 the values of d_1/y are smaller and points of both the situations are overlapping. But the value of Q/y^3 increases the value of d_1/y also increases but there is scattering of the points due to effect of discharge and tail water depth on maximum depth of scour.

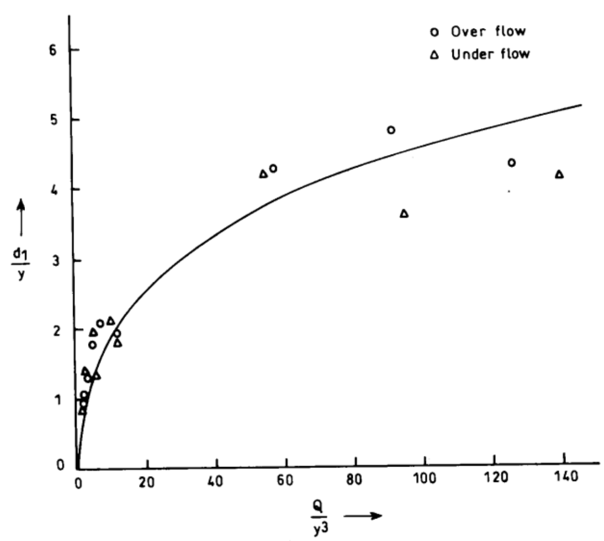

Figure 3: Variation of Magnitude of Maximum Depth of Scour with Discharge.

Table 1: Experimental Data Collected in the Present Study.

Run no	Discharge Q (l/s)	Opening a(cm)	x_1(cm)	x_2(cm)	x_3(cm)	x_4(cm)	d_1(cm)	d_2(cm)	y(cm)
(Completely Overflow)									
1	4.161	0.0	7.00	31.0	47.6	109.0	13.58	6.80	14.16
2	4.161	0.0	7.00	32.0	42.0	121.0	16.04	4.94	9.16
3	4.161	0.0	7.00	34.0	48.0	155.0	17.84	1.28	4.16
4	6.220	0.0	21.0	50.0	76.0	176.0	16.10	10.02	14.16
5	6.220	0.0	16.5	49.0	83.0	186.0	18.74	8.13	9.16
6	6.220	0.0	15.0	50.0	80.0	198.0	20.04	6.76	4.16
7	9.120	0.0	31.0	61.0	107.0	141.0	19.02	9.65	14.16
8	9.120	0.0	35.0	67.0	99.0	151.0	17.34	5.1	9.16
9	9.120	0.0	20.0	76.0	134.0	256.0	17.61	2.54	4.16
(Under Overflow)									
10	3.932	2.44	21.0	45.0	58.0	171.0	12.41	7.34	14.16
11	3.932	2.44	24.0	54.0	86.0	218.0	17.54	3.81	9.16
12	3.932	2.44	24.0	55.5	120.5	293.0	17.73	3.67	4.16
13	6.975	2.44	28.0	64.0	112.0	200.0	18.73	7.28	14.16
14	6.975	2.44	24.0	63.0	130.0	273.0	18.63	4.57	9.16
15	6.975	2.44	21.0	73.0	167.5	310.0	15.49	3.42	4.16
16	10.104	2.44	25.0	62.0	101.0	156.0	18.83	7.86	14.16
17	10.104	2.44	23.5	65.0	120.0	216.0	16.99	3.85	9.16
18	10.104	2.44	24.5	66.5	167.0	310.0	16.86	3.17	4.16

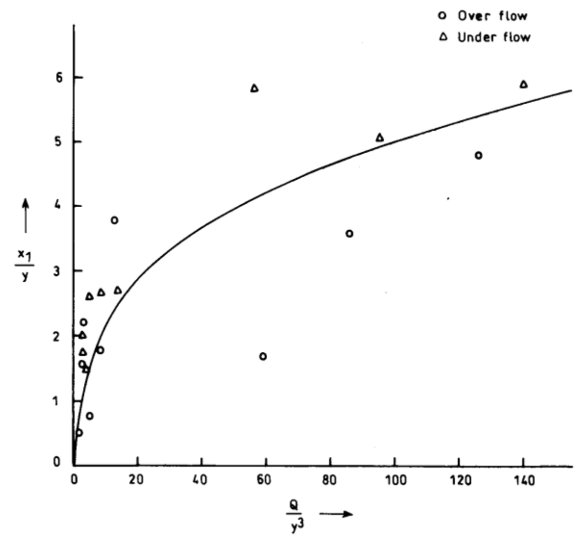

Figure 4: Variation of Magnitude of Maximum Depth of Scour with Discharge.

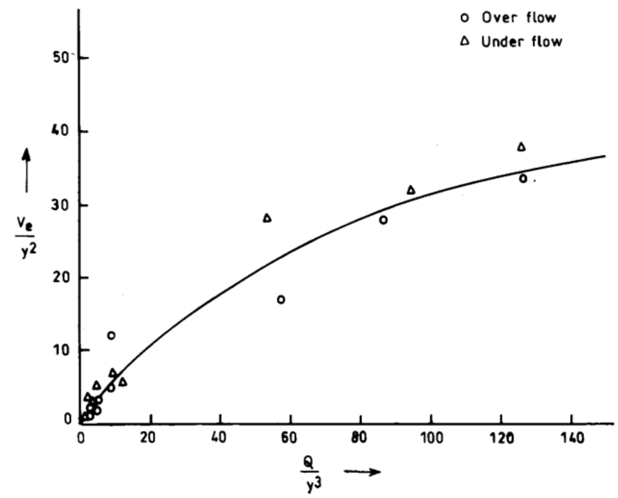

Figure 6: Variation of Volume of Scour with Discharge.

Figures 5 an 6 are plotted between Q/y^3 and Ve/y_2 an Vd/y_2. The perusal of both figures shows that as Q/y^3 B increases Ve/y2 an Vd/y2 are closely matching at the lower values of Q/y^3 abut after words it does not indicating that there is a larger effect of flow conditions on the volume of erosion an volume of deposition.

But the volume of deposition of material at higher discharges is less as compare to volume of erosion for same discharge.

Figure 7 has been plotted d_1/y and x_1/y for both flow conditions. As d_1/y increases the value of x_1/y also increases also. Most of the points are lying near 45^o line an there is deviation at higher values of d_1/y due to increase in discharge.

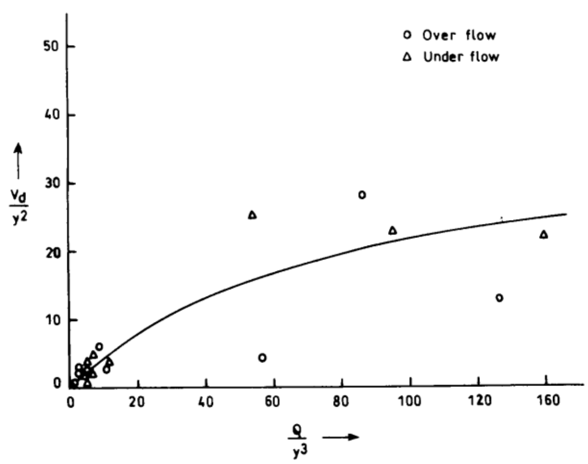

Figure 5: Variation of Volume of Deposition of Scoured Material with Discharge.

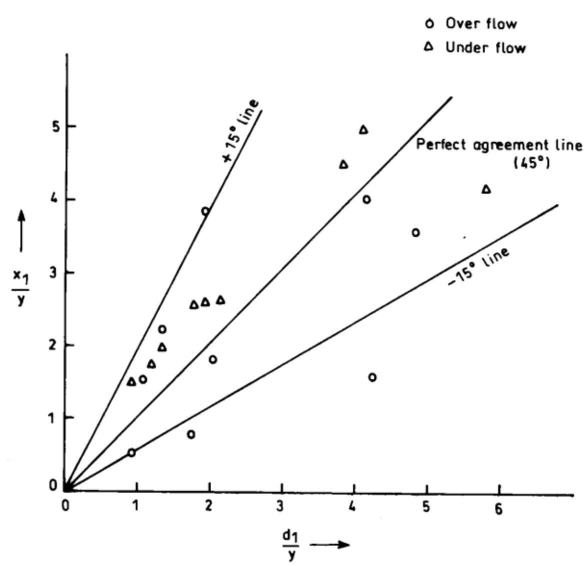

Figure 7: Variation of Location of Scour with Maximum Depth of Scour.

SUMMARY AND CONCLUSIONS

The scour behind the sluice gate depends on discharge and tail water depth. It also depends upon the flow condition whether flow is over the gate and under the gate and gate opening as well. It equals found experimentally that the on the basis of the analysis of experimental data, The maximum depth of scour, extent of scour and volume of scour, volume of scour deposition are sensitive to discharge, tail water depth an flow condition especially at higher discharge an lower tail water depths on the vertical gate.

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Arun Goel obtained a B.Tech. (Hons), M.Tech. (WRE, distinction), and Ph.D. (Hydraulics Eng.) degrees from REC (presently NIT) Kurukshetra in the years 1985, 1988, 1999, respectively. He joined REC Kurukshetra in year 1985 as a Research Fellow and has been working as Assistant Professor since year 2000. He has published more than 90 technical papers (international and national journals /conferences in the USA, UK, Canada, Australia, Europe & Asia), guided a number of B.Tech. projects, M. Tech. dissertations, and Ph.D. thesis. He has received the G.M. Nawathe award in the HYDRO-2000 for best paper presentation at NIT Kurukshetra. He has received second Best Paper award in the international conference (WHSC-2009) for best paper presentation at IIT Kanpur. He has presented research papers and chaired sessions in the international conferences at USA (2006), Spain (2007), USA (2008), Bangladesh (2009), USA (2009), and many in India. He has participated in 40 short term training programs, 30 conferences and workshops in India and abroad. He is a life fellow of IE, IWRS, ISH and member of ASCE (USA), EWRI (USA), ISTE, IYH, & IAHS. He is the recipient of Visiting International Fellowship award of EWRI of American Society of Civil Engineers, Kansas City, USA in 2009. He is national level executive committee members of IWRS (2007-2009, 2009-2011), Institution of Engineers (2006-2009, 2009-2011), Indian Society for Hydraulics, Pune (2007-2009). He is the reviewer of ASCE, ICE (UK), Elsevier, Kluwer, Interscience, Springer, IWRS, ISH etc. He has two patents to his credit. He has organized four Short term training programs, workshops and winter schools at NIT Kurukshetra. He has 24 years of experience in teaching, research, and administration. He has been selected as Professor in Delhi Engineering College, Delhi by UPSC, India

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