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EXPERIMENTAL INVESTIGATION OF LOCAL SCOUR AROUND SUBMERGED VANES

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ABSTRACT: Increasing capital costs, emerging environmental concerns and rising maintenance expenses of the conventional river training works around the world have led to the development of submerged vanes in practice. Submerged vanes are being favoured for control of sediment movement, scour and deposition. The submerged vanes functions through generation of secondary circulation for bringing about desired sediment redistribution within the channel cross-section. The strength of secondary circulation is profoundly influenced by the magnitude of the incident angle of vane to the approach flow direction. Most of the studies on submerged vanes are restricted to the incident angle in the range of 15^0-20^0. In recent years, researchers have been experimenting with higher incident angles in their search for an optimal angle of a submerged vane to extract optimal level of secondary circulation. The present study is to find the volume of local scour for different shapes of submerged vanes and varying the angle of attack for different shapes of submerged vanes. In this study, elaborate experimentations have been conducted to investigate the problem in depth with different submerged vanes configurations to determine the optimal angle of attack. The local scour around the different types of submerged vanes such as rectangular, trapezoidal and curved were studied. The maximum scour depth was observed to have taken place in the case of rectangular vanes. Therefore, scour influencing variables were identified for rectangular vane.

Keywords: submerged vanes, local scour, angle of attack

INTRODUCTION: Sediment control in alluvial channels, in particular the control of sediment movement, scour, and deposition, is one of the most difficult problems encountered by river engineers. Bed scour along the outer bank of river bends frequently causes undermining of the banks and loss of land. Deposition of sediment in the river bed often reduces flood-conveyance capacity of river and interferes with navigation. The diversion of flow from one channel to another or to a water intake or to reduce sediment entrainment at water intakes requires sediment management. Vertical wall bridge abutment of single span bridge is also affected by deep scour hole around it. The main difficulty in the treatment of these problems is the absence of cost-effective, low maintenance and environmentally acceptable sediment control structures with a wide range of applications. One of the principal obstacles to amelioration of the sediment control problem is the affordable cost and inadequacy of the currently available conventional sediment control structures. The submerged vanes have been developed to meet the above problems and these have been successfully employed in some countries**.** The submerged vanes are small and submerged foils aligned at an angle to the flow to modify the near-bed flow pattern and redistribute flow and sediment transport within the channel cross section.

Submerged vanes are frequently used as vortex generating devices that have several applications, such as protection against bank erosion (Odgaard and Kennedy, 1983; Odgaard and Wang, 1991 a,b); maintaining depth in navigation channel (Odgaard and Spoljaric, 1986); sediment control at water intakes (Wang et al., 1996); design aspects of submerged vanes (Zwol, 2004); investigation on the dimension and shape of submerged vane for sediment management in alluvial channel (Ouyang Huei-Tau, 2009); effect of the angle of submerged vane on scour hole (Alireza Masjedi, Behnam and Ali Savari, 2011). The vanes can be laid out to make the water and sediment move through a curve as if it were straight. As per Odgaard and Spoljaric (1986), significant changes in depth can be achieved without causing significant changes in cross-sectional area, energy slope, roughness and downstream sediment transport. As per literature, number, size and layout of the vanes depend on the channel morphology, velocity and depth at a meander bend. Vanes stabilize a channel reach without inducing changes upstream or downstream of that reach. Vanes may not be visible in time as they become buried by depositing sediment and aid the stream in doing the work by redistributing the flow energy to produce a more uniform cross-section without an appreciable increase in the energy loss through the reach.

The submerged vanes function by generating secondary circulation in the flow, which alters the magnitude, and direction of the bed shear stresses and causes a change in the distribution of velocity, depth and sediment transport area affected by vanes. They are constructed on a river or stream bed and set with an angle of attack to the direction of flow to create secondary current.

The strongest circulation will give the maximum effects of submerged vanes at optimal angle of attack and at a same time local scour holes might develop around the submerged vanes, which may dislodge the submerged vanes.

LABORATORY FLUME USED: The flume used is 20 meter long having concrete floor at bottom and side walls are brick wall with tile finishing. The depth of flume is 1.28 m and width of flume is 1m. The sand-bed of the flume is supported on concrete floor. The thickness of the sand bed is 40cm and the longitudinal slope provided to the sand bed is 0.0001. The flume is connected with one pump to generate the flow having capacity 15HP. At the downstream end, water is drained out and re-circulated from a reservoir. The discharge is regulated with the help of a gate valve placed after the pump.

SUBMERGED VANES USED: The vanes used for the experiment were made of steel plate, whose dimensions are as follows-

Table 1. Submerged vanes used in the experiment

Type of vane	Length (cm)	Thickness(cm)	Height(cm)
Rectangular vane	15.0	0.2	13.0
Trapezoidal vane	Top length-15cm Bottom length-30cm	0.2	13.0
Curved vane	15.0	0.2	13.0

Table 2. Different flow parameters during the experiment

Flow depth "d" (m)	Flow velocity "V" (m/sec)	Discharge "Q" (m^3/sec)	Froude No. "Fr"	Degree of submergence	Angle of attack "α"	Vane Type
0.10	0.20	0.020	0.20	0.50	15°, 20°, 25°, 30°, 35°, 40°.	Rectangular
0.10	0.20	0.020	0.20	0.50	15°, 20°, 25°, 30°, 35°, 40°.	Trapezoidal
0.10	0.20	0.020	0.20	0.50	15°, 20°, 25°, 30°, 35°, 40°.	Curved

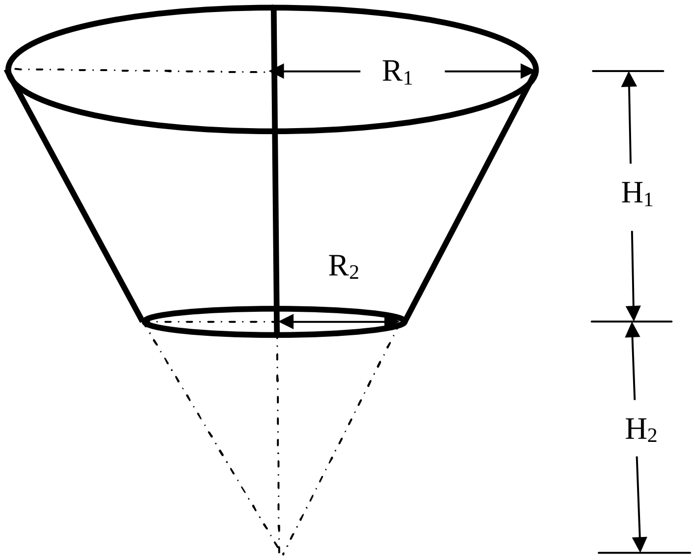

Figure 1. *Idealised typical local scour hole at the leading edge of submerged vane*

The local scour, which develops at the leading edge of submerged vane, can be idealized in conical shape. With R_1 as average radius of the top circular shape of cone; R_2 as radius of bottom circular shape of cone; H_1 as depth of idealised scour hole; and H_2 as depth of the bottom tip of idealized cone from the bottom of actual scour hole, the volume of scour hole can be expressed as,

$$\text{Volume of scour hole} = \frac{1}{3}\Pi\left\{R_1^{\,2}(H_1 + H_2) - R_2^{\,2}H_2\right\}$$

Table 3. Estimation of volume of scour hole

Fr. No.	R_1 (cm)	$R_2 = 0.4R_1$ (cm)	H_1 (cm)	$H_2 = \frac{H_1R_2}{R_1 - R_2}$ (cm)	Volume of scour hole = $\frac{1}{3}\pi\left\{R_1^{\,2}(H_1 + H_2) - R_2^{\,2}H_2\right\}$ (cm^3)	Angle of attack	Vane Type
0.20	4.5	1.80	2.8	1.87	92.69	15°	Rectangular
0.20	4.9	1.96	3.3	2.20	129.44	20°	Rectangular
0.20	5.7	2.28	3.8	2.53	201.60[33]	25°	Rectangular
0.20	6.8	2.72	5.2	3.47	392.94	30°	Rectangular
0.20	7.8	3.12	5.3	3.53	526.59	35°	Rectangular
0.20	8.9	3.56	5.6	3.73	724.41	40°	Rectangular
0.20	3.3	1.32	2.0	1.33	35.55	15°	Trapezoidal
0.20	3.3	1.32	2.2	1.47	39.17	20°	Trapezoidal
0.20	3.4	1.36	2.5	1.67	47.25	25°	Trapezoidal
0.20	3.6	1.44	2.6	1.73	55.01	30°	Trapezoidal
0.20	3.9	1.56	2.6	1.73	64.56	35°	Trapezoidal
0.20	4.2	1.68	2.8	1.87	80.74	40°	Trapezoidal
0.20	3.17	1.27	1.6	1.07	26.29	15°	Curved
0.20	3.43	1.37	2.1	1.40	40.37	20°	Curved
0.20	5.03	2.01	2.6	1.73	107.40	25°	Curved
0.20	5.53	2.21	2.9	1.93	144.81	30°	Curved
0.20	6.90	2.76	3.5	2.33	272.08	35°	Curved
0.20	7.20	2.88	4.0	2.67	338.90	40°	Curved

CONCLUSIONS: In this experimental study, to find the effect of local scour around the submerged vanes, three different shapes of submerged vanes i.e. rectangular, trapezoidal and curved vanes have been used with different angle of attack of installation.

Based on the study following conclusions are made:

1. Local scouring effect is more in rectangular vane than the trapezoidal and curved vanes..
2. By varying the angle of attack for different shape of submerged vanes, it has been found that smaller the angle of attack minimum local scour takes place and as the angle of attack increases more local scouring takes place around the vane.
3. Volume of scour hole is less in case of trapezoidal vane as compared to the rectangular vane and curved vane.

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