

Experimental Study of Aerated Vertical Jets on Scour Hole Development

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1-Introduction

Generally energy dissipation process in plunge pools take place by turbulence. The magnitude of the water jet energy entering the plunge pool from a large dam depends on its falling height, jet thickness and environmental conditions. Normally in a large dam, free falling water jet mixes with the air and vertically impacts water surface in the pool. Literature review showed that the volume of air entering the jets in experimental models is less than the corresponding value in prototype. Therefore, the effect of an aerated jet on scour hole geometry needs more study. The purpose of the present study is to introduce a relation for estimating dimensions of scour hole caused by pre-aerated vertical jets.

2- Research Methodology

A tank of 2 m length, 1 m width and 1m depth has been used to simulate the plunge pool. A 4 inch circular pipe supplied the water for a 25mm nozzle. The injected air was mixed with water before jet left the nozzle. An alluvial river with uniform sediment of $\sigma = 1.26$ and $D_{50} = 11.1$ mm has been used for modelling. Sediment density was considered to be 2650 kg/m^3 . Three downstream water depths of 0.325, 0.385, 0.435m were used in this study. Water discharge varied from 3.95 to 6.12 lit/sec and air discharge varied from 0 to 1.91 lit/sec so that the air concentration varied from 0 to 26 percent. The nozzle mouth was kept submerged about 1cm below the water surface to prevent the air entering it due to falling and impacting of the jet. Duration of each experiment was 5 hours. Figure 1 illustrates hydraulic and geometric parameters. Using the Buckingham pi theorem gives the governing equations of hole geometry in the form of equations 1 and 2.

$$d_s/h_{tw} = f(Fr_{tw}, C_a) \quad (1)$$

$$L_s/h_{tw} = f(Fr_{tw}, C_a) \quad (2)$$

in which Fr_{tw} is downstream Froude number and C_a is air concentration.

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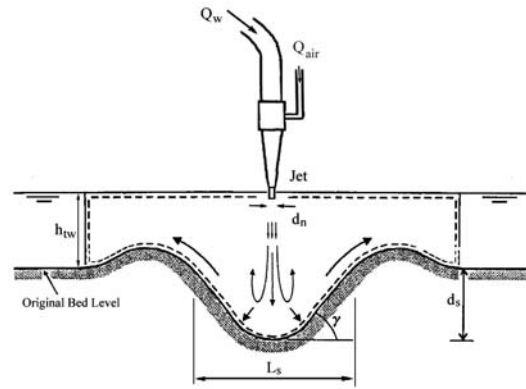


Fig.1 Hydraulic and geometric parameters

3- Discussion and Conclusion

Coefficients of equations 1 and 2 have been determined using experimental data and statistical methods. The resulting equations are as follows:

$$d_s/h_{tw} = 0.0719 (1 - C_a/100)^{4.51} Fr_{tw}^{0.8446} \quad (3)$$

$$L_s/h_{tw} = 0.2934 (1 - C_a/100)^{3.1112} Fr_{tw}^{0.4866} \quad (4)$$

Which are valid when Froude number varies from 4 to 9 and volumetric air concentration are from 0 to 26 percent.

To assess the accuracy of equations (3) and (4) using the functions of mean absolute error (MAE), root mean square error (RMSE), the remaining weight coefficient (CRM) and correlation coefficient (R^2) were calculated. The results are summarized in Table 1.

Table 1- Statistical analysis uses equations (3) and (4)

Parameter	d_s/h_{tw}	L_s/h_{tw}
MAE	0.0078	0.0111
RMSE	0.0211	0.0236
CRM	-0.0029	-0.0002
R^2	0.861	0.869

The results obtained by equations (3) and (4) as predicted values are depicted in the Figs. 2 and 3, compared to that of the observed values.

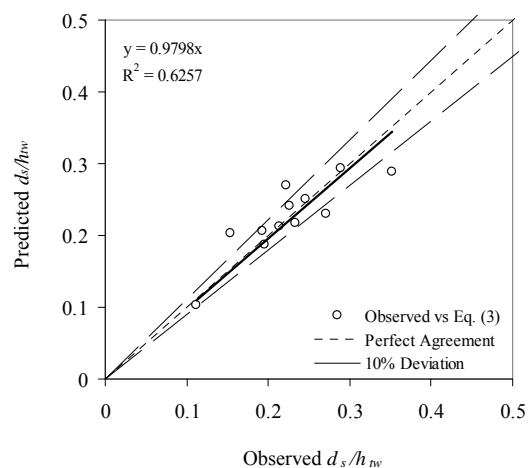


Fig. 2- Observed versus predicted relative scour depths d_s/h_{tw}

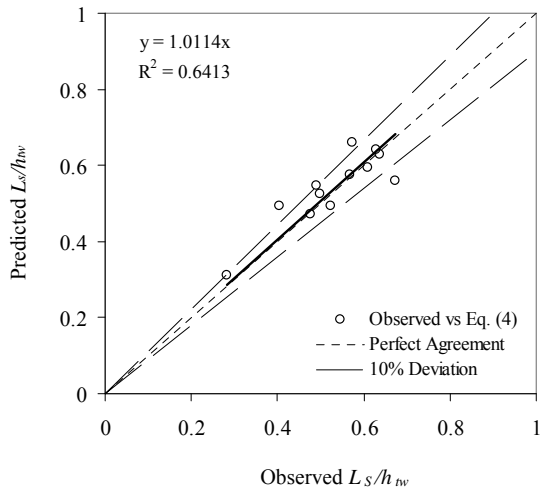


Fig. 3- Observed versus predicted relative scour length L_s/h_{nw}

The behavior of equations (3) and (4) is depicted in graphical form in Figures (2) and (3), respectively. Analysis of results show that the proposed equations can estimate (d_s/d_{so}) and (L_s/L_{so}) with mean error of -0.02% and +0.011%, respectively.

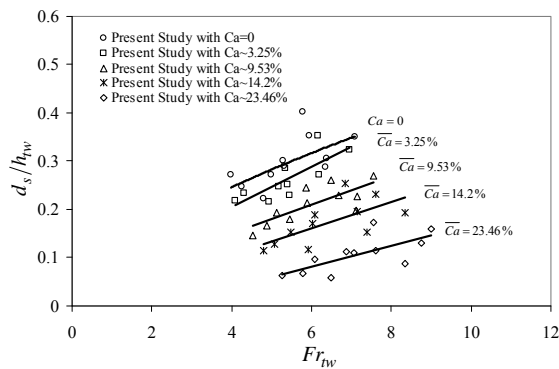


Fig2. Variation of maximum scouring depth against Froude number for different air concentrations

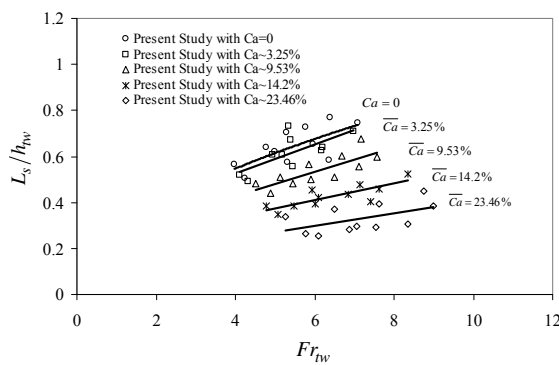


Fig3. Variation of relative scouring length against Froude number for different air concentrations