Annexure 5.2: CFD Analysis

CFD - Computational Fluid Dynamics

CFD analysis for vortex-free hydraulic design of intake and sump is developed over last two decades as acceptable alternative to sump model test which is very expensive and time-consuming. Originally CFD analysis was evolved for pump impeller, volute, suction and delivery nozzles, and other components through which flow passes. The basis for all CFD analysis is the Navier-Stokes equation and Reynolds number. The CFD analysis has partly replaced conventional methodology making sump models and testing.

The CFD analysis evolved for pumps is further applied for hydraulic design of intake and sump. The outcomes are highly dependable. Recently numbers of commercial software are available. Any modification or corrective measures required for prevention of vertices can be analysed and concluded.

However, the literature recommends that measures determined by CFD analysis shall be reconfirmed by conducting sump model test.

1.0 Sump Model Test

Basis for sump model test is Froude number which is non-dimensional parameter and kept same for prototype and model. The Froude number F_D is given by,

$$F_D = \frac{V}{\sqrt{gL}}$$

Where V = Flow velocity

g = acceleration due to gravity

L = any dimension of prototype/model

If R = Linear scale ratio of model to prototype

L_m = Any linear dimension of model

L_p = Corresponding linear dimension of prototype

Q_m = Discharge in model

Q_p = Discharge in prototype

Then $\mathrm{R} = \frac{\mathrm{Lm}}{\mathrm{Lp}}$

$$\mathrm{Vm} = \mathrm{Vp} \times \sqrt{\mathrm{R}}$$

$$\mathrm{Qm} = \mathrm{Qp} \times \mathrm{R}^{2.5}$$

Thus, if Vp = 1.2 m/s, Qp = 2.4 m^3/s and ratio R = $\frac{1}{4}$

Then, $V_m = 1.2 \times \sqrt{\frac{1}{4}}$ = 0.6 m/s

$Q_m = 2.4 \times (1/4)^{2.5}$ = 0.075 m^3/s

Essential requirements for sump model test

(i) In model, all physical dimensions such as width of pump bay, approach channel, slope, bottom clearance, back clearance, centre to centre distance between bell mouths/suction inlets should be in the scale ratio.

(ii) Submergence is linear dimension. Hence, submergence measured from lip of bell mouths/inlet to minimum water level shall be in ratio R. In the example, if submergence for prototype is 1.9 m, the submergence for model shall be $1.9 \times \frac{1}{4}$ = 0.475 m.

The test should be conducted at minimum required submergence for model.

(iii) The external surfaces of the bowl assembly including bell mouth, and internal geometry from bell mouth to eye of impeller must be modelled to scale R.

(iv) Model test should be conducted at two velocity values, i.e., velocity as per Froude number and also at least 1.5 to 2 times the Froude velocity.

(v) Any surface swirl, surface dimple, dye core air bubble, or air core should be observed at free surface and subsurface (below water level)