II-202 Sediment Generation Rate of Turbulent Line Vortex

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INTRODUCTION: Many works have been carried out in the past on the subject of sediment suspension. A complete theoretical approach to the particle pick-up rate is not yet feasible as the phenomenon is complex. However sediment pick-up in the uni-directional flow has been studied by many. References also can be found on the correlation of the entrainment of sediment with the intensity of the vertical velocity of the turbulent eddies(1). Sediment suspension is associated with the vortices formed behind the ripples. Towards this end, the present study is a report on the experiment and analysis carried out to estimate the sediment pick-up due to a turbulent line vortex.

EXPERIMENTAL SET-UP: The apparatus as shown in Fig.1 consists of a horizontal rod which can be rotated above the sand bed. The total sediment suspension at any time is measured by taking the sample at various points and integrating over the flow field. Three types of profile for the sand bed and two rotating speed for the rod were considered. For all these six cases, the uniform sand of dia. 0.2mm was used. The velocity field is found out by flow visualization method by introducing polysterene particles in the flow.

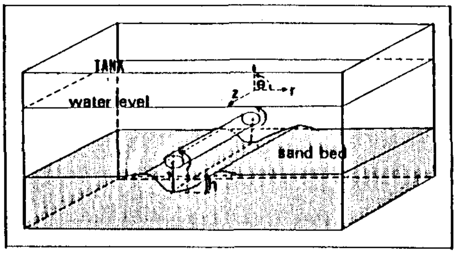

Fig.1 Experimental Set-up

ANALYSIS FOR SUSPENSION: Suspension at any time can be taken as

Sediment in suspension = Sediment Generated − Sediment dispersed out − Sediment settled

The general equation in two dimensional case can be written as

$$D\frac{\partial^2 c}{\partial r^2} + \frac{D}{r}\frac{\partial c}{\partial r} + W\sin\theta\frac{\partial c}{\partial r} + \frac{D'}{r^2}\frac{\partial^2 c}{\partial\theta^2} + \frac{v}{r}\frac{\partial c}{\partial\theta} + \frac{W\cos\theta}{r}\frac{\partial c}{\partial\theta} = \frac{\partial c}{\partial t} \quad (1)$$

where D and D' are eddy diffusivities, u and v are average velocities in r and θ directions, respectively, and W is falling velocity. The approximate solution of above equation is obtained by perturbation method with the assumption that

$$u = 0 \quad ; \quad \partial v/\partial\theta = 0 \quad ; \quad D' \ll D \quad (2)$$

The solution in integrated form can be written as

$$C(t) = A\ e^{-Bt}\left[1 - \frac{BR^2}{12D} - \frac{BWR^3}{36\pi D^2}\right] \quad (3)$$

where, C is total suspension at any time t, and R is representative bed distance from the center of the rod.

EXPERIMENTAL RESULTS AND ANALYSIS: The velocity field measured could be explained by the expression for the turbulent line vortex(2) as shown in Fig.2. The constants are obtained by curve fitting by least square method. The same method was used to obtain the parameters A and B. The typical case for one initial bed condition is shown in Fig.3. The generation G can then be obtained from

$$G = A\ e^{-Bt} \quad (4)$$

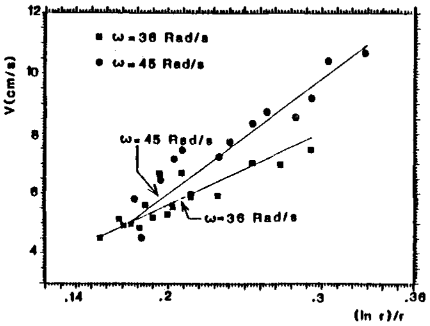

Fig.2 Typical Velocity Profile (experimental and fitted)

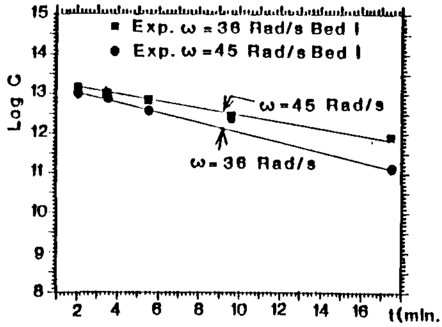

Fig.3 Typical Total Concentration (experimental and fitted)

The dispersion coefficient in radial direction, D is not known. Hence another sub-experiment was carried out by feeding of sand in the flow field due to the vertical rotating rod. By measuring the concentration distribution at various radius r in one horizontal plane,(3) and considering D = a.C, the value of 'a' is approximated to a constant $4*10^{-6}$ for ω = 45 rad/sec and $3.5*10^{-6}$ for ω = 36 rad/sec.

As in earlier studies carried out for uni-directional flow , we consider same type of non-dimensional pick-up rate defined(4) by

$$\phi = E/[\rho_s(\Delta gd)^{.5}] \tag{5}$$

with

$$E = G/(At') \qquad \Delta = (\rho_s-\rho)/\rho \tag{6}$$

where A is bed area from which sand is suspended; ρ_s is sediment density; ρ is fluid density; and t' is time at which G gms. of sand is suspended.

Here we relate pick-up rate to the velocity due to vortex at the bed. For this purpose we choose a non-dimensional transport parameter T,

$$T = \frac{n[U^2 - 9.59\{h(3-h/R)/R\}^{1/2}] - U_{*cr}^2}{U_{*cr}^2} \tag{7}$$

where U_{*cr} is the critical bed-shear velocity, U is v at R. U_{*cr} as first approximation, is obtained from the Shield's curve. Knowing the final equilibrium bed position, U_{eq} can be found which is used to obtain the constant n, since at equilibrium T reduces to zero. The results obtained for the six cases performed along with the curve fitted is shown in Fig.4.

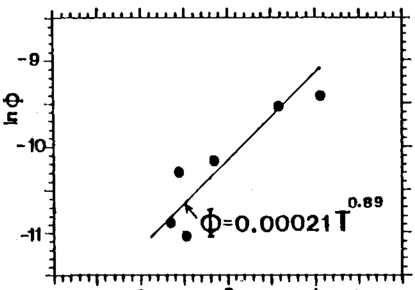

Fig.4 Sediment Pick-up

CONCLUSION: An experimental analysis was carried out for the suspension due to a vortex. The type of pick-up function used in the case of uni-directional flow can be said to be applicable in the case of line vortex.

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