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FLEXIBLE EMERGENT VEGETATION IN STAGGERED CONFIGURATION AS BIOSHIELDS

L. Noarayanan[1], K. Murali[2], V. Sundar[3]

Vegetation or bio-shields is increasingly being considered as an effective protection measure for coasts and river banks against extreme coastal hazards like tsunamis and storm surges, and erosion. The great Indian Ocean Tsunami has demonstrated that plantations along a coastal belt can play a significant role in limiting the disaster levels by minimizing the run-up as well as the inundation distance on coastal structures and beaches respectively (Sundar et al., 2007). In order to study the behavior of vegetation in steady flow conditions and to have a preliminary idea as to how the vegetal parameters influence the flow behavior, experiments in an open channel have been carried out. Over the past, the flow resistance through the model vegetation in terms of Darcy *f* has been quantified through measurements in open channel experiments by several authors (Fathi-Moghadam, 2007; Jarvela, 2002). In general, it may be noted that the interaction between vegetation and flow has not been modeled appropriately and the elastic characteristics of vegetation has not been given due importance. The present work aims to investigate the Darcy's *f* for various flow as well as vegetative parameters including the elasticity of vegetation. The flexibility, being more of a material property, is directly related to rigidity (*EI*) of the vegetal material. The root diameter of the vegetal models were arrived at to reproduce the rigidity of typical forest plants in model. This is the advantage of modeling rigidity rather than Young's modulus.

The Darcy's *f* has the following functional relationship with other variables.

$$Darcy, f = f\left(BG, \rho, g, h, h_{avg}, l, SP, D_t\right) \tag{1}$$

where, BG = length of the green belt; ρ = mass density of water; g is gravitational constant; h is depth of flow; h_{avg} is average value of water depths on upstream and downstream of green belt; R_s is relative spacing of green belt; f_1 is Natural frequency of vegetal stems; V is velocity of flow; V_{avg} is average velocity of flow; l is height of the vegetation; SP is centre to centre distance between plants within the green belt and D is diameter of vegetal stem. Following are the dimensionless parameters arrived at:

$$F_r = \left(\frac{V_{avg}}{\sqrt{gh}}\right), V_r = \left(\frac{V_{avg}}{f_1 D}\right), VFP = \left(\frac{EI * \left(BG/D\right)}{\rho h_u l^3 V_{avg}^2 \left(SP/D\right)}\right), \mathrm{Re} = \left(\frac{h_{avg} * V_{avg}}{\upsilon}\right) and\ R_s = \left(\frac{SP}{D}\right) \tag{2}$$

where, F_r is the Froude number; V_r is the reduced velocity of vortex induced vibration of vegetal stems; *VFP* is a new Vegetation Flow Parameter; *Re* is the Reynolds number ; υ is the kinematic viscosity and other variables as defined earlier.

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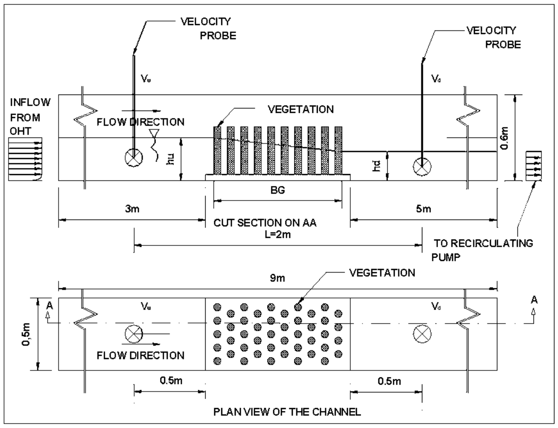

Fig. 1 Schematic diagram of test set-up in flume

The experiments were conducted in a flume of 10m long, 0.5m wide and 0.6m deep. Closely spaced slender cylindrical members representing vegetation (with *E*=3.8E+09 N/m2) were positioned at a distance of 6 m from one end of the flume in staggered configuration. The water depths and velocities were observed on the upstream and downstream of model vegetal patches of 250 mm, 625 mm and 1000 mm long. Three different flow depths (210 mm, 180 mm and 80 mm) for vegetal models placed in two spacing and two diameters in staggered configuration. The details of the flume and the experimental set-up are shown in Fig. 1.

Using the measurements, the effects of the vegetal stems in the flow have been quantified through the Darcy's friction factor *f*.

The resistance offered by the vegetation decreases with an increase in both *Re* (146179 to13693) and *Fr* (0.23 to 0.60). The Darcy friction factor *f* varies between 0.124 and 5.7 for the aforementioned range of *Re* and *Fr*. The energy loss varies between 0.029% and 0.92%. The reduced velocity, *Vr*, plays a significant role in enhancing vegetal resistance / drag for the range of 3.7 < *Vr* < 4.3 along with enhanced by proximity effect that occurs around the relative spacing of *SP/D* ~ 3.75 (Fig.2). A distinct relative rigidity parameter, *VFP* is proposed that includes the parameters of structural rigidity of vegetal stems, green belt parameters and flow parameters. The friction factor exhibits an excellent correlation with its variation with the proposed Relative Rigidity, Fig.2 (Noarayanan *et al*., 2010).

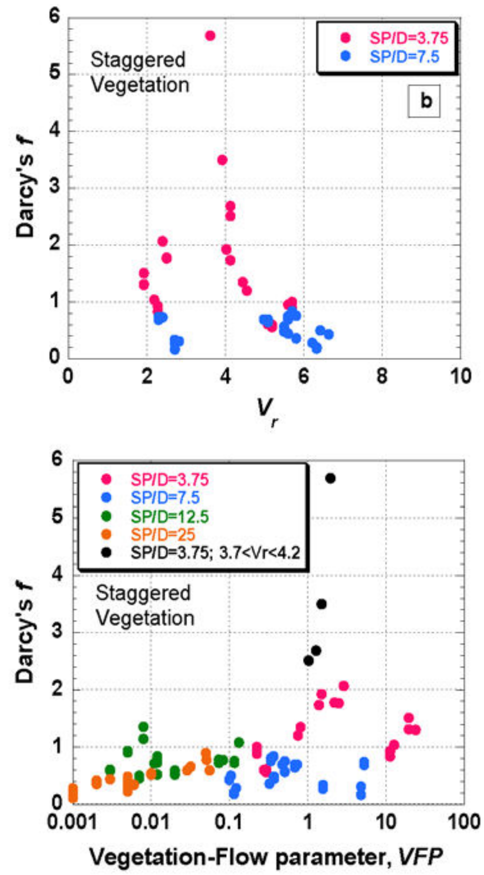

Fig. 2 Variation of Darcy's *f* with V_r and Vegetation flow parameter.

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