EFFECTS OF A VEGETATION ZONE ON FLOW AND SCOUR DEPTH AROUND A DOWMSTREAM BRIDGE PIER

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Downstream flow variation due to an isolated vegetation zone and its effect on scour around a bridge pier in an open channel were examined experimentally. Experiments were performed in a tilting flume of 12m long, 0.45m wide and 0.6m high with 2m long recess, which was filled with river sand of median particle size d_{50}=0.59mm and geometric standard deviation σ_g=1.72>1.25. Velocities were measured by 2-D electronic current meters and scour depths by point gages. The experiments were conducted under a flow condition of flow depth 15cm, discharge 0.01m^3/s and velocity 15cm/s. As model vegetation slender twigs of reed were used since they are flexible and the thickness of their stems becomes thinner along the stems to the end and are considered to reproduce the natural vegetation very closely. Typical average diameter of the model vegetation is 0.15mm and its cross sectional area is 0.00017cm^2.

The vegetation zone acts as bluff body and thereby the flow in the downstream region becomes a complex recirculating flow incorporated with wake behind the vegetations. Flow velocity in the vegetation layer, which is the flow region up to the vegetation height, is decreased significantly as low as 10% of the average velocity, meanwhile flow velocity in the surface layer, which is the flow region above the vegetation crown, is increased compared with velocity without the vegetation zone. The velocity profiles are S-shaped and the vegetation height is found the most influential factor for velocity profile.

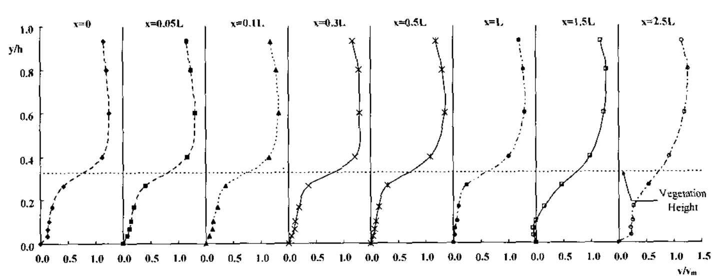

Fig. 1 Velocity Profiles in Downstream Region from Vegetation Zone (h_v=4.9cm and ρ_v=0.00283)

The wake and recirculating flow in the downstream region due to the presence of the upstream vegetation zone weaken the downflow along the upstream face of the pier, which in turn reduces the horseshoe vorticies at the bed around the pier significantly in size and strength. Another reason for substantial decrease in the downflow is that in the immediate downstream region velocity in the vegetation layer is reduced as low as one tenth of the surface velocity and this weakens the downflow tremendously. These overall effects contribute to reducing scour depth around the pier.

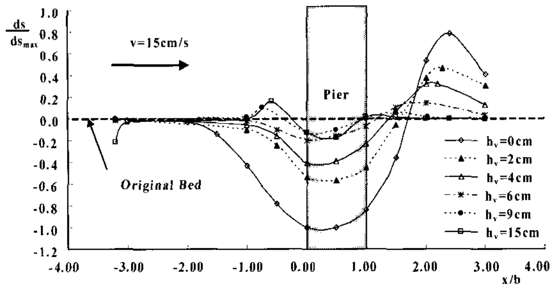

Fig. 2 Local Scour Depth with Different Vegetation Height(W=2b, L=2b, and ρ_v=0.00283)

The scour depth around the bridge pier is affected significantly by both geometric characteristics of vegetation and vegetation zone. When the pier is located at the immediate downstream from the vegetation zone the scour depth is reduced to 10% of the maximum scour depth d_{smax} without a vegetation zone. The reduction of scour depth is maximum when the length of the vegetation zone is equal to the size of the pier and it is largest when the width of the vegetation zone is twice the size of the pier. The maximum scour reduction occurred at $h_v/h=0.4$ and no further reduction is observed at higher value of h_v/h. At the density of vegetation ρ_v <0.00566 the scour depth can be reduced to $0.1d_{smax}$ without causing erosion around the vegetation zone.

Momentum exchange between the surface layer and the vegetation layer is the measure of an infiltration depth into the vegetation layer, which is defined as a distance at which the maximum turbulence stress is reduced to one tenth of it(Nepf 1999), depends on the density of vegetation.

At low density of vegetation the infiltration depth increases and then the momentum exchange is activated. As the density of vegetation increases, the infiltration depth decreases. Consequently the velocity in the immediate downstream region becomes very small and the flow capacity for entraining and transporting of bed material is weakened noticeably and the corresponding reduction in scour depth around pier is followed. These overall phenomena can be summarized by a statement that the presence of a vegetation zone is a very effective means for reducing scour at a bridge pier and there exist an optimum dimensions to both vegetation and the vegetation zone.

Nepf, H. M.(1999) Drag, turbulence and diffusion in flow through emerged vegetation, Water Res., Res., 35(2), 479-489