Entrance Zone Effect on the Sediment Trapping Efficiency in Desilting Tanks of Run-of-River Type Mini-Hydropower Plants

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Introduction

Development of run-of-river type mini-hydropower plants is receiving increased attention in Sri Lanka at present owing to the incentives announced for developers of renewable power generation projects during the last decade by the Sri Lankan government. The sources for most of the run-of- river type mini hydropower plants are mountainous streams where the discharges experience significant seasonal variation with frequent flash floods. The catchments of these streams are generally steep and face an increasing trend of soil erosion due to cultivation and other human activities. Therefore, the stream flows carry high sediment loads during seasonal floods. This sediment-laden flow enters the headrace canals feeding water to the turbines of the min-hydropower plants. Sediment in the water passing through the turbines with high velocity erode the contact surfaces of turbine components. The erosion of turbine components leads to a drop in hydraulic efficiency and to a high maintenance cost of the turbines.

Removal of sand carried with the flow in the headrace canals of run-of-river mini hydropower plants is therefore an important issue for the developers to reduce the maintenance cost of the turbines (Singal and Ranendra, 2006). Introduction of a de-silting tank in series with the headrace canal is one of the commonly used techniques for this purpose. De-silting tanks are designed as settling basins to settle sediment greater than a targeted size (Janssen, 2004).The shape and the size of the de-silting tank are major factors affecting the sand trapping efficiency of the de-silting tank. Several empirical and semi-empirical relations for the efficiency of sediment removal of de-silting tanks have been obtained (Ranga Raju *et al.*, 1999). Ranga Raju and Kothyari (2004) provide an empirical relation for efficiency based on analysis of all the available data where efficiency is related to the cross sectional areas of the de-silting tank and the approach channel and the shear velocity in the de-silting tank. However, the effect of the shape of the de-silting tank on the efficiency of sediment removal has not been given attention. This paper presents the results of a series of laboratory experiments carried out using scale model of a de-silting tank to investigate the effect of the flare angle of the entrance zone on the sand trapping efficiency of de-silting tanks.

Methodology

Parameters of the mini-hydropower plant were selected to represent the plants installed in the country: discharge = 3 m^3/s, headrace canal width =1.5 m, slope = 1:1000, flow velocity = 1.5 m/s and Manning's coefficient = 0.012, target size of settling particles = 0.3 mm, de-silting tank size 15m×6m×2m. The laboratory model test was carried out based on Froude similarity using a 1: 6 scale model and sand in 90 - 125 μm range was used as scaled sediment size (65 μm), which falls into the silt region. The particle Reynolds number was in the laminar region. The model was built of plywood in the outdoor modeling yard of the Hydraulics Laboratory, University of Peradeniya and the de-silting tank comprised a tapered entrance zone followed by a rectangular tank as shown in Figure 1. Tests were conducted by changing the expansion angle of the entrance zone to 7, 10, 20, 30 and 90 degrees while keeping the length of the tank constant. Tests were repeated for three discharge rates, 15, 20 and 25 *l*/s, corresponding to different admission ratios of the prototype. Sand was fed to the upstream of the canal to maintain dynamic equilibrium in the canal bed. Sand trapping efficiency was calculated by measuring the sand trapped inside the tank and sand supplied to the tank.

Results

Figure 2 presents the variation of sediment removal efficiencies with the expanding angle for three discharges of the canal. The figure shows that the sediment trapping efficiency of the de-silting tank depends strongly on the expanding angle at the entrance. As the angle decreases in the range of 7 to 90 degrees, the trapping efficiency increases from 60% to 80%.

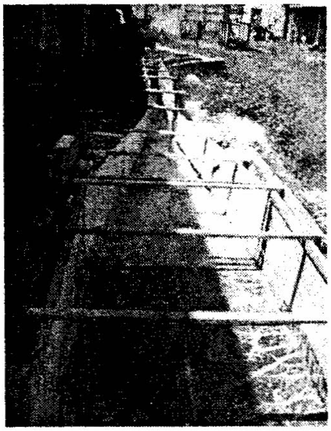

Figure 1. Part of testing set up

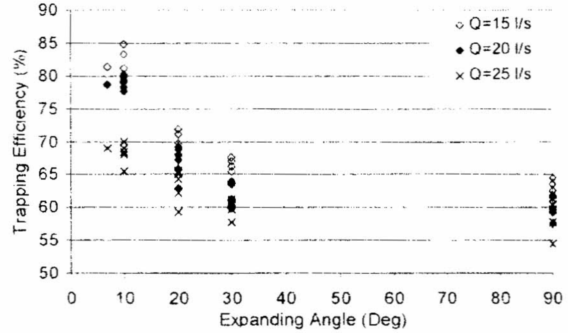

Figure 2. Variation of sediment trapping efficiency with flaring angle

However, as the flow entrance angle is decreased, the construction cost of the de-silting tank increases and therefore the optimum entrance angle can be decided only after a cost analysis. When the discharge through the tank is below the design value the sediment removal efficiency increases.tank increases and therefore the optimum entrance angle has to be decided only after a cost analysis. When the discharges through the tank is below the design discharge, the sediment removal efficiency increases.

Conclusions

The entrance zone of the de-silting tanks has a considerable impact on the trapping efficiency of the sediment in the de-silting tanks. The trapping efficiency of the tank increases with the reduction of the expansion angle of the entrance zone in the de-silting tanks. The optimum expansion angle is found to be about 10 degrees. Nevertheless, further investigations covering different sediment sizes are recommended.

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