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Design of hydraulic jump type stilling basin at Warana canal

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ABSTRACT

Hydraulic jump type energy dissipaters are widely accepted methods of energy dissipation while designing the hydraulic structures like dams, weirs and barrages. They are popular for their simplicity and efficiency, but have certain limitations when there is variation in discharge conditions. The energy dissipaters satisfactorily function at design discharge condition. But in case of varying discharge conditions they are not efficient as the location of hydraulic jump tends to shift on apron. This would result in percentage reduction in energy dissipation and in turn damage hydraulic structures and adversely affect tail channel conditions. Therefore it is necessary to address the issue of controlling the location of hydraulic jump and evolve a new technique for the same. This paper discusses the design of hydraulic jump type stilling basin for the overflow weir of canal escape at Warana dam (India). It also throws light on the aspect of jump location and percentage energy dissipation. A physical model study is carried out by applying Froude's model law.

Introduction

Dams, Weirs and Barrages are necessary to fulfil the needs of drinking water, irrigation and Industrial requirements of water. They help in developing economy of a Nation. It is therefore necessary to look after the safety of these hydraulic structures, of the causes those create problem of safety of a structure. Major problem is associated with the energy dissipating arrangements of the hydraulic of structure

When excess water is released over spillway or weir, by the time it reaches the foot of spillway, whole of its potential energy gets converted into kinetic energy and it takes the form of high velocity jet. It has high scouring potential and hence this kinetic energy needs to be dissipated to avoid further damages. Many dams around the world have been reported to have been encountered with the problem of energy dissipating arrangements. The energy dissipaters are mainly designed to cater the design discharge of a hydraulic structure. However, these structures are also required to pass the lower discharges than the design discharge and majority of failures have been reported to be occurred for the discharges less than the design discharge.

Literature survey

For energy dissipation in stilling basins, maximum energy dissipation occurs when a clear hydraulic jump forms inside basin (Chow 1959; Wu and Rajaratnam 1995). A clear jump indicates non submerged and non-swept jump inside stilling basin with its front located near toe of spillway. The length of apron depends upon the length and location of jump (for design discharge condition) which in turn depends upon the pre jump depth (y_1) and the relative magnitudes of required post jump depth (y_2) and available tail water depth (y_t) (Rajaratnam and Subramanya 1966; Peterka 1984). In rectangular stilling basin with horizontal slope, front of jump occurs at a location where sequent depths satisfy Belanger momentum equation (Rajaratnam and Murahari 1971; Hager and Bremen 1989). Similar studies based on power generation were carried in 2013. (N. P. Sonaje et. al., 2013)

From Practical point of view jump will no longer operative properly when the tail water depth approaches 0.98(y_2)for a Froude number of 2,or 0.94 (y_2)for a Froude number of 6or 0.96 (y_2) for a number of 10or 0.975 (y_2) for a number of 16 (Peterka 1984).

In case of tail water deficiency condition, tail water rating curve (TWRC) lies below jump height curve (JHC) for all discharges and hydraulic jump may partially or fully sweep out of the basin. This may prove to be dangerous from safety point of view of stilling basin, tail channel and other hydraulic structures (Tung and Mays 1982; Moharami et al. 2000). To address this problem, Hinge et al (2012) have given the end weir geometry that assures formation of clear jumps within stilling basin for design as well as lower discharges.

Warana Dam Canal Escape: A Case Study:

The Warana project is a major irrigation project in the Warna valley of Krishna basin in Maharashtra. The Warana dam is located near village Chandoli in Shirala taluka of Sangli district. It is a earthen dam with a masonry spillway on right bank and power outlet and irrigation outlet on left bank. Power tail channel meets the irrigation canal just downstream side of dam and is thereafter called as Warana canal. The canal has escape structure and escape channel in first km of main canal and water is released through this escape channel to the river and other power house (2 X 2 MW). The level difference between Warana canal bed level and river bed is about 25 meters. To negotiate this level difference escape channel has been provided with number of fall structures. The variation of discharge in escape channel is in the range of 10m^3/sec to 50m^3/sec.

The present study is under taken to design the hydraulic jump type basin for a fall adjacent to escape structure as this overflow has damaged the tail channel as shown in Fig. 1. The Y-junction of canal escape is shown by Fig. 2. The left side

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branch goes to existing powerhouse and the right side branch goes to overflow weir.

Fig 1. View of damaged tail channel of overflow structure

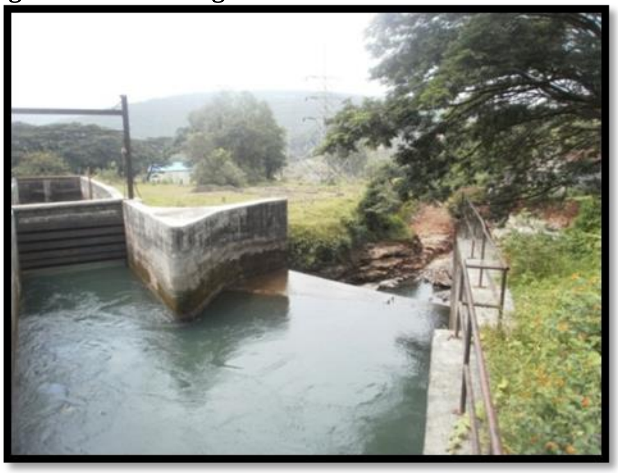

Fig 2. View of Y-junction

Methodology:

The Hydraulic jump type energy dissipaters are designed by using Froude's Model law. The simplest type of energy dissipator is by formation of Hydraulic jump at the downstream of the spillway. However the amount of energy dissipated depends on the type of the jump formed, which in turn depends upon the amount of flow entering the stilling basin, the subcritical depth of flow and the initial Froude number.

The hydraulic jump type stilling basin is designed in the form of rectangular channel with horizontal apron at bottom and end weir at the end to match the water level after jump to tail water level. Sometimes apron floor is depressed to achieve the above situation however it has been observed in the present case that TWRC remains below the JHC for all the discharges. Therefore this case leads to a deficient tail water condition and there is no simple remedy available for a tail water deficiency. Increasing the length of basin which is the remedy often adopted in the field will not compensate for the tail water depth, Baffle piers and sills are partly successful in substituting for tail water depth as these are designed with respect to the post jump height y_2 which is varying itself for different discharges.

Proposed Solution:

To have appropriate location of hydraulic jump in a stilling basin for all probable varying discharges, it is proposed to provide stepped end weir at the end of apron The end weir is designed in such a fashion that it tends to form the hydraulic jump at the foot of spillway for wide range of discharge (i.e. from 20% to 100% of design discharge). The design of stilling basin and end weir is done as per the guidelines given by Hinge et al (2012).

Scale model and experimentation

The width of the weir and tail channel downstream side of weir in the present case is 8.30 m and maximum discharge is $50 m^3$/sec. On account of the discharge constraints in the laboratory, it is decided to construct a sectional model, thus out of 8.3m, 2m width of overflow weir is reproduced. The model is designed as per Froude's model law and the scale adopted was 1:20.Fig 3 shows the schematic of experimental set up.

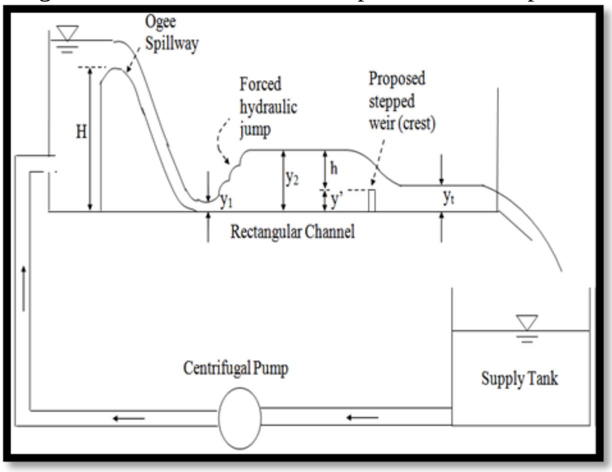

Fig 3. Schematic of experimental set up

The important dimensions in model are as follows.

Head on upstream	= 0.3 m
Width of stilling basin	= 0.1 m
Design discharge	= 0.00674 m^3/s
Discharge coefficient	= 0.623
Starting weir height	= 0.022 m
Length of basin	= 0.88 m

Fabrication and Installation of Model:

As per above design, the model is fabricated in Perspex. Various components of the model are shown in Fig.4 and Fig. 5.

Fig 4. View of model with escape structure and Main Weir

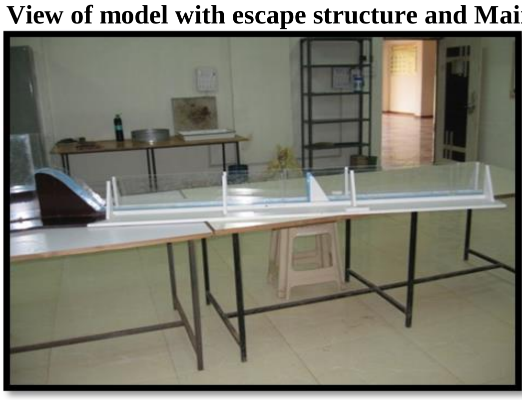

Fig 5. View of main weir, apron, stepped weir and Tail channel

Experimental observations:

The model is tested in laboratory for variable discharges ranging from design discharge to around 20% of design discharge. It was observed that for low discharges the hydraulic jump was found to be slightly submerged and for high discharges it was pretty clear. The pre jump depths, post jump depths, tail water depths were measured for each discharge. The parameters like Froude number and percentage energy dissipation are calculated and presented in Table 1

Though the hydraulic jump was formed at the foot of spillway and length of jump was within the stilling basin, velocity of flow in the tail channel was more than 2 m/sec for the above trial, as such to reduce the velocity, baffle blocks are introduced in the tail channel and model was again tested for the discharge range as per above trial. The results are presented in the table no 2

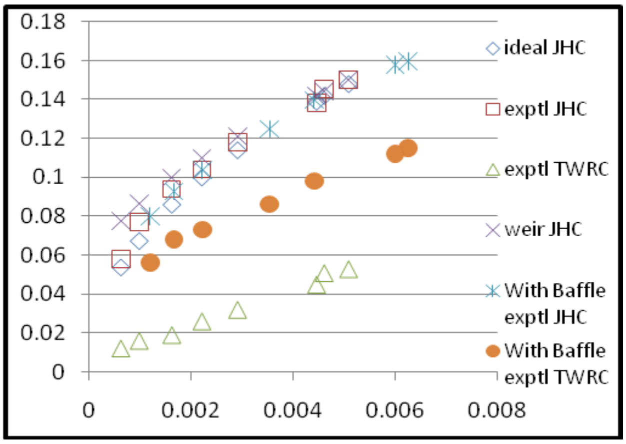

Fig. 6. JHC's and TWRC

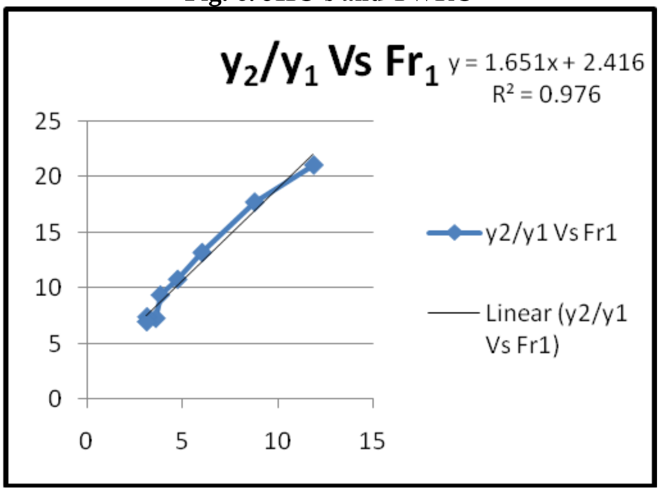

Fig. 7. y_2/y_1 Vs F_{r1}

Results and discussions

Figure 6 shows the plot of discharge against experimental y_2 depths corresponding to stepped end weir and that for the broad crested weir (normally provided as end weir), ideal y_2 depth corresponding to Belanger equation. It is observed that in the case of stepped weir (experimental) JHC lies slightly below the ideal JHC for lower discharges however, it matches for the ideal JHC for higher discharges. This shows that for all the discharges the energy dissipation is satisfactory. JHC for broad crested weir appears to be above the ideal JHC for all discharges showing the jump is submerged for all the discharges. Fig.7 Shows a plot of y_2/y_1 Vs F_{r1} which fairly represents as straight line.

Conclusions:

- The location of hydraulic jump was satisfactory for all discharges. Therefore the energy dissipation was found to be maximum in all cases.
- As the clear hydraulic jump formed at high discharges, it assures maximum air entrainment and thus reduces the cavitation problem.
- The overall flow scenario in the stilling basin tends to produce stabilized condition on downstream.
- Provision of baffle blocks in the tail channel assures velocity of water in tail channel within specified limits of 2 m/sec.
- The arrangement of Energy dissipation ensures the length of stilling basin within reasonable limits in fact stilling basin length is minimum possible for a satisfactory location of jump for varying discharges.

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