STEPPED SPILLWAY OF JAMBHIRA EARTH DAM, SUBARNAREKHA PROJECT, ORISSA

P.C.Nayak
Scientist, NIH, Deltaik Regional Centre
Kakinada - 533 003 (AP)

D. Nagesh Kumar
Asstt. Prof., Deptt. of Civil Engg.
Kharagpur-731 302

ABSTRACT

A hydraulic model investigation was conducted to evaluate the performances of a stepped spillway. The stepped spillway has contineous steps from crest to the toe. The steps significantly increase the amount of energy dissipation on the spillway face, thus eliminating or greatly reducing the need for the large energy dissipation work at the spillway toe. Primary objective of the investigation was to evaluate the quantity of the energy dissipation at the spillway toe.

As far as the construction process is concemed the advantage of stepped spillway in maintaining continuity in both types of material used and geometry is quite evident. There will be less financial expenditure and a shorter construction time.

The model studies were conducted keeping in view the proposed construction of stepped spillway over Jambhira earth dam on Subarnarekha river in Orissa State. Energy loss for designed discharge is 80.89%.

INTRODUCTION

A stepped spillway is an energy dissipater having profile made up of steps. It dissipates much more energy than other types of spillways, when water is flowing over the spillway profile and reduces the large energy dissipation basin otherwise required at the toe of the structure. The stepped spillway is more efficient and the time and cost required to construct the same is lesser than that required for other types of spillways(Diez-cason et al 1991).

Although stepped spillway concept is not new, it is gaining importance and considerable amount of research is going on in that direction. A stepped spillway was used on New Croon Dam built in 1892-1906. In the countries like USA, UK, Russia and Africa some stepped spillways had been constructed as per Stephenson (1991), Sorenson (1985), Pradivets et al. (1981 & 1989).

Jambhira earth dam is going to be constructed in the Subarnrekha irrigation Project under the Department of Water Resources, Government of Orissa. Due to the delay in completion of the Galudhia Right Bank Canal in Bihar, Govt. of Orissa proposes to construct a truncated earth dam to store the yield of its own catchment to provide early irrigation to entire right command (3550 hectares) or culturable command area.

The peak design flood of 1167 cumecs (standard Project Flood) when routed through unabated spillway will cause a peak flow of 510 cumecs which is proposed to be passed over the truncated earth dam through a 75m wide spillway located in the river bed. This construction needs to be flexible so as to be dismantled easily and later to continue the construction of the earth dam to the final FSL. For this purpose a stepped precast concrete block spillway over the embankment fills is proposed in 1:6 slope. Before the construction of the prototype, laboratory experiments are needed to evaluate the efficiency of the stepped spillway.

In the present work a laboratory model was constructed to evaluate the efficiency of the stepped spillway in dissipating the energy. The model was constructed with a scale 1:16.76 considering the Froude model law, as gravitational force is the only predominating force in open channel flow.

PRESENT MODEL SIMULATION AND METHODOLOGY

The experimental work on scale model is often the most efficient and sometime indeed the only method of solving the problem. Simulation by the use of scale model is the only direct method

available for simulating the real solution. Flow over a spillway involves significant horizontal and vertical component of velocity and acceleration. Thus, a spillway model should be built to undistorted model. Since gravity force is the only predominant force the governing laws that apply model to prototype scale relationship is the Froude model law (Sorenson 1981 and Novak 1981).

For Froude similarity

$q_r = l_{r3/2}$ (1)

$V_r = l_{r1/2}$ (2)

Where l_r is the model to prototype length ratio, q_r is the discharge per unit width of spillway ratio, and V_r is the velocity ratio.

In the present study the peak design flood of the Jambhira earth dam is 1167 cumec when routed through unabated spillway will cause a peak out flow of 510 cumec which is proposed to be passed over the truncated earth dam through a 75m wide spillway. The height of the spillway is 23m and stepwise slope 1:6. The size of each step block is (1.2 X 1.2 X 0.2)m.

From the field data discharge per unit width of the spillway q_m = 6.8cumec/meter. In laboratory (where model is constructed) maximum discharge intensity possible is q_p = 0.0991 cumec/meter.

Considering equation no(1) model/prototype scale ratio l_r is 1:16.76. From this scale ratio 65 nos. of steps having size (1250 X 72 X 12)mm. with total height of 780 mm. and length 7.53m spillway was constructed.

CONSTRUCTION DETAILS OF THE MODEL

The model is constructed in the long masonary flume in the Water Resources Engineering laboratory, IIT, Kharagpur. The two side walls are constructed on the flume having clear distance 1.25m and 7.53m length. In between the side walls 65 nos. of steps having size (1250 X 72 X 12) mm were monolithically constructed instead of step blocks. The side walls were constructed in the brick masonary with cement mortar 1:6. Steps were constructed with cement mortar having proportion of 1:4. Below the steps sand was filled and compacted. Proper slope was maintained in the rear portion of the stepped spillway. For uniform passage of water wave breakers were fixed upstream of the spillway model. Every possible care was taken during the construction and level of each step was checked with the help of sprit level.

The water is allowed into the spillway through V-notch and discharge is measured from calibration curve (head vs discharge) of the V-notch with the help of point gauge. For the measurement of the depth of flow over each step of the spillway, two rolling bridges mounted with a point gauge were installed. The bridges were capable of moving in the direction flow. The rolling bridges were placed over the parallel rails on the side of walls of the flume. A point gauge was fitted to each rolling bridge to measure the elevation of water surface. The point gauge was also capable of sliding over the measuring bridges in lateral direction. These movements in both the direction fasciliated taking observation for cross profile at any desired section.

DESCRIPTION OF EXPERIMENTAL PROCEDURE AND COMPUTATION

The experiments for present model consists of 9 runs having discharges 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.11 cumecs. Observations to the test model consisted of measuring flow profile at different steps along the stepped spillway profile considering different discharges. The depth of flow was measured at the end of each step. After passing of water from the toe of the spillway, uniform downstream depths were also measured by the movable measuring bridge. For the analysis of energy loss following method is adopted. The energy loss is $\Delta E = E_0 - E_1$ where E_0 and E_1 is the energy at the spillway crest and toe.

RESULTS AND DISCUSSIONS

The Table summarises the results obtained in the scale model. From that table we observe that, at the designed discharge the energy loss is 80.89% and as the discharge is decreasing the

energy loss is increasing. At the lowest, discharge of 0.01 cumec, the energy loss is 95%. The energy loss Vs discharge graph is shown in Fig. 2. For all the readings, the flow was skimming flow. At the lowest discharge, it is observed that there is air entertainment on each step, afterwards as the discharge is increasing air entertainment is reducing. From depth measured at each step, velocity head is calculated. The flow and velocity head profile at different steps are shown in fig. 1(a) and 1(b) in exagerrated scale for discharge 0.06 and 0.08 cumec.

Q Cumec	q cumec/m	Y_c m	E_o m	Y_1 m	V_1 m/s	E_1 m	ΔE m	$\Delta E / E_1$ %
0.01	0.008	0.021	0.812	0.014	0.571	0.0306	0.781	95.23
0.02	0.016	0.033	0.829	0.021	0.762	0.0506	0.778	93.90
0.03	0.024	0.042	0.843	0.026	0.923	0.0694	0.774	91.76
0.04	0.032	0.047	0.851	0.028	1.143	0.0946	0.756	88.89
0.05	0.040	0.055	0.863	0.031	1.290	0.1158	0.747	86.58
0.06	0.048	0.062	0.873	0.036	1.333	0.1266	0.746	85.50
0.07	0.056	0.069	0.884	0.040	1.440	0.1399	0.744	84.17
0.08	0.064	0.075	0.893	0.042	1.523	0.1602	0.733	80.89
0.11	0.088	0.092	0.918	0.045	1.956	0.2400	0.678	73.86

Q - Discharge in cumec, q - Discharge in cumec/m, Y_c - Critical depth on the top of the spillway
E_o - Energy at the top of the spillway, Y_1 - Uniform depth on the spillway toe, V_1 - Velocity at the toe,
E_1 - Energy at the toe of the spillway, ΔE - Energy loss

CONCLUSION

All the experiments had been conducted in Water Resources Laboratory, Department of Civil Engineering, IIT Kharagpur. The experiment consists of 9 runs considering the discharge 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08 and 0.11 cumec. The Model scale adopted for the construction for the stepped spillway was 1:16.76. Connsidering the same scale ratio, 65 number of steps having size (1250 X 72 X 12) mm is monolithically constructed. The height and length of the spillway is 0.78 m and 7.53 m. The following conclusions are drawn based on experimental investigations and the discussion of results are presented above.

1. Appreciable amount of energy loss on the spillway section justifying the stepped spillway utility.
2. Upto the designed discharge, the energy loss is acceptable.

From the experimental study, it is concluded that the stepped spillway is efficient in taking care of the hydraulic energy to be dissipated and technically a very sound alternative to conventional spillway structures.

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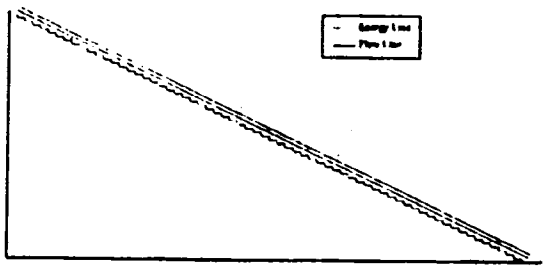

Fig.1(a) Flow and velocity head profiles for the discharge 0.06 cumec

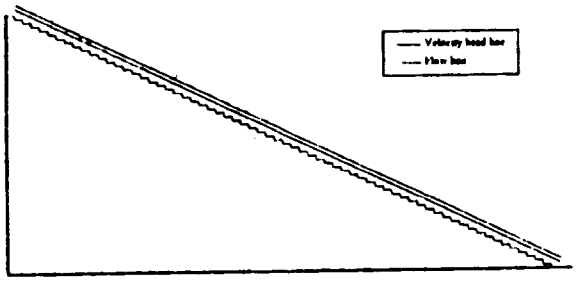

Fig.1(b) Flow and velocity head profiles for the discharge 0.08 cumec.

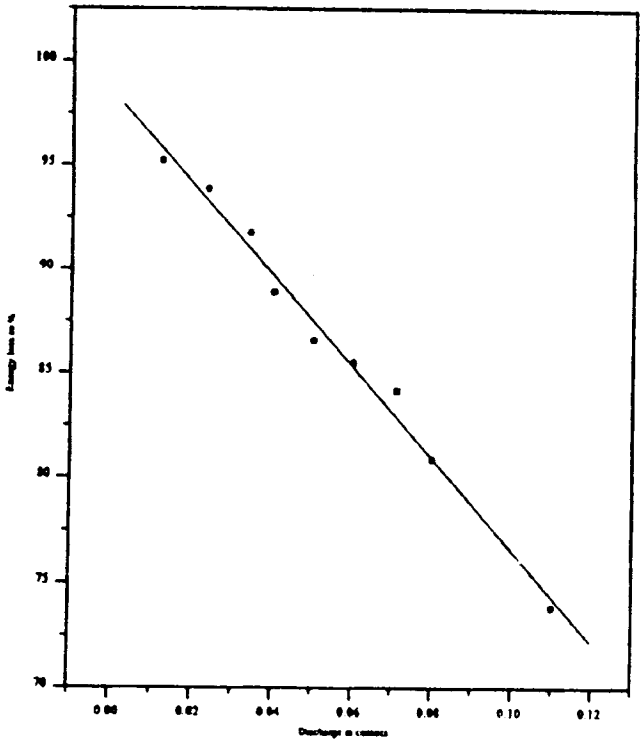

Fig.2. Energy loss Vs discharge