Design of Dam Spillway Cum Downstream Wave Basin Physical Model for Kalpasar Project—A Case Study

P. A. Kashyape, R. R. Bhate, H. B. Jagadeesh, and Prabhat Chandra

Abstract Government of Gujarat has major proposal of development a multipurpose project, Kalpasar in the Gulf of Khambat. This project consists of constructing a 30 km long dam and concrete spillway of about 2.3 km length with 105 numbers of gates. After completion of this project, it is estimated that about 10,000 mm^3 of fresh water could be made available to the Saurashtra Peninsula; along with this other benefits were perceived related to use of the dam to support a transportation link between Surat and Bhavnagar districts, to fisheries development etc. Since year 1995 various feasibility and other studies had been carried out for the project by various research and academic institutes. Various studies are also under progress at CWPRS for the development of Kalpasar project; one of them is hydraulic physical model study to finalize the design of spillway by simulating discharge over spillway along with the effects of sea waves on the downstream of the dam. This dam spillway cum wave basin is a captive model housed in hanger of size 60 m × 40 m and developed to the scale of 1:55 G.S. (geometrically similar). In this model at one end spillway with about 90numbers of gates and on downstream of spillway at a distance of 31.79 m (about 1750 m in prototype), a unidirectional random sea wave generator having wave flap of length 33 m controlled by SCADA is proposed. On this model, it is proposed to test discharging capacity of spillway with full and partial operation of gates along with performance of energy dissipater for various tidal levels with superimposition of waves, water surface profiles for entire range of discharges, pressures over spillway surface under the influence of waves and tides for entire range of discharges. This paper presents the glimpses of the hydraulic design of dam spillway cum downstream wave basin physical model for Kalpasar.

Keywords Dam · Spillway · Discharging capacity · Wave basin · Wave generator

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1 Introduction

Gujarat is a water scarce state with having only 2% of water resources of India [10]. As per 2011 census per capita availability of water in Gujarat is 1050 cubic meter annually which is far less than the national average per capita water availability (1567 m^3 per annum) of India. As per estimates total surface water availability in Gujarat is about 38,100 MCM and at present state is having water storage capacity of 20,480 MCM in its total 196 major and medium projects [10]. In order to overcome on the situation of water scarcity in the state, Government of Gujarat has proposed project of closure of Gulf of Khambat by constructing a 30 km long dam across it, which will result in storage of 10,000 MCM of surface water [8]. This project will be a multipurpose one which supports a transportation link between Surat and Bhavnagar districts; it will help to bring 10.54 lakh ha of land in Saurashtra region under irrigation [8] and also to fisheries development etc. This Kalpasar dam is proposed to have a spillway of length 2310 m and having 105 numbers of gates. Since early 1990s, various feasibility and other studies had been carried out for the project by various research and academic institutes. Various studies are also under progress at CWPRS for the development of Kalpasar project; one of them is hydraulic physical model study to finalize the design of spillway by simulating discharge over spillway along with the effects of sea waves on the downstream of the dam. The design of this physical model for Kalpasar project is challenging one since it comprises dam spillway at one end, random sea wave generation system at another to create wave basin on the downstream of spillway and water recirculation system. A designed layout of model is shown in Fig. 1.

2 Design and Discussion

2.1 Physical Model of Kalpasar

As shown in Fig. 1, this model is housed in hangar of size 60 m × 40 m. In this model at one end spillway with about 90 numbers of gates and on downstream of spillway at a distance of 31.79 m in model (about 1.75 km in prototype), a unidirectional random sea wave generator having wave flap of length 33 m and water recirculation system is proposed.

2.2 Selection of Scale

In order to achieve similitude in model and prototype depending upon requirement of problem a suitable model scale is selected. Scale for coastal engineering physical models of waves is varied from 1:100 to 1:150, while that of for spillway and energy

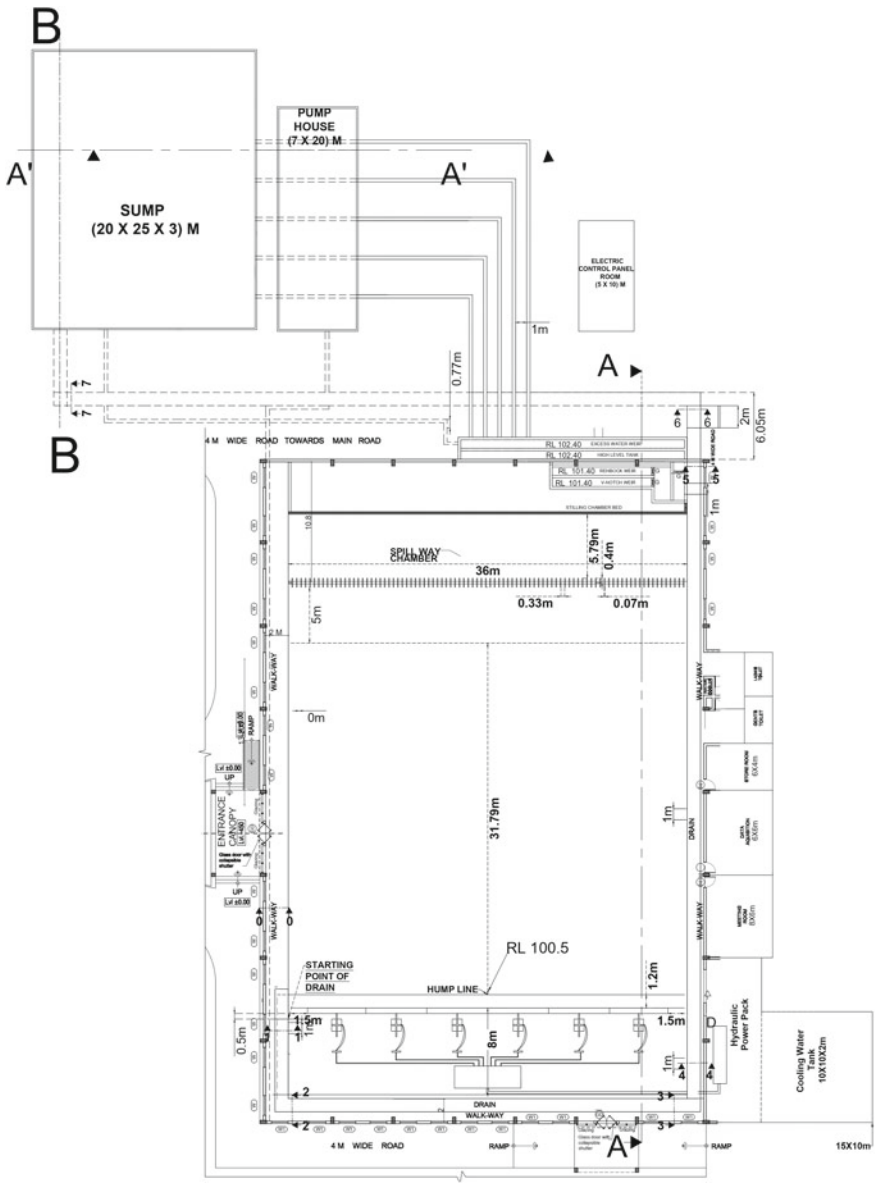

Fig. 1 Layout of Kalpasar model

dissipator is varied in range of 1:25–1:60. In case of spillway and energy dissipator, larger the section in model better will be interpretation of results. However if scale showing larger sections in model is selected for coastal engineering models, then it will lead to increase in the cost of Random Sea Wave Generation (RSWG) system and power requirement. Since, this Kalpasar model is a combination of both sea wave basin and dam spillway the scale for this model is selected as 1:55 geometrically similar.

2.3 Spillway and Energy Dissipator in Model

The proposed spillway is about 2.3 km long consisting of 105 spans of 18 m width each divided with 5 m thick piers. The spillway is designed [7] to pass the flood of the magnitude of 120,000 m^3/s [4]. Energy dissipator provided is in the form of 50 m long stilling basin with invert El of − 10 m. Figure 2 shows the plan and cross section of the proposed design of spillway. The 1:55 scale GS spillway model based on Froudian simulation criterion will be utilized to finalize the proposed design. In the available width of 36 m, about 90 spans of spillway would be reproduced. The spillway and stilling basin will be constructed in masonry and finished in smooth cement plaster painted with enamel paint. Piers, breast walls, and gates will be fabricated in FRP/perspex. The following aspects would be studied on this model:

1. Discharging capacity for the conditions of free overflow and submergence by the tide levels with superimposed waves.
2. Pressures on crest and appurtenant structures for various hydraulic conditions
3. Performance of energy dissipator for different operating conditions and under varying tide levels. The objective would be to optimize the design so as to make it workable for as many conditions as possible.
4. Measures for protection of spillway and appurtenant structures from the attack of waves and storm surge.

2.4 Random Sea Wave Generation in Model

The Gulf of Khambat is tide dominant region with maximum tidal range of about 11 m [5]. However, Sanil Kumar et al. [9] observed that the significant wave height (H_s) in the Gulf of Khambat is about 1.6 m during south-west monsoon and wave direction between 180° and 225°, while Kumar et al. [6] observed the same about 1.8 m. National Institute of Ocean Technology (NIOT), Chennai, in its survey report carried out for Gulf of Khambat Development Project observed that H_s in the region between 0.8 and 5.2 m with wave period between 8 and 12 s; and waves are from South-West and North-East direction [1, 2]. Also at CWPRS, a mathematical model study for wave tranquility at downstream side of spillway for Kalpasar is under

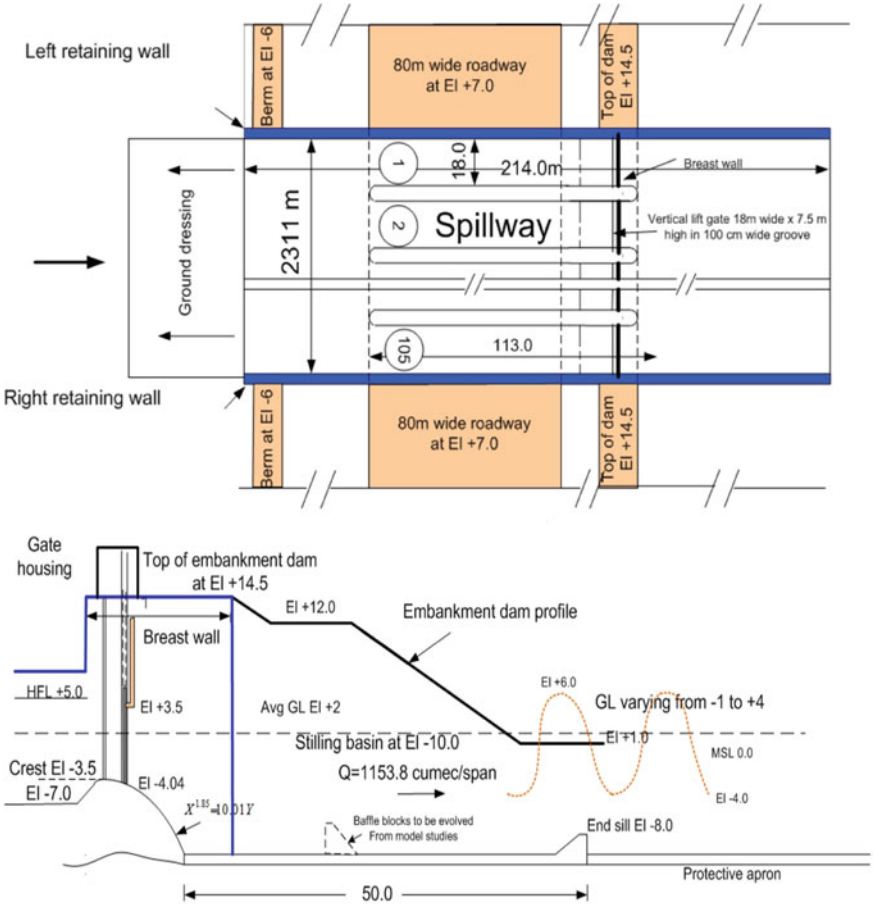

Fig. 2 Plan and cross section of proposed spillway

progress, and preliminary results of this study that shows the H_s in the region are within the range of 3.29–5.31 m. Considering all these in this model RSWG system is designed to generate unidirectional sea waves having significant wave height (H_s) up to 4 m and wave period (T_p) of 10 s, considered as superimposed over various tidal levels. Figure 3 shows the water levels considered for the design of RSWG in model with respect to corresponding levels in prototype.

RSWG system consist of Hydraulic Power Pack (HPP), SCADA controlled electro-hydraulic servo system, six numbers of wave boards each of 5.5 m length connected to separate servo valves (total six servo valves) synchronized to make wave board of 33 m long, data acquisition system. Schematic flowchart of this system is shown in Fig. 4. Waves will be generated by moving a piston operated wave boards by an electro-hydraulic servo system through servo actuators which is controlled by a signal generating unit [3].

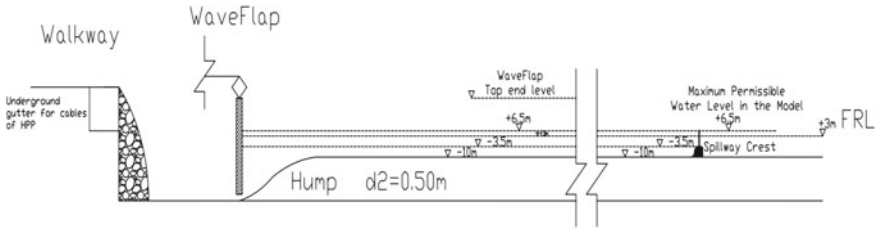

Fig. 3 Water levels considered for design of RSWG system

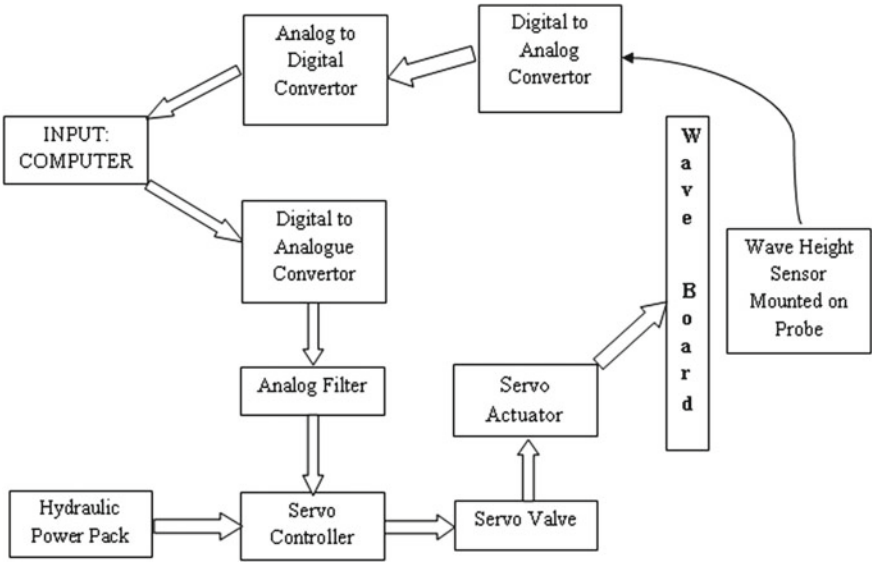

Fig. 4 Flowchart of sea wave generation system at CWPRS

2.5 Water Recirculation System

Water recirculation system of model consisting of a sump of capacity 1500 m^3 (25 $\times$ 20 $\times$ 3 m), high head water tank of size 20 $\times$ 2 $\times$ 1 m, overflow weir, Rehbock weir, V-notch weir, stilling basin chamber, wave basin, and returning channel. Water from sump will be pumped in to high head tank at a rate of 20 cusec then it enters in to Rehbock and V-notch weir after that it enters in to the stilling basin chamber then it enters in to the upstream reservoir of dam and flows over the spillway and enters in to stilling basin portion. On the downstream of spillway, a wave basin will be created in order to generate the wave of different wave heights (H_s up to 4 m with T_p of 10 s) for different conditions. Excess water from wave basin is allowed to enter in to retuning channel of rectangular cross section of size 1.2 $\times$ 0.6 m with slope of

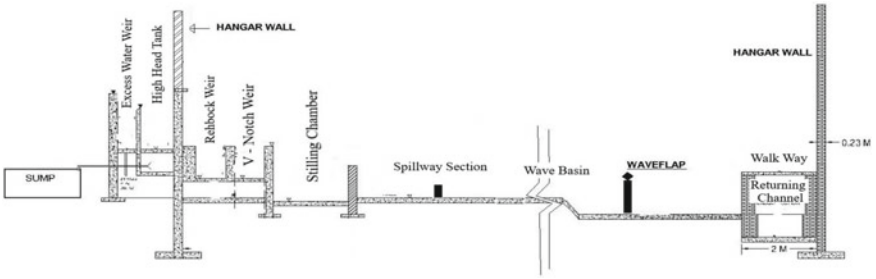

Fig. 5 Cross section showing water circulation system in model

1:400 and length 180 m. At end water again enters in to sump. A cross section of this system is shown in Fig. 5.

3 Conclusions

This model is unique one which consists of both spillway and random sea wave basin. Studies on this model will be helpful in

- Design of spillway of Kalpasar dam.
- Assessing the discharging capacity of spillway.
- Operation of spillway gates and performance of energy dissipator.
- The impact of downstream wave conditions on the spillway discharging capacity can be studied on this model, as well as downstream flow conditions due to interaction of sea waves and discharge over spillway.

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