HYDRAULIC MODEL STUDIES FOR ADDITIONAL SPILLWAY OF HIRAKUD DAM, ODISHA

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ABSTRACT

There are 5264 large dams in India which play an important role in ensuring the water security of the country and constitute a major responsibility in terms of asset management and safety. More than three-fourth of these dams are at least two decades old. Hirakud one of the major and oldest dams which became operational in 1957 is under consideration to construct additional spillways as the design flood of Hirakud Dam has been reassessed by CWC from 42,450 m^3/s to 69,632 m^3/s in order to improve the safety and operational performance. To safely pass the additional flood, additional spillways have been proposed on the left and right dyke of the main dam. The present paper describes the model studies conducted on 2-D sectional and 3-D comprehensive models of Additional Spillway on left dyke of Hirakud Dam to assess the discharging capacity of spillway, overall performance of spillway and energy dissipator, approach flow conditions, flow conditions along the spill channel and in the vicinity of outfall channel joining the Mahanadi River during combined operation of existing spillways and additional spillway.

1. INTRODUCTION

Hirakud Dam is built across River Mahanadi about 15 km upstream of Sambalpur town in the state of Odisha. It is a composite dam of Earth, Concrete and Masonry structure. There are two spillways in the main dam on the left and right sides located on the two channels of the main river. The left bank spillway of the Hirakud dam has 40 no. of sluice gates and 21 no. of crest gates. The right bank spillway has 24 no. of sluice gates and 13 no. of crest gates. The total discharging capacity of both the spillways is 42,450 m^3/s. The project was commissioned in the year 1957. Central Water Commission (CWC) reassessed the revised design flood as 69,632 m^3/s. In order to safely pass the additional flood of 27,182 m^3/s inflow revised design flood, it was proposed to provide two additional spillways, first at the left bank (1st gap dyke of Hirakud Dam near 2nd saddle of Gandhi hillock) with 5 nos. of spillway gates of size 15 m x 15 m each to discharge 9122 m^3/s at FRL El. 192.024 m and MWL El. 192.454 m of flood water into the River Mahanadi just downstream of left spillway and another additional spillway at Right dyke with 8 nos. of spillway gates to discharge 13571 m^3/s flood water.

The paper describes 2-D hydraulic model studies of Additional Spillway at Left bank of Hirakud Dam conducted at CWPRS on 1:40 scale 2-D sectional model for evolving the efficient and economical design of spillway and energy dissipator. Figure 1 shows the general layout plan of Hirakud main dam incorporating layout plan of additional spillway. The paper also discusses the 3-D comprehensive model studies to assess the approach flow conditions, discharging capacity of spillway and flow conditions along the spill channel and at the junction of River Mahanadi for entire range of discharges and combined operation of existing spillways and additional spillway.

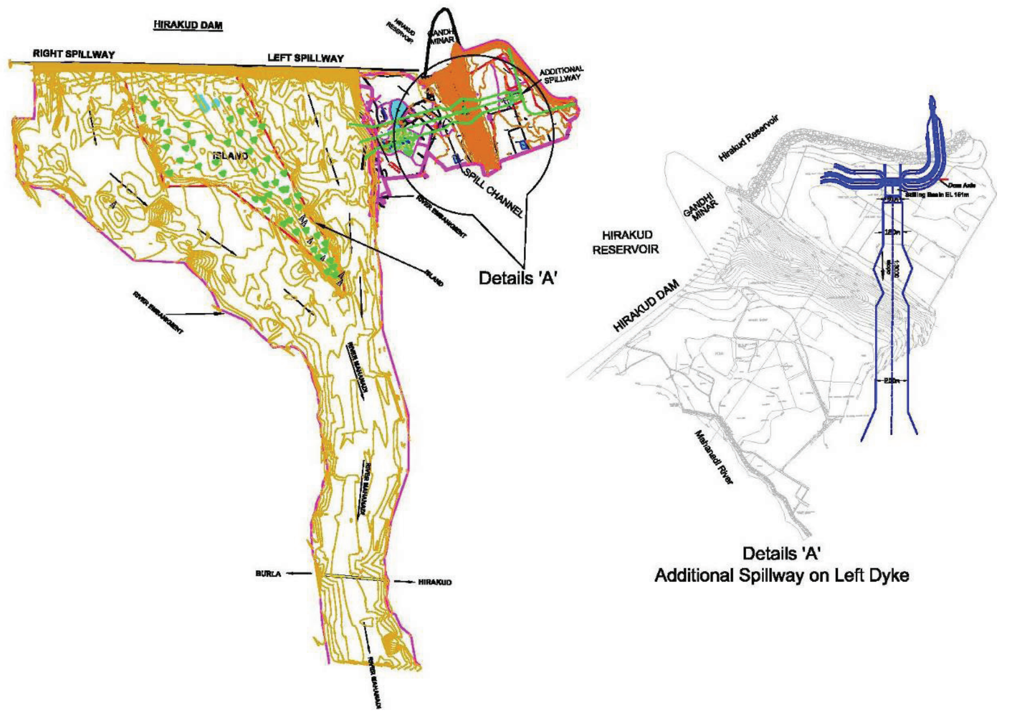


Figure 1 : General layout plan incorporating layout plan of additional spillway

2. SECTIONAL MODEL STUDIES OF ADDITIONAL SPILLWAY

Hydraulic model studies were conducted on 1: 40 geometrically similar scale model. It was observed that the performance of stilling basin was unsatisfactory as the length of the stilling basin of 71 m was insufficient to contain the hydraulic jump. Therefore, it was recommended either to increase the length of the stilling basin or to adopt optimum combination of increasing the length as well as lowering the stilling basin floor level considering the techno-economic feasibility. Photo 1 shows the performance of stilling basin for the discharge of 6841.5 m^3/s gated operation of the spillway.

Photo 1 : Performance of stilling basin for gated operation of spillway for the discharge of 6841.5 m^3/s (75 %) at FRL El. 192.024 m

2.1 Hydraulic Model Studies for the Modified Design

Based on the model studies, the length of the stilling basin was modified from 71 m to about 90 m in the existing 1:40 scale 2-D sectional model. Model studies revealed that the performance of stilling basin was satisfactory as the length of the stilling basin provided was sufficient to contain the hydraulic jump. Therefore, it was felt that the length of the stilling basin of 90 m was sufficient for the energy dissipation. Photo 2 shows the performance of stilling basin for the discharge of 9122 m^3/s for ungated operation of the spillway.

Photo 2 : Flow condition downstream of spillway for ungated operation of spillway for the discharge of 9122 m^3/s (100%) at RWL El. 191.45 m

As per the recommendation of CWPRS, either to increase the length of the stilling basin or to adopt optimum combination of increasing the length as well as lowering the stilling basin floor level, studies were also conducted by considering another alternative of lowering the stilling basin floor level by 2 m i.e. El. 149 m in the existing 2-D sectional model.

2.2 Model Studies with Stilling Basin Floor Level El. 149 m and Length 90 m

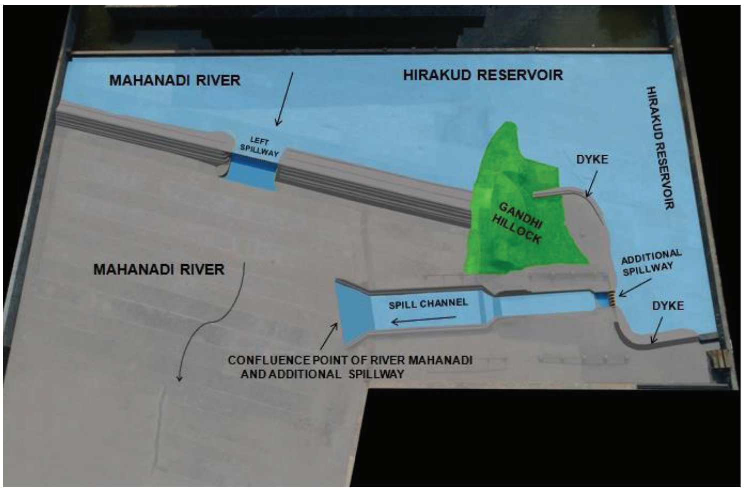
Hydraulic model studies were conducted with 90 m long stilling basin and modified stilling basin floor level El. 149 m for assessing the efficacy of energy dissipator for the entire range of discharges up to design discharge of 9122 m^3/s and reservoir water levels up to MWL El. 192.454 m. It was observed that the hydraulic jump was forming in the stilling basin for gated and ungated operation of the spillway. But no significant improvement was observed in the performance of the stilling basin as compared to the performance of the stilling basin with floor level at El. 151 m. Flow conditions in the stilling basin were similar to stilling basin with floor level at El. 151 m. Therefore, lowering of the stilling basin floor level by 2 m i.e. El. 149 m was not recommended and it would also be uneconomical. Therefore, it was recommended to adopt the stilling basin with length of 90 m and stilling basin floor level El. 151 m. Photo 3 shows the performance of stilling basin for the discharge of 9122 m^3/s for ungated operation of the spillway.

Photo 3 : Performance of stilling basin for ungated operation of spillway for the discharge of 9122 m3/s (100%) at FRL El. 192.024 m

3. 3-D COMPREHENSIVE MODEL STUDIES

The 3-D comprehensive model was essential to assess the approach flow conditions and its effect on discharging capacity of spillway and to assess the flow conditions along the spill channel and adequacy of its size and flow conditions in the vicinity of spill channel outfall of additional spillway joining the Mahanadi River during combined operation of existing spillways and additional spillway.

Therefore, hydraulic model studies were conducted on 1: 100 scale geometrically similar 3-D comprehensive model incorporating existing dam complex with left spillway, about 1 km of reservoir and 3 km river downstream of dam axis. The model also incorporates proposed additional spillway with part of upstream reservoir, 1756 m long spill channel and Mahanadi River up to 300 m downstream of confluence of left and right limb of Mahanadi River. The design of the energy dissipator i.e. stilling basin with floor level El.151 m and length 90 m finalized from the sectional model studies was adopted for studies in the 3-D comprehensive model. The spillway, stilling basin, piers, chute blocks and dentated end sill of the additional spillway were fabricated in PVC Foam Sheet and painted with enamel paint. The radial gates were fabricated in M.S. sheets. The overflow & sluice spillway, ski-jump bucket and piers of the existing dam complex with left spillway were fabricated in PVC Foam sheet and painted with enamel paint. The radial gates were fabricated in M.S. sheets. Photos 4 to 8 show the top view of the model showing existing left spillway of main dam and additional spillway, upstream view of the left bank spillway, side, upstream & downstream views of the model of additional



spillway respectively.

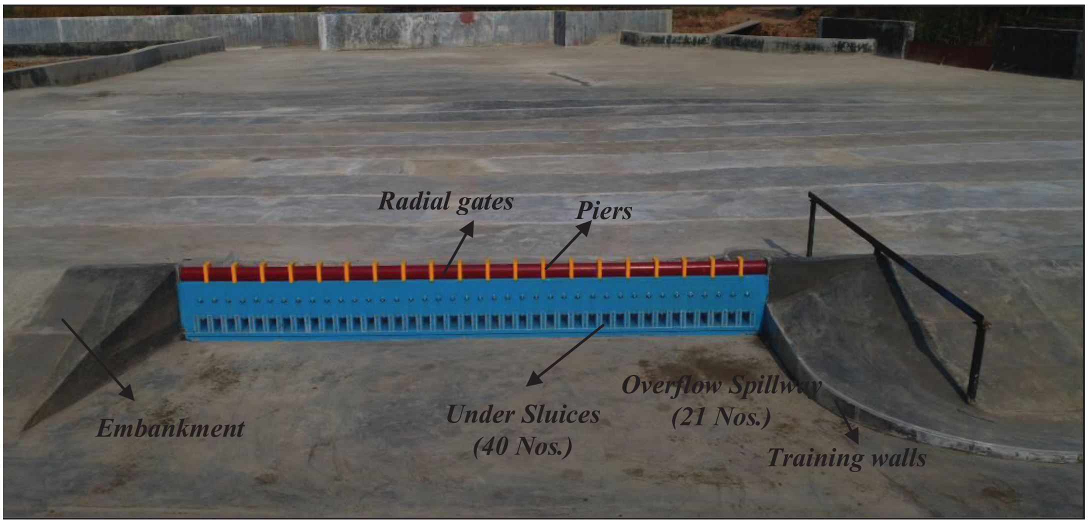


Photo 4 : Bird's eye view of the model showing existing left spillway of main dam and additional spillway

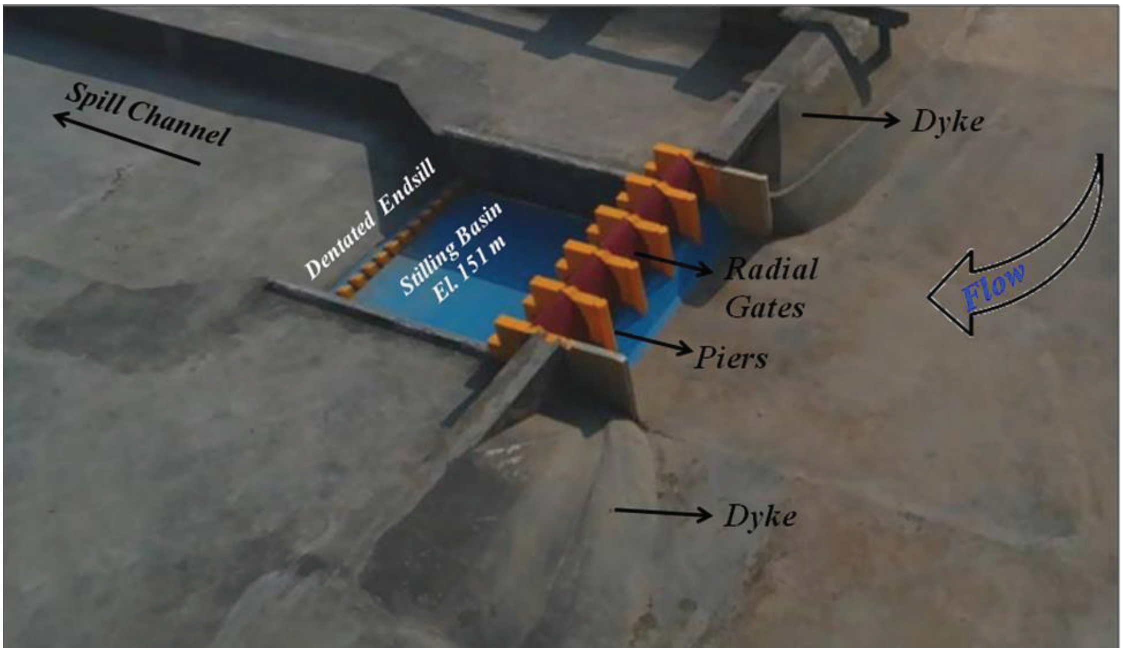


Photo 5 : Upstream view of the model showing existing left spillway of main dam

Photo 6 : Side view of the additional spillway model

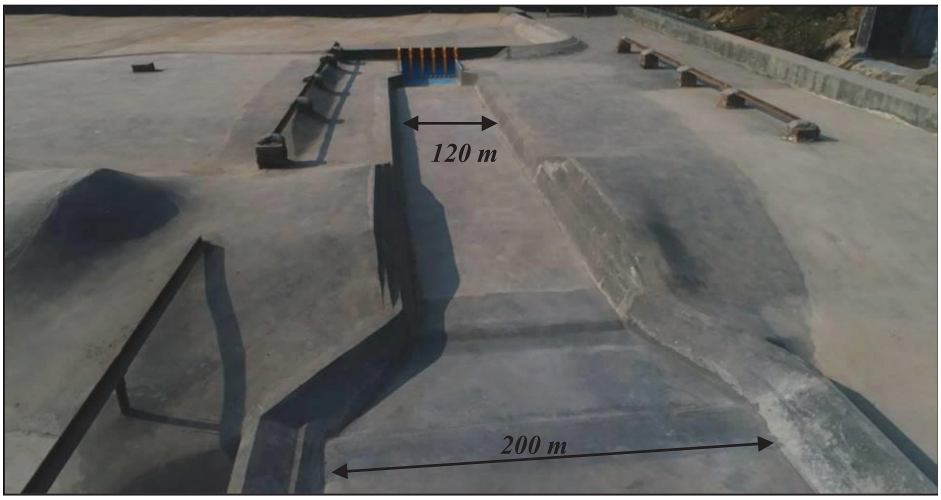


Photo 7 : Upstream view of the additional spillway model

Photo 8 : Downstream view of the additional spillway model

Two tail water rating curves supplied by the project authorities were used for conducting the studies. Figure 2 shows the tail water rating curve at about 300 m downstream of confluence point of spill channel of additional spillway and Mahanadi River (Tail channel of existing left bank spillway) and at about 200 m downstream of the confluence point of tail channels of the right and left bank spillways.

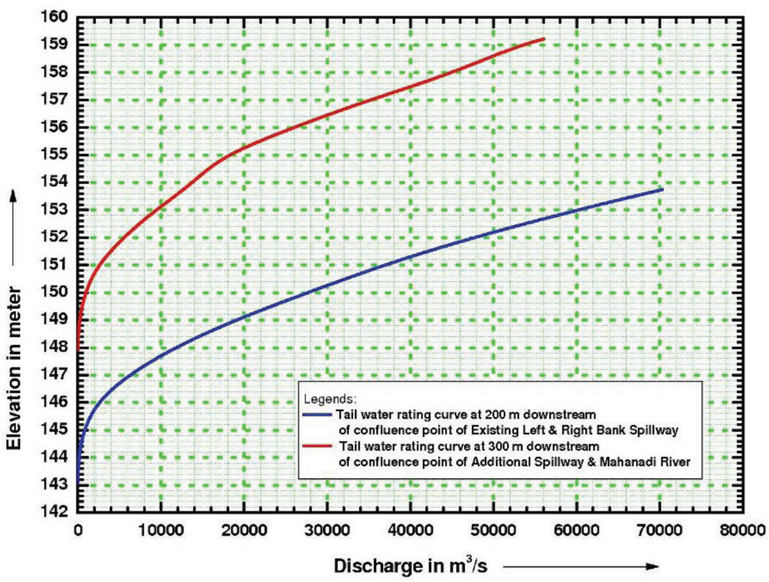


Figure 2 : Tail water rating curves

3.1 Approach Flow Conditions

Studies revealed that the flow conditions near the left and right training wall of additional spillway in front of 1st and 5th span were abrupt causing sudden drawdown condition as shown in Photo 10. Therefore, it is suggested to provide curved guide walls to improve the approach flow conditions in front of end spans. The flow conditions near the earthen dyke were satisfactory.

It was also observed that the approach flow conditions upstream of existing left spillway of main dam was found to be satisfactory. Photos 9 to 11 show the approach flow condition of additional spillway, flow condition near the upstream left and right training wall and approach flow condition of existing left spillway of main dam respectively.

Photo 9 : Approach flow condition of existing left spillway of main dam

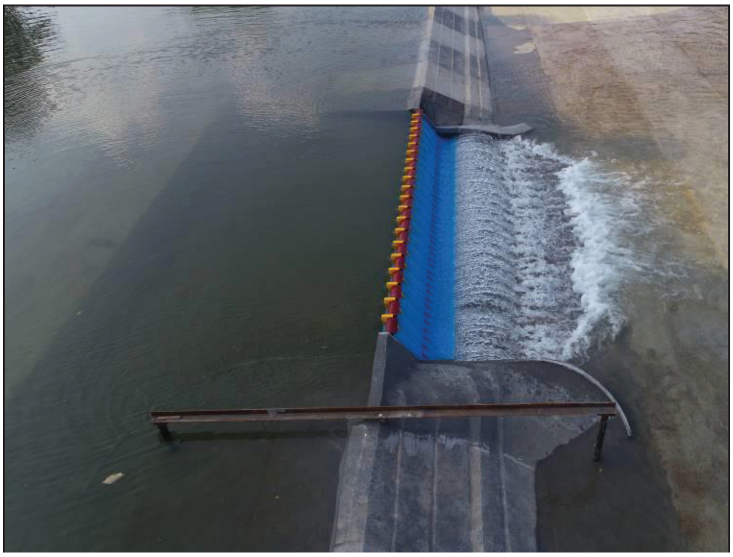


Photo 10 : Upstream flow condition near the left and right training wall

Photo 11 : Approach flow condition of existing left spillway of main dam

3.2 Performance of Energy Dissipator and Spill channel

It was observed that the performance of stilling basin of the additional spillway was satisfactory as the length of the stilling basin provided was sufficient to contain the hydraulic jump. Uniformly distributed super critical flow was observed along the entire length of spill channel. The flow was contained within the spill channel without overtopping indicating the adequacy of size of spill channel. It was seen that the flow conditions at the confluence of spill channel and River Mahanadi were not satisfactory. The flow from the spill channel was hitting the left limb of River Mahanadi in the downstream at 90^0 during the combined operation of existing left spillway of main dam and additional spillway. It was also observed that the flow emerging from the spill channel was pushing the flow coming from existing left bank spillway towards the island. Detailed studies for various operating scenarios of combined operation of existing left bank spillway and additional spillway are scheduled to decide the orientation of spill channel outfall joining the left limb of Mahanadi. A curved spill channel towards the left (downstream side) near the confluence would facilitate to guide the super critical flow smoothly at the confluence of River Mahanadi.

It was observed that the performance of ski-jump bucket and under sluices of existing left bank spillway were satisfactory. Photos 12 to 16 show the performance of the stilling basin of additional spillway, entire spill channel, from RD 857 m to RD 936.26 m, ski-jump bucket of existing left bank spillway of main dam and combined operation existing left spillway

of main dam & additional spillway respectively.

Photo 12 : Performance of Stilling basin of additional spillway

Photo 13 : Flow condition in the entire spill channel

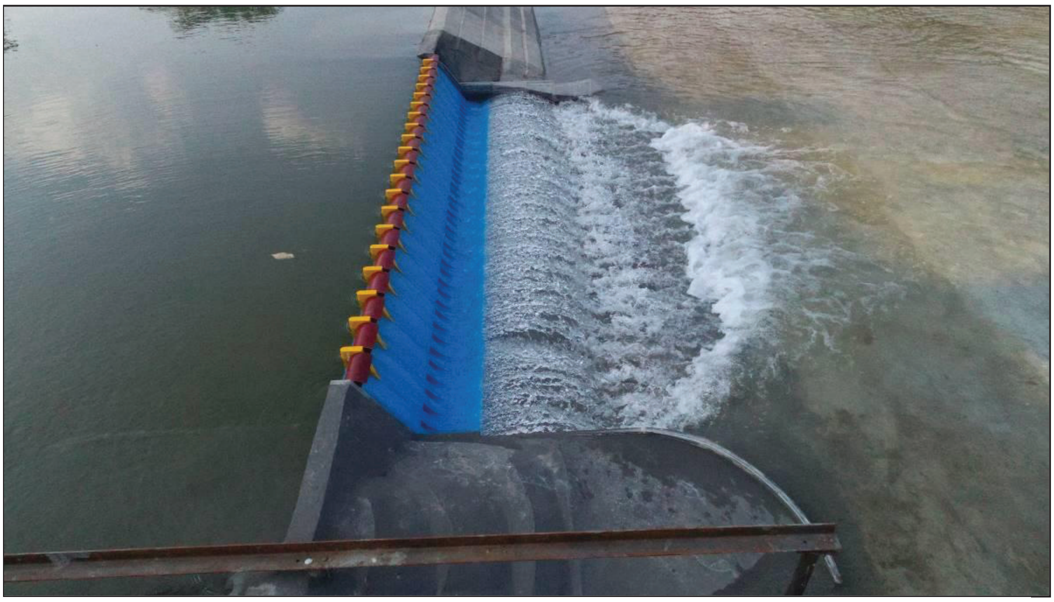


Photo 14 : Flow condition in the spill channel from RD 857 m to RD 936.26 m

Photo 15 : Performance Ski-jump Bucket of existing left spillway of main dam

Photo 16 : Combined operation of existing left spillway of main dam and additional spillway

Detailed studies for assessing the discharging capacity of spillway for ungated operation with all the five spans, water surface profiles for entire range of discharges, performance of stilling basin and flow conditions along the spill channel and at the junction of River Mahanadi for entire range of discharges and combined operation of existing spillways and additional spillway are in progress.

4. CONCLUSIONS

Hydraulic model studies play a significant role in optimizing the design of spillway and energy dissipator. 2-D model studies on original design indicated the requirement of increasing the length of stilling basin from 71 m to 90 m to optimize the hydraulic performance of the energy dissipator. With the optimized design of the energy dissipator, 3-D model studies were conducted for assessing the overall performance of the spillway and energy dissipator for the additional spillway along with existing left bank spillway on main dam. Modification for the upstream left and right training wall are suggested to guide the flow approaching spillway smoothly. Combined operation of additional spillway and left bank spillway of main dam indicated the necessity of modification in the design of the spill channel at the exit. Detailed studies for various scenarios of combined operation of existing left bank spillway and additional spillway would also be conducted with the help of two tail water rating curves at different locations. This combined operation would help in assessing the discharging capacity, effect of flood inundation on the island located between left and right bank spillways downstream of main dam and flow conditions in the vicinity of confluence required for adopting downstream protection works. Thus, the model studies would play a crucial role in enhancing the overall performance of spillway, energy dissipator and other appurtenant structures based on techno-economic feasibility.

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REFERENCES

1. Bhajantri, M R. et al (2019). International Dam Safety Conference- 2019, 13-14 February 2019, Bhubaneswar, Odisha, India
2. CWPRS Technical Report No. 5627 (2018). Hydraulic Model Studies for Additional Spillway of Hirakud Dam, Odisha. 1:40 scale 2-D Sectional Model
3. CWPRS Technical Report No. 5743 (2019). Hydraulic model studies for Revised Design of Additional Spillway of Hirakud Dam, Odisha. 1:40 scale 2-D Sectional Model