CONSIDERATIONS IN SELECTING A CONCRETE FACE ROCKFILL DAM IN A WATER RESOURCES PROJECT IN HIMALAYAS:

A CASE STUDY

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ABSTRACT
The development process of a multi-purpose water resources project from concept to commissioning is a multi-stage, inter-disciplinary and arduous task. Proper planning and design of individual components is fundamental to the success of the project. One such vital component is the dam or diversion structure. The selection of a particular choice of dam for a project has to take into account many considerations. The paper discusses about a multi-purpose project in the Himalayas envisaging construction of a high dam. After studies, the choice of dam finally narrowed down to Concrete Face Rockfill Dam (CFRD). The various factors considered in selecting a CFRD for the project is discussed in detail in the paper.

1. INTRODUCTION

The project development traverses its journey through stages viz. conceptualization, pre-feasibility, feasibility, detailed engineering and lastly the execution stage. The project layout planning has to keep in view the end objectives and their priorities. Proper planning and design of individual components is fundamental to the success of the project. One such vital component is the dam or diversion structure. The selection of a particular choice of dam for a project has to take into account many planning considerations viz. topographical, geological etc. The paper discusses about a case of a water resources purpose project in the Himalayas envisaging construction of a high dam.

Initially at pre-feasibility stage, at the selected site, an earth and rockfill dam was proposed. Later it was also suggested to consider a concrete gravity dam in feasibility studies. The required survey, surface and sub-surface investigations were carried out to generate enough data on the geological aspects at the dam site. The results of sub-surface investigations along dam axis and the laboratory test results along with the information about the availability of the construction materials, in the vicinity of the dam, has also been examined during detailed planning. Based on various considerations, the choice of the dam finally narrowed down to a Concrete Face Rockfill Dam (CFRD).

2. DAM SELECTION

The multipurpose water resources project in Ravi basin envisages construction of a dam of about 110 metres high (from river bed) with about 2.5 km long HRT leading to a surface power house. The dam site is located in a narrow gorge and rocks are exposed on both the abutments. The abutments are of sandstone with clay bands. The rocks are dipping downstream at a steep angle of about 60°-70°. In the pre-feasibility stage, in the year 2004, the dam in the project was conceived as an earth and rockfill dam with a chute spillway on the left bank saddle.

During a visit of multi-disciplinary team of experts in 2009, a concrete gravity dam option with an integral ogee/orifice spillway was also recommended for assessing its feasibility considering the steep abutments, narrow gorge and less overburden (15-20m). Moreover it was felt that being a storage scheme, requirement of low level outlets for emergency depletion, controlled initial filling and sediment exclusion and outlets for minimum release of water for d/s environmental needs can be better planned in a gravity dam. It was also concluded that a decision on the final choice of dam can

be taken on the basis of the recommendations from geologists on foundation rock after results of sub surface investigation are available. If the results are not found suitable for a concrete gravity dam, then a central clay core rockfill dam or concrete face rockfill dam can be considered.

In Aug, 2011, preliminary testing report after carrying out the laboratory investigation of drilled cores obtained from drill holes in the dam area were received. Only four samples which survived after performing the tests on wave velocity in saturated state could be tested for uni-axial compressive strength (UCS) & deformability from the one rock sample (two failed in first loading itself) out of the eight prepared samples.

It was seen that no sample of the drill cores in sandstone (coarse grained), retained its shape, after being tested for wave velocity in saturated state, as it started getting disintegrated from the corners and finally collapsed in saturation device before performing either the tri-axial compression test or the UCS & deformability test. The rock samples of claystone (Brownish & Reddish) had disintegrated on saturation. The same situation was noticed in the samples taken in sandstone from the location of intake structure.

From the constructional material survey study carried out, it was found that the borrow areas for clay material of required quality and quantity for the construction of core of rockfill dam are located at a distance more than 100 km from proposed dam site.

These reports of GSI and CSMRS and the inferences drawn therein were discussed at length between CWC, CSMRS and GSI. Based on the laboratory investigation results, it was concluded that the site is not suitable for a concrete gravity dam. As regards a rockfill dam, the borrow area for clay material required for construction of core of rock fill dam is not available close to the dam site. As per the report, it is found to be located more than 100 km away from proposed dam site.

3. CFRD OPTION : AN ALTERNATIVE TO CLAY CORE ROCKFILL DAM

As an alternative to conventional central clay core rockfill dam, possibility of CFRD was also explored. While CFRD has been designed and constructed world over, in India, the only dam completed is Dhauliganga project in Uttarakhand by NHPC, though many such dams have been proposed in the DPR for adoption in other projects in the country. *ICOLD Bulletin No. 141 on "Concrete Face Rockfill Dams-Concepts for Design and Construction*" provide guidelines in respect of design and construction aspects and the merits and demerits.

The project location according to BIS falls under Seismic Zone – IV. In a CFRD, all of the zoned rockfill being downstream of the water barrier, the entire rockfill is dry, hence the earthquake shaking cannot cause internal pore water pressure. The conditions of high shear strength, no pore pressure, and small settlement under seismic loading make the zoned rockfill inherently resistant to seismic loading. The only credible mechanism of failure of a CFRD founded on rock is erosion by sustained overtopping flow. Hydrology, spillway, and freeboard design is the response to this risk. Piping of the foundation is a potential mode of failure as a result of the increasing use of CFRDs on weathered rock and alluvial foundations.

On various considerations, it could be concluded that a concrete face rockfill dam is a feasible technical alternative to conventional central clay core rockfill dam in the instant case. The plan of the concrete face rockfill dam and typical section proposed for the project is shown in *Figures 1* and *2* respectively.

4. COST COMPARISON

A cost comparison study at 2012 price level was therefore carried out between these two types of rockfill dams. It was found that in the instant case, the quantity of rockfill required for a conventional rockfill dam with central clay core works out to be more than twice that required in case of a CFRD. A lead of 100 km. was considered for clay core material. Considerable amount of cost in transportation of clay from 100 km distance to the project site (about Rs.204.63 crores) and its compaction (about Rs.85.09 crores) is involved in case of conventional rockfill dam with clay core. On

the whole it could be seen that the overall cost for a conventional clay core rockfill dam is far more than the cost involved in providing a RCC slab on the upstream face of rockfill in case of CFRD for this project.

5. CONCLUSION

Various aspects had to be considered in selecting the choice of dam for the project. The paper has dealt with some of the main considerations. Keeping in view the various considerations, a decision has been taken to adopt a concrete face rockfill dam in the above multi-purpose water resources project.

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REFERENCES

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2. Technical Reports of CWC, GSI and CSMRS on the project

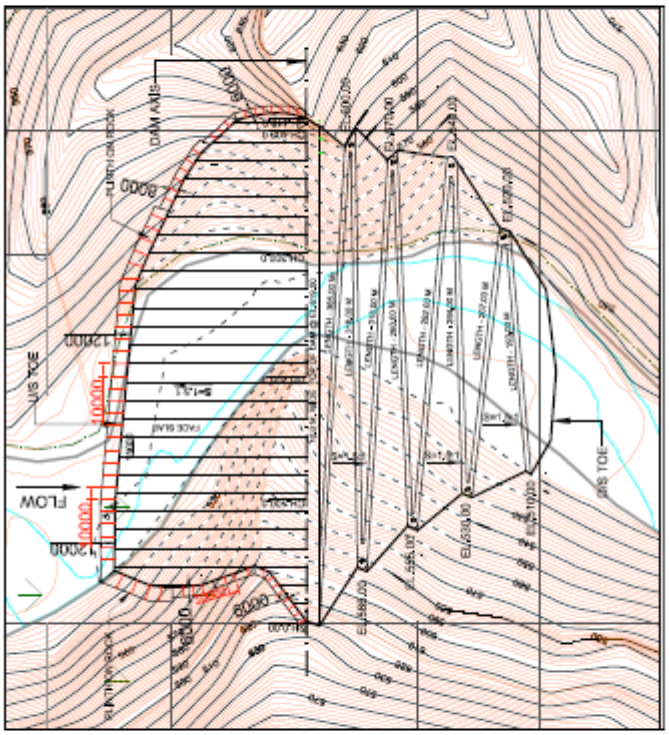

FIG. 1 PLAN OF THE POPOSED CONCRETE FACE ROCKFILL DAM FOR THE PROJECT

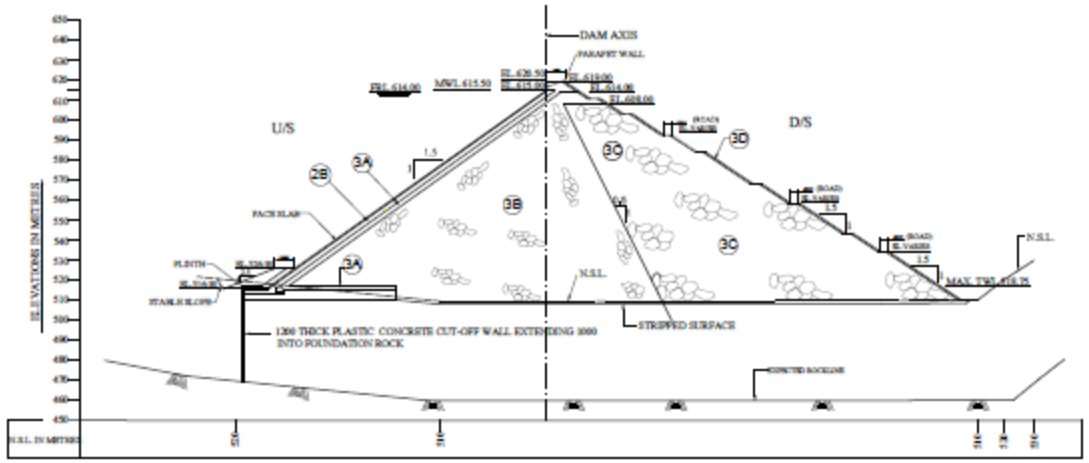

FIG. 2. TYPICAL SECTION OF THE PROPOSED CONCRETE FACE ROCKFILL DAM FOR THE PROJECT

ZONING DETAILS

ZONE	DESCRIPTION	SOURCE	GRADATION			COMPACTION PARAMETERS			
			D MAX (MM)	< 5 MM (%)	< 0.1 MM (%)	LAYER TH.(CM)	NO. OF PASSES	WATER CONTENT %	ROLLER (t)
1A	SILTY FINE SAND		--	--	--	20	--	--	BY CONSTRUCTION EQUIPMENT
1B	RANDOM FILL		--	--	--	40	4	--	10
2A	PROCESSED FINE FILTER	PROCESSED FROM QUARRY	40	35-60	5-10	20	--	--	BY MANUAL VIBRATOR
2B	PROCESSED FILTER	PROCESSED FROM QUARRY	100	35-45	4-7	30	4	--	10
3A	TRANSITION (PROCESSED ROCKFILL)	EXCAVATION FROM QUARRY	300	20-30	<5	30	6	25	10
3B	MAJOR ROCK FILL (MAIN FILL)	EXCAVATION FROM QUARRY	600	4-15	<5	60	4	25	10
3C	ROCKFILL OR GRAVEL	EXCAVATION FROM QUARRY	600	<20	<5	100	4	--	10
3D	OVERSIZE BOULDER	EXCAVATION FROM QUARRY	--	--	--	--	--	--	--