02 Jun 1988, 10:30 am - 3:00 pm

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Proceedings: Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, 1988, St. Louis, Mo., Paper No. 2.28

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SYNOPSIS: The valve house of the Tons Hydel Project, Madhya Pradesh, India is located just adjacent to a steep escarpment. The stability analysis of scarp near the valve house was made by the Central Water and Power Research Station, using finite element method. The problem was treated as a plain strain case. The analysis under self weight and with seepage forces indicated tensile stresses less than 4 kg/cm^2 in the scarp. A proposal by the project authorities namely removing rock in the area above R.L.230 m at 74 degrees and filling lean concrete below the overhang was found to provide a stable condition. The state of stress in the scarp near the valve house was obtained under different conditions. The finite element method thus proved to be a very useful tool in analysisng problem

INTRODUCTION

Bansagar-Tons hydel project is located at a distance of about 45km, from Rewa town, in Madhya Pradesh, India, shown in fig. 1. The rivers Tons and Beehar, after their confluence, flow into the Gangetic plains. Downstream of the confluence there are a series of Cascade falls within a short reach of 8 kms. Use is made of this natural topography which provides a gross head of 180 m for the generation of power. However, there are no suitable sites on rivers Beehar and Tons for storage reservoirs and during postmonsoon periods sufficient water is not available for power generation. To overcome this difficulty water from Bansagar multipurpose project (on Sone river) is diverted into the Tons-Beehar valley. This accumulated water at

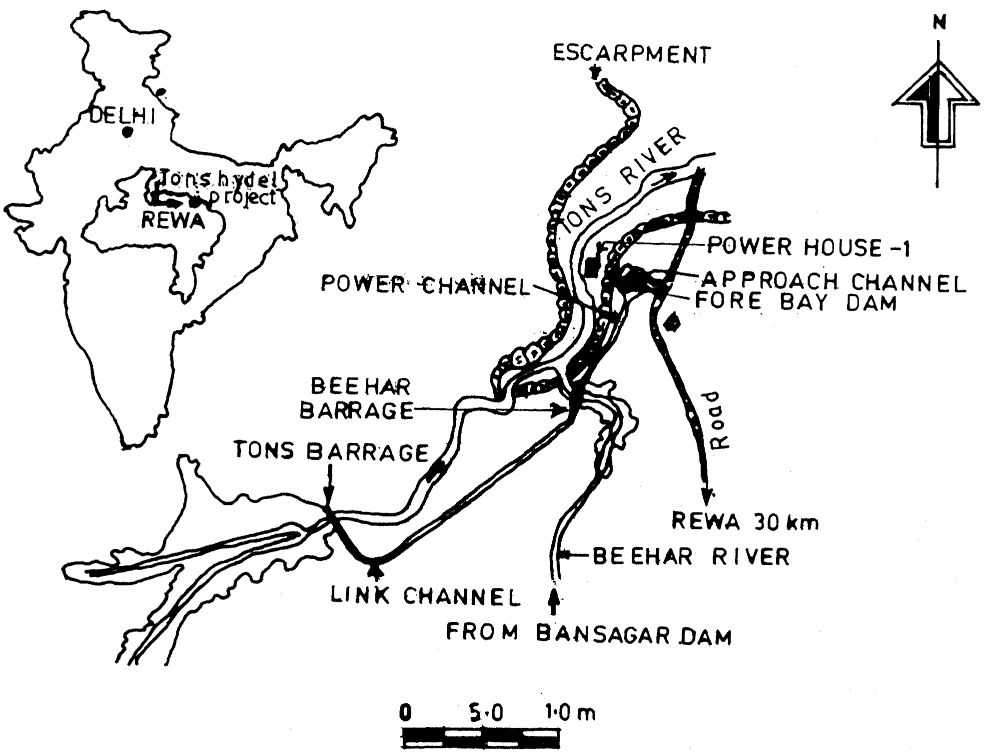

Fig 1 : Index Map of Tons Hydel Project, Madhya Pradesh, India.

Beehar barrage and water from Tons river is taken through 9.4 km long power channel to Forebay dam and from here regulated discharge is released through a 310 m long power tunnel trifurcating into three steel lined penstocks leading to valve house located at the foot of the Rewa scarp. In order to ensure the safety of the valve house against any rock fall, the stability of the escarpment was investigated.

Geology of Rewa Scarp (Ref.1)

Rewa scarp lying on the northern gentle limb of Rewa syncline, exposing Rewa formation of the Upper Vindhyan group, overlooking Tons valley at valve house consists of unusual 'Concave slope' segment at crown and pronounced overhang with 'acute convex segment association' of magnitude of about 15 m. The scarp is composed of blocky rock mass of sandstone belonging to Rewa formation of Upper Vindhyan group. This sandstone at places rests on shale formation.

The unusual morphology of the scarp with concave slope close to crown, is attributed to the occurrence of swallow/absorption points along joints. The scarp is under process of active erosion, the factors causing this process are fractures, phenomenon of valley relief, run-off, infiltration and seepage, chemical weathering of heterogenous cross beds, etc. There were broadly three rock zones in the scarp vide fig. 2 which could be assigned values of modulus of elasticity (E) based on the strength rating (Ref.1)

a) Massive coarse grained sandstone with large scale cross stratifications having through spatulate confining beds and heterogenous fine grained lithology with open joints,

$E= 0.1 \times 10^6$ kg/cm^2

b) Moderately bedded, medium grained sandstone with flat beddings and lenticular intercalations

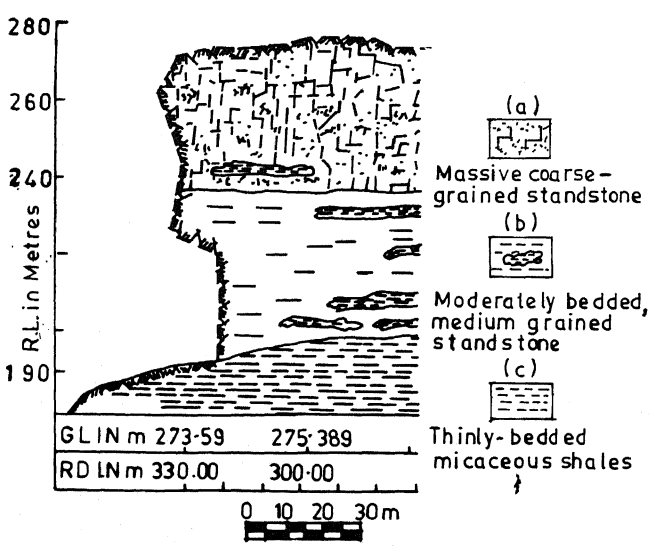

Fig.2 Geological Section of Escarpment

of shale

$E=0.8 \times 10^5$ kg/cm^2

c) Thinly bedded, reddish brown, chocolate and greenish grey coloured micaceous shales with massive silt stone units and lenticular bands of sand stone.

$E= 0.4 \times 10^5$ kg/cm^2

ANALYSIS OF THE PROBLEM

The problem was studied by finite element method (Ref 3) treating it as plain strain case, using eight noded isoparametric elements. The escarpment structure was discretized into 160 elements incorporating 533 nodes. The detailed idealised model incorporating the extent of scarp near the valve house is shown in fig.3.

While the Young's Modulus values for the three zones were adopted as indicated earlier, density of rock for all the layers was assumed to be 0.0025 kg/cm^3 and Poisson's ratio was taken to be 0.2. The studies were carried out for the following loading conditions

i) Scarp under self weight
ii) Scarp under self weight with seepage forces

From results of the above cases it is seen that the maximum tension is of the order of 4 kg/cm^2. It was also observed that the effect of seepage was insignificant. However, since valve house is an important component in power generation system where discharge is controlled, its failure would seriously affect the power generation. As such an alternative proposal was suggested by the project authorities. This proposal envisaged removal of some overhanging rock at 74 degrees above R.L.230 m and concrete filling below overhang as shown in fig 4. This modified proposal was also investigated. The variation of tensile stresses on the outer face of the scarp near overhang, under existing condition and with the proposal by project authorities is shown in fig.5. The idealised model of this proposal is shown in fig.6. The results obtained for all these cases are shown in table below.

Deitails of cases studied	Max.Tensile Stress kg/cm^2	Max.shear Stress kg/cm^2
1. Escarpment under self weight	3.97 (Element 71) Fig-3	8.59 (Element 61) Fig-3
2. Escarpment with concrete filling below overhang and removal of some of the portion of the overhang at 74 degree	1.95 (Element 62) Fig-5	4.18 (Element 10) Fig-5

Sliding Stability Check

The above check (Ref.3) for the escarpment was made from the principal stresses obtained by finite element analysis and assuming plane of failure 45,60 and 74 degrees with the

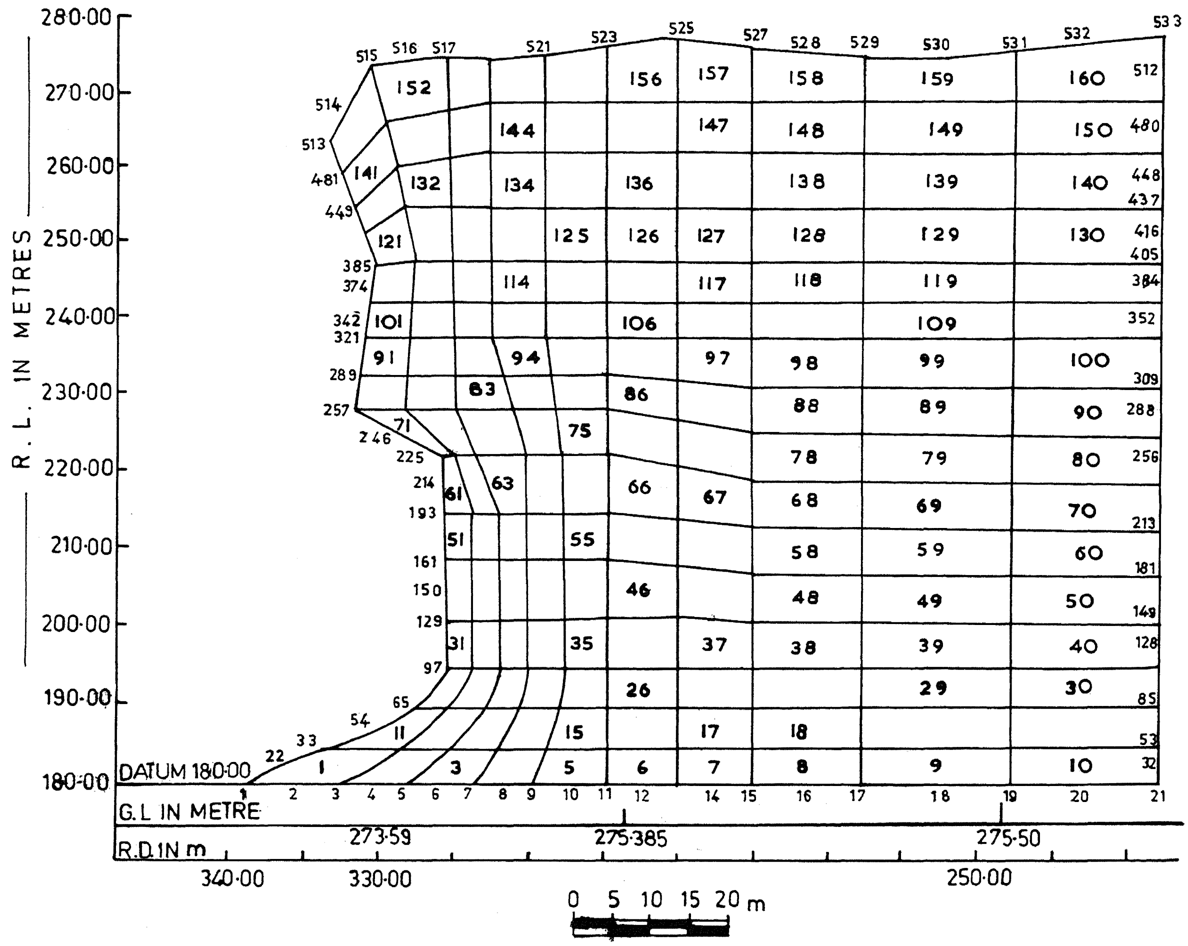

Fig.3 Finite Element Idealisation For Escarpment Near Valve House

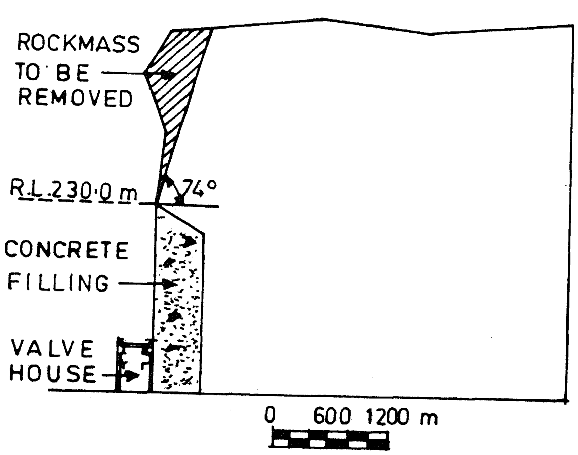

Fig.4 A Proposal by Project Authorities

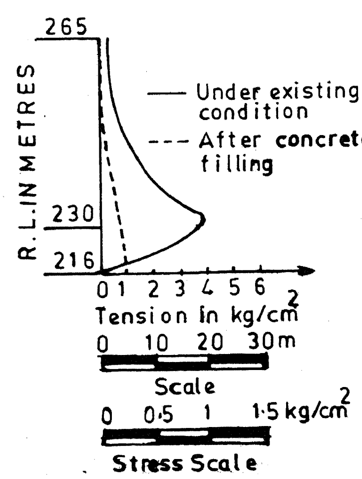

Fig.5 Variation of Tensile Stresses at The Outer Face of Scarp near Overhang

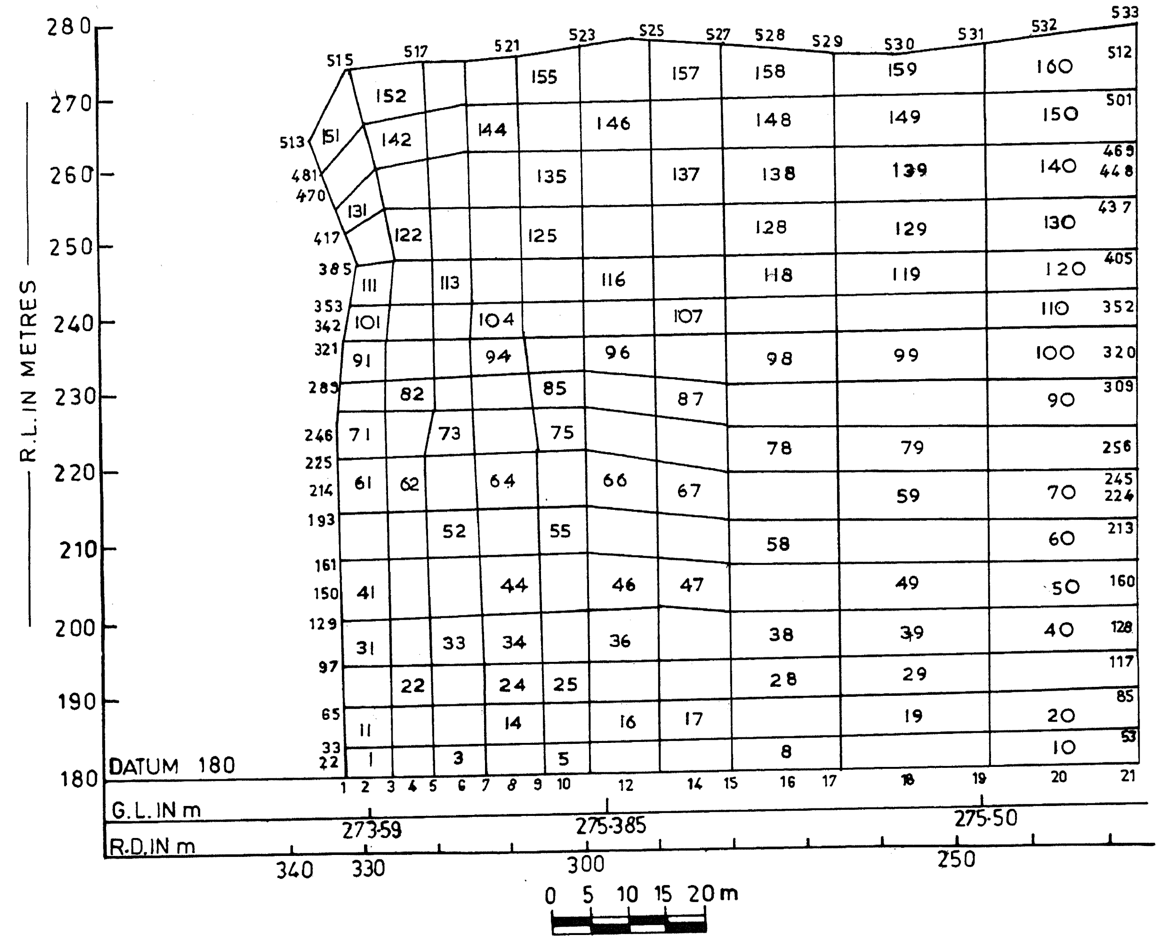

Fig.6 Finite Element Idealisation For Escarpment (Near Valve House) with Concrete Filling below Overhang

horizontal. The ratio of shear strength/shear stress obtained for all the cases was more than one indicating that there will not be any sliding failure.

DISCUSSION OF RESULTS

The results are presented in table. Studies indicate that the values of tensile stresses under different conditions are small. The effect of seepage on the state of stress in the scarp is also insignificant. Stability of the escarpment was examined from the point of sliding stability along the different assumed planes of failure i.e.45,60 and 74 degrees. For all these conditions factor of safety obtained was more than 1.5 for the assumed value of angle of friction equal to 45 degree and cohesion 5 kg/cm^2. The shear and tensile stresses are further reduced for the case where some of the overhanging portion of the rock is removed and concrete filled under the overhang.

REMEDIAL MEASURES

In order to ensure the stability of the scarp, the proposal as suggested by the project authorities, of removing the rock above R.L.230 m at 74 degrees was found to provide quite a stable condition for the scarp. It was also recommended that shallow anchoring by few rock bolts above R.L.230 m would be effective to prevent any local rock fall on the valve house. Further to reduce the effects of seepage forces suitable drainage system for diverting the surface runoff through the stream draining the scarp area was suggested. It was also advised to make ample provision for draining the interface of concrete and rock for releasing water pressure behind the concrete.

CONCLUSION

The two dimensional analysis using finite element method helped in understanding stability of the scarp and suggesting strengthening measures.

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