सिञ्चतु माता मही रसा नः

Landslide Blockade on the River Satluj and its Removal by Underwater Blasting

Rajiv Badal
V.M. Sharma
K. Venkatachalam
A.K. Dhawan
R.B. Singh

Central Soil and Materials Research Station
New Delhi - 110 016, India
Fax: (11) 6853108, Tel. No: 663140-43

ABSTRACT

Blockade of rivers by landslides have been causing a lot of suffering to the human beings from times immemorial. The damage is further aggravated if the blockade is in the vicinity of a River valley project. The Sanjay Vidyut Pariyojna (Bhaba Project) located in Kinnaur District, Himachal Pradesh is one of such examples. It is a run of the river scheme located on the right bank of river Satluj utilising the water of Bhaba Khad, a tributary of Satluj river. The landslide blockade near the project caused flooding of the power house and interrupted the power generation in the project. Various factors responsible for the landslide and blockade of river have been studied. A strategic program of surface and underwater blasting was adopted to remove the blockade and restart the power generation. The paper presents the above aspects in brief.

Key Words: Landslide blockade, flooding, underwater blasting, trenching

1.0 INTRODUCTION

A large scale landslide blockade between the existing Sanjay Vidyut Pariyojna- Bhaba power house and the proposed Nathpa Jakhri dam site on the river Satluj took place on 8th July, 93 around 1430 hrs. (Fig. 1). This blockade created a huge artificial reservoir which in turn flooded the power house through its tail race tunnel. The power generation was suspended immediately due to the submergence of most of the power generating units. This was of immediate concern to the Himachal Pradesh State Electricity Board (H.P.S.E.B.) as they were incurring a direct loss of about three million rupees per day due to the non-generation of electricity. Hence the H.P.S.E.B. was trying hard for an early removal of blockade to resume power generation. In view of above, a team consisting of experts from Central Soil and Materials Research station and specialised divers from Indian Navy visited the blockade site and took up the task for removal of the blockade by surface as well as under water blasting operations in consultation with the project authorities.

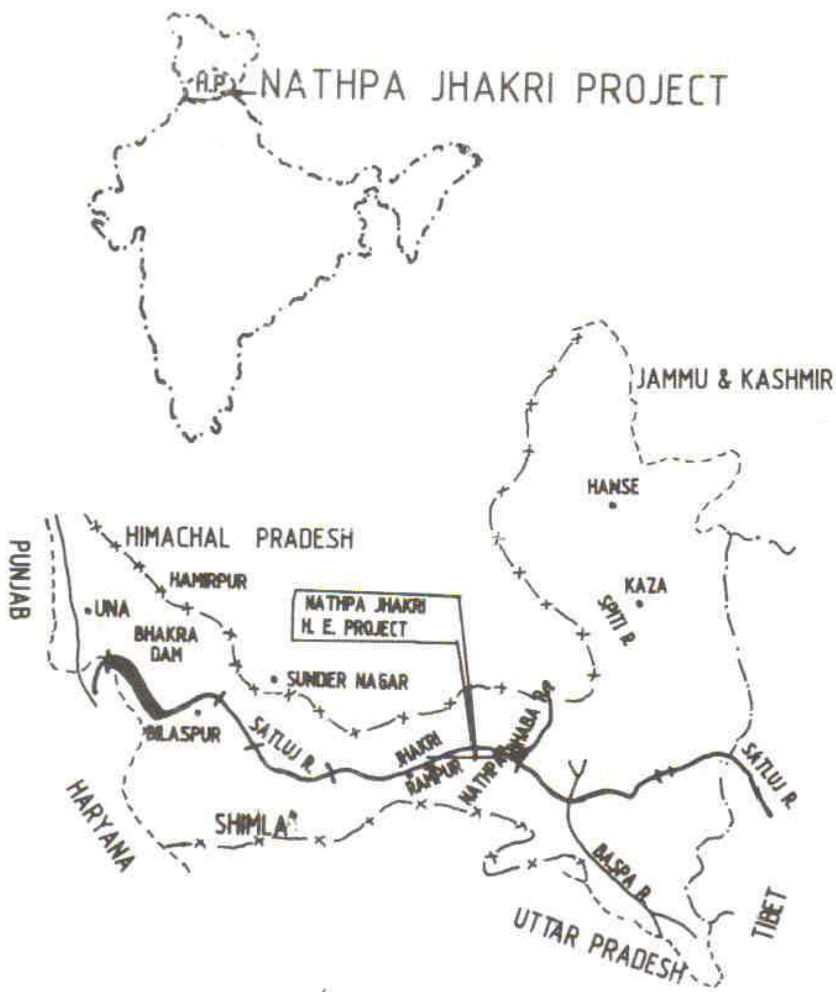

FIGURE 1 Location Map of Sanjay Vidyut Pariyojana and Nathpa Jhakri Project

2.0 GEOLOGICAL FORMATIONS OF THE BLOCKADE SITE

The rock formation exposed in the area and its vicinity belong to Precambrian (Proterozoic) age, which are essentially metamorphic rocks with acid and basic intrusion. In Jeori-Wangtu area, the rocks exposed belong to Jeori Gneissic complex (Bhargava, 1980) comprising gneiss, augen gneiss, quartz mica schist, biotite schist with intrusive granite, apatite, pegmatite quartz veins and metabasic (ambhibolite). The rocks at the project area, the Jeori Gneissic complex, are bounded to the east (upstream end) by Jutogh thrust now designated as Main Central Thrust (MCT) and to the west (downstream end) by a thrust fault near Rampur which brings these rocks over Rampur group of rocks. Figure 2 shows the geological formations exposed at the site of the landslide.

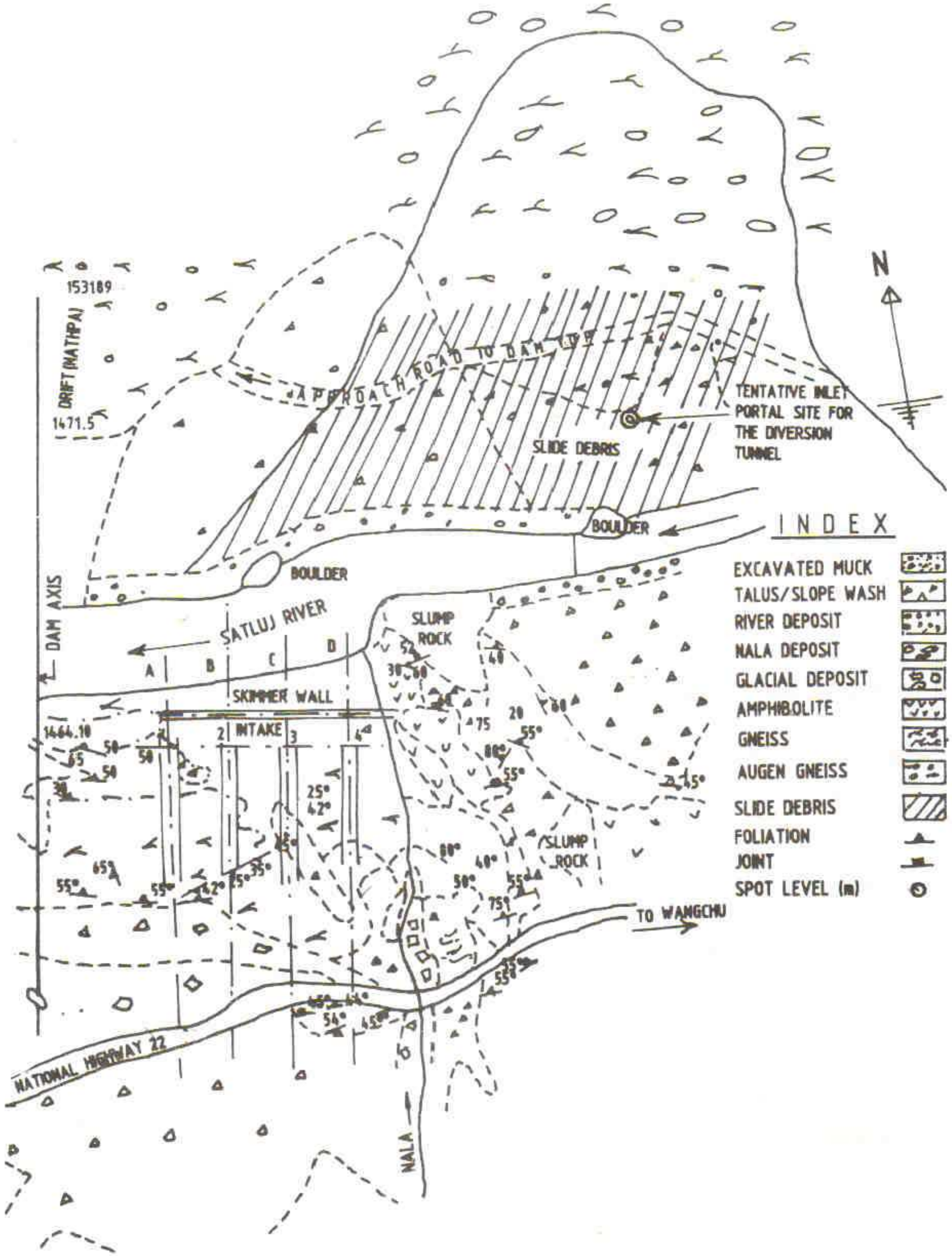

FIGURE 2 Geological Map of Intake Area of Nathpa, Dam

The rock formation is highly jointed and contains four major sets of joints in the areas indicated below:

Set No. 1 : Foliation joints striking NW-SE to E-W with a dip ranging from 30° - 70° towards N

Set No. 2 : Joint striking N-S with dip vertical to sub-vertical

Set No. 3 : Joint striking NW-SW with dip 45° towards SE.

Set No. 4 : Joint striking NEN-SWS with sub-vertical dip.

The most prominent joints observed on the exposed area of the slide are the foliation joints (Set No. 1) which are in general moderately/closely foliated and some of them are sheared. The second prominent set of joints observed are gently dipping with the direction S-E (Set No. 3). These joints are clay filled and frequently show seepage of water. These joints are exposed as planes and rock mass had a tendency to move along these joints. The joints of Set No. 1 and Set No. 3 intersect to form blocks with the help of third joint (Set No. 2) which strike N-S and are vertical to sub vertical. The blocks formed due to intersection of these three sets of joints along the valley dipping joints (Set No. 3).

3.0 DESCRIPTION OF RIVER BLOCKADE

On the 8th July, 1993 around 1430 hrs. a huge rock mass of about one million cubic meters from a height between 50 to 300 m above the river bed slided down and blocked the Satluj river. This occurred between 100 and 325 m upstream of the proposed Nathpa dam site and about 850 m down stream of Bhaba Power House. The massive rock slide created an artificial reservoir across the river Satluj. The reservoir was approximately 2 km in length and 100 m to 250 m in width. The depth of accumulated water at the blockade site was about 35 m. A view of this artificial reservoir and landslide is shown in Figures 3 and 4. The rise in water level resulted in flooding of the power house through the tail race tunnel (Figure 5). Further the link between NH-22 and power house through Bailey bridge was cut off and the road over the tail race tunnel in front of the power house got submerged. Some store sheds on the left side of river were submerged. Due to rise of water level in the mentioned artificial reservoir, the road between Wangtu and the power house on the right bank also breached at a point near a Glacier Nala.

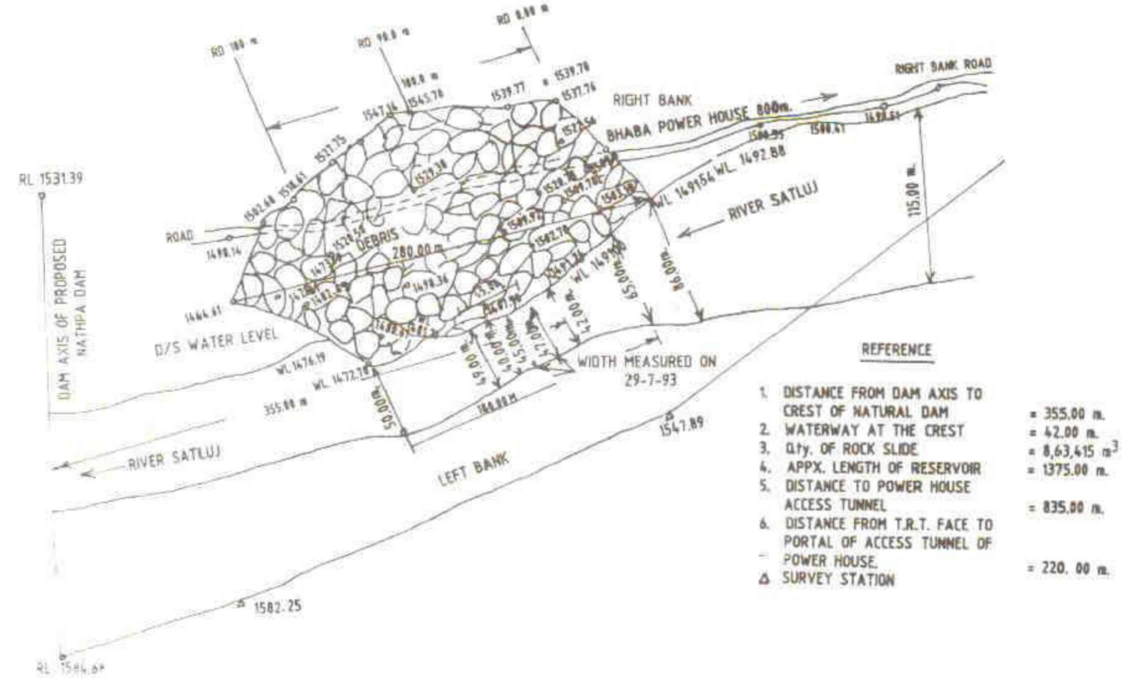

FIGURE 3 Plan Showing Debris on River Satluj u/s of Dam Axis at Nathpa

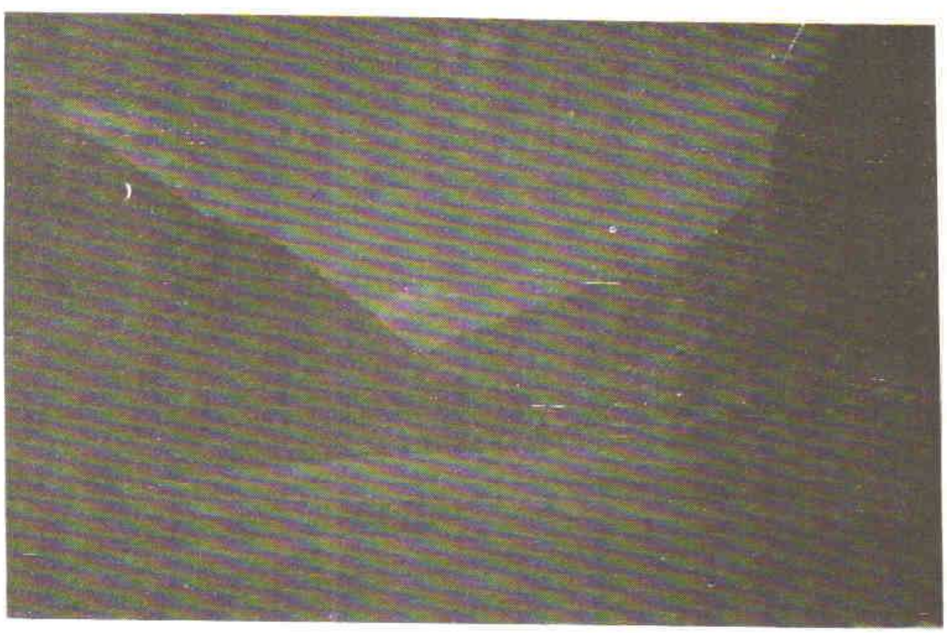

FIGURE 4 Reservoir from Lake Slide

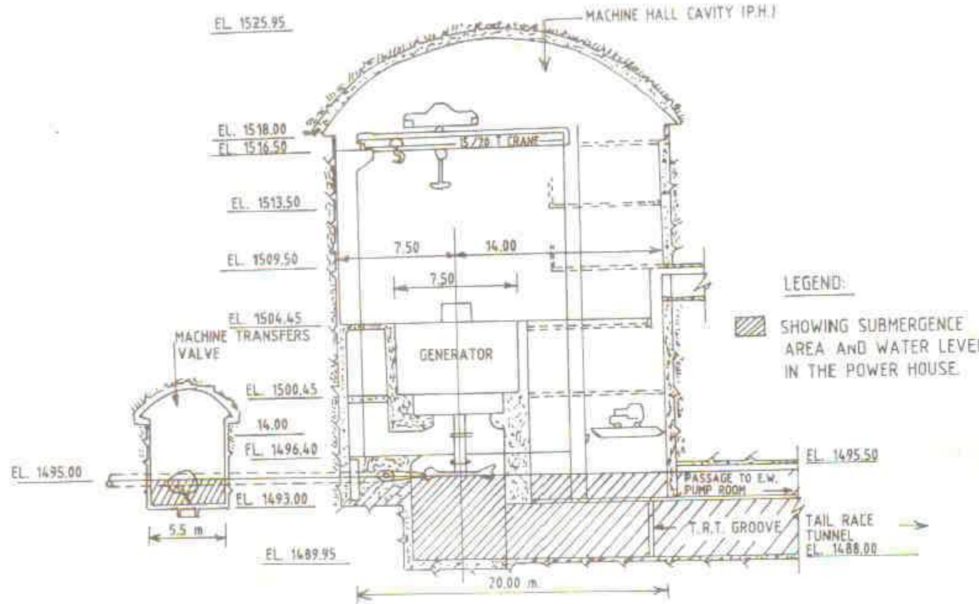

FIGURE 5 Water Level in Power House

4.0 STRENGTH AND DEFORMATION CHARACTERISTICS OF GNEISSIC ROCKS

The area from where the slide had taken place consisted mainly of weathered augen gneisses with pegmatic veins which were moderately foliated and blocky in nature. The strength and modulus values found by testing of intact samples of gneiss rock showed that these values were dependent on the orientation of foliation. In addition, the unconfined compressive strength values varied between 22.2 to 113.9 Mpa under dry condition and between 9.0 to 80.6 Mpa under saturated condition. The values of cohesion (c) varied between 1.15 to 4.0 Mpa and the values of angle of shearing resistance varied between 57.2° to 64.2° (CSMRS Report 1988).

5.0 FACTORS RESPONSIBLE FOR LANDSLIDE AND BLOCKADE

At the proposed Nathpa Dam site, the river Satluj flows through a narrow gorge with right valley slope rising to a height of about thousand meters at a slope ranging between 60° to 70° from the horizontal. It is said that the slope was in a state of high stresses and development of a set of stress relief joints was also observed in the recent past. The left abutment slope is found to be gentle. The width of river is about 40m. The physiographic setting of the river valley was responsible for landslide blockade as indicated in section 2.

The stereographic plot of geological discontinuities of the right bank of the river also showed that it was not stable. It is presumed that the orientation, the persistence and the spacing of the four dominating discontinuities had major influence on the whole phenomena of the slide. The stress relief joints and other discontinuities had permitted the rain water to percolate through the joints. This resulted in reduction of cohesive strength along the joint planes. In addition to this, the rock mass was completely weathered at the surface and along the joints planes forming the wedge. Moreover the whole wedge was making a steep angle almost parallel to the river valley. The reduction in the frictional strength of the discontinuities and the gravitational forces resulted in the downward movement of the wedge. Also, the removal of toe by uncontrolled blasting for the construction of road also disturbed the state of equilibrium of this highly stressed hill slope.

6.0 BLASTING OPERATIONS

Underwater blasting refers to blasting where the ground is fully or mostly covered by water. Underwater blasting operation needs more precautions as compared to surface and sub surface blasting. The various explosives used, explosive factor adopted and techniques adopted for the removal of mentioned blockade are briefly described below.

6.1 Explosives and Accessories

Explosives for underwater blasting should have the properties such as water resistance, high density, high bulk strength, low susceptibility to sympathetic detonation and very low sensitivity towards high hydrostatic and blast generated pressure. Considering the above aspects. Nitroglycerine based gelatinous explosives of small diameter of 25 mm and large diameter of 83 mm were used. The density of these explosives varied from 1.25 to 1.30 g/cm^3. Detonation velocity of these explosives varied from 4000 to 4500 m/sec. In general, underwater initiation is achieved by the combination of electric detonators and detonating cord. In the present case for initiation of detonating cords, electric/plain detonators were used. However, to control rock throw on different trajectories, delay detonators were used.

6.2 Explosive Factor

The explosive consumption per ton or per cubic meter of rocks is always an indication of rock condition. In general, if the number of available free faces are low, the explosive consumption for breaking and loosening the burden is likely to be very high. However in arriving at the explosive factor, the rock condition, blast geometry and rock displacement have been considered together so as to optimise the blasting operations. Based on the above explosive factors of 1.0 kg/m^3 for the rock on surface and 2.3 to 2.5 kg/m^3 for underwater rock blasting were used for digging a channel on the right bank of the river.

6.3 Techniques Adopted

In general, drilling and blasting practice is employed for the blasting of underwater rock. However, in the present case since the rock was already broken into big boulders, it was difficult to adopt the above technique to remove blockade. In addition, approach to the site to deploy the heavy earth moving machines was also feasible. To overcome the above difficulties and to remove the blockade on a time bound basis, the following techniques were adopted.

- Under water trenching
- Mud capping and plaster shooting with direction throw
- Over casting of the boulders
- Pipe charges

Underwater Trenching : Since the approach from the left bank was not safe ·as decided to carry out all the blasting operation from the right bank and mid stream of the rover. The attempt was to dig a reservoir channel. To carry out the trenching operations in the right bank, bundles of explosives of 20 to 25 kg, properly tightened with protruding ropes were prepared (Fig.6). Using this protruding ropes, these bundles were tied to the main rope an interval of 2 m so as to control the placement locations against the actions of swift water current (Fig.7). Insofar as the mid- stream is concerned, considering the very high water current, pulley and wire rope was used to place the explosive at the desired locations. The photograph taken immediately after the mid-stream underwater blasting operation is presented in Fig.8.

Mud Capping and Plaster Shooting with Direction throw : In this technique, the charge was applied on the boulders in such a way that the explosive make a good contact with the face of boulder and mud was used to cap the charge. The quantity of charge required was decided based on the shape of the boulders. The direction of the movement or throw of the rock boulders was equally important. Considering the importance of direction of movement or throw of the rock boulders immediately after blasting, at the time of placement of charge, a proper trajectory for throw of each boulder was imagined to give the desired destiny and this technique was found to be a success.

Over-casting of the Boulders : Normally, the technique of over casting is employed for

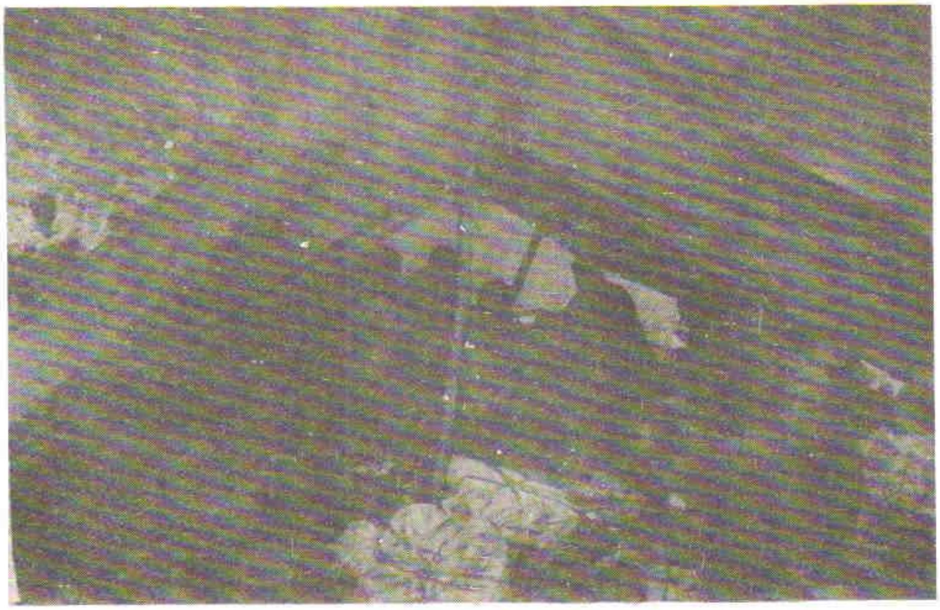

FIGURE 6 Charge Preperation for Underwater Blasting

FIGURE 7 Underwater Charge Placement at the Right Bank

FIGURE 8 Underwater Blasting in Midstream of the River

handling of over burden from each face to spoils by using explosives. In the present case, the initial plan was to use a big explosive operation of over casting for removal of the blockade. But considering the in-situ limitations, this technique was used mainly for shifting of the big boulders to increase the space so that the water flow through the blockade could be improved.

Pipe Charges : A special type of mild steel sheet slotted pipe of approximately 170 mm diameter and 3500 mm in length was fabricated and an additional support of steel rods was provided to strengthen the pipes. These pipes were filled with the gelatinous explosive of 1.3 g/cm^3 to excavate a trench under water of about 2 m width, 2.5 m deep and 5.5 m in length from each pipe charge per round of operation in over topping water. However, this technique could give only a little success in view of very heavy water current.

7.0 CONCLUSIONS

Adopting the above mentioned techniques, the blockade could be successfully removed to the required depth and the power generation of Bhaba power house restarted on 8th September, 1993. Considering the factors responsible for such slides and the problems created by slides when they block the rivers, it is suggested that a through investigation of the slopes on the banks should be done for their stability and wherever considered necessary slope of rock mass should be stabilized by shotcrete/rock anchors so as to minimise such slides in future particularly in the vicinity of the river valley project.

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