Impact of Landslides on the Construction Schedule of a Major Hydro Power Project in the Lesser Himalayas, Jammu & Kashmir, India

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Abstract

The unprecedented snow fall and rains in Chenab valley and the following floods generated a series of landslides in the project area, jeopardizing the river diversion system and concrete pouring system; besides the approach roads and bridge etc. The paper enumerates the colossal loss and generates a discussion on the site specific studies and measures needed for mass movements in hydro power projects.

Introduction

The Chenab valley, of the Indus River System, with a hydropower potential of 11400 MW is being systematically harnessed with a number of cascading projects. Baglihar hydroelectric project with an installed capacity of 900 MW, internationally known for its lineage to the Indus Treaty with Pakistan, is developed in two stages of 450 MW each with two sets of water conductor systems, one dam complex and one power house complex. The Stage-I of the project, is in the active stage of construction since 1999, under an EPC contract by JKPDC with Jaiprakash Associates Ltd. The 144.5m high concrete gravity dam with the associated 9.5m dia; 2069 m long Head Race Tunnel (HRT), under ground power house complex with three large cavities and a short TRT of 120 m is in the advanced stage of construction with a schedule of 54 months.

The unprecedented heavy rains and snow fall experienced in the Chenab Valley from January to March 2005, and the subsequent snow melting due to steep rise in ambient temperatures, and probably due to breaches of blockades due to water rising in some tributaries, brought in flash floods from normal 3900 cumecs to 6000 cumecs for a short duration. The unprecedented floods played havoc at the dam site of Baglihar HE project. Besides the colossal loss, in terms of damages to the appurtenant and logistic structures for the dam like river diversion arrangement, concrete pouring system (cable cranes), approach roads and bridge etc., a series of landslides occurred on valley slope, which have caused an inordinate delay in the construction schedule of the project.

Sequence of Incidents

- In June 2005, the flood discharge at the Dam site was recorded as 3900 cumecs which rose to 6000 cumecs for a short duration.
- On 1st July' 05 the river water rose to El 762.8m from the river bed causing large scale landslides on right bank slopes (Slide 1) and road failures due to under scouring and erosion of the left bank along the river section (Photo-2, 2.a).
- On 2nd July' 05 the floods by-passed the left abutment of the steel bridge located 500 m downstream of the dam leading to its collapse (Photo 2.a).

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- On 3rd July' 05 the water level in the river rose up to about El 763m which went down by about 29m to El 734m in the following few days.

- On 5th July' 05 the subsequent sudden drawdown of 24m in the reservoir level (from El 758m to 734m) in a short span of just 24 hours caused a landslide (2A) of about 50,000 m^3 over the intake portal of diversion tunnel 2 (DT-2), causing blockade/ choking of the intake of DT-2 on the right bank (Photo-1).

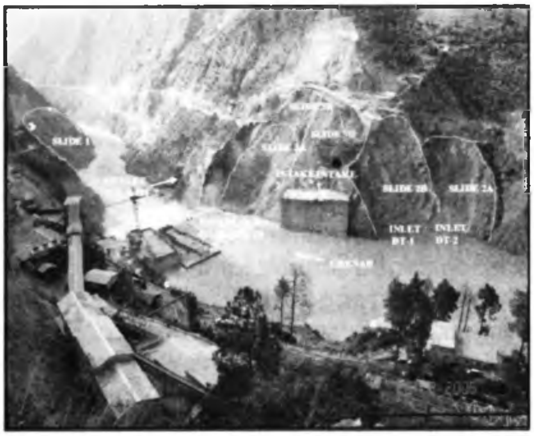

Photo-1: Panoramic view of dam site showing the recent landslides

- On 7th July' 05 a high flood of 6000 cumecs was again recorded followed by a fast recession in the river water level.

Photo-2: Damages to roads left bank

- On 14th August '05 another slide, of over 1 lakh m^3, (Slide-2B) occurred in the quartzite rocks. As a result, the U/S end of tail track concrete block got detached and slided down blocking the portal of DT-1 (Photos-1 & 3).

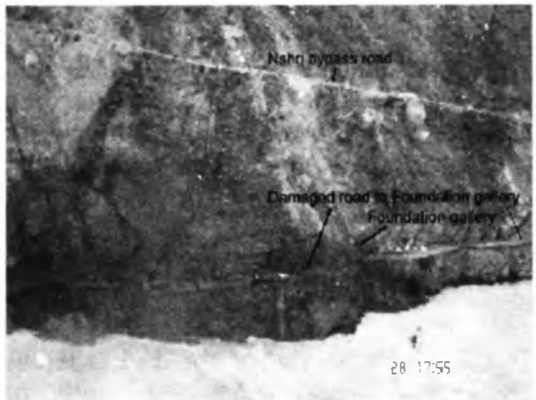

Photo 2.a: Damage to road and bridge

- The river, which was flowing through DT-1 since 5th July '05 started rising and over-topped the under construction dam blocks 11–14 (El 760m) located close to right abutment.

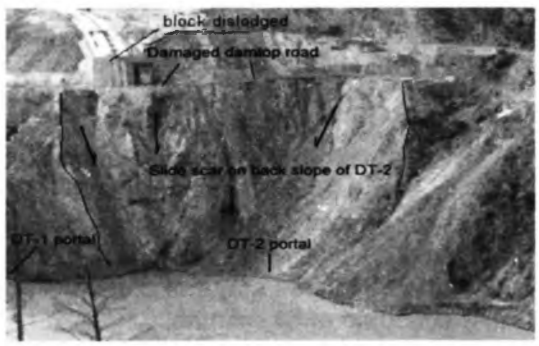

Photo-3: Right bank - Back slope of DT inlet portals with multiple slides

- The created water fall of about 45m due to overtopping eroded the toe of the right abutment hill slope, as a result, a huge landslide (Slide-3A) of over 1 lakh m^3 occurred with a crest at a height of about 110m above the river bed level (Photo-1).

The slide (Slide-3B) undermined the foundation for the tail track of the concrete pouring system with 3 cable cranes. Transverse cracks in the concrete (Photo-4) and longitudinal cracks on the hill side/ behind the track were developed due to settlement in debris reach (Slide-3C).

Photo-4: Transverse cracks in the tail-track

Besides, movements of the track towards valley side were also noticed. The increasing displacements of the track, monitored with precision instruments, endangered the track getting pulled in to the valley, i.e. over the dam, under the pulling effect of the sagging cables with buckets; and also endangered the material and equipments on the dam body. Two cable cranes had to be dismantled immediately to avert the eventuality of a collapse of the track.

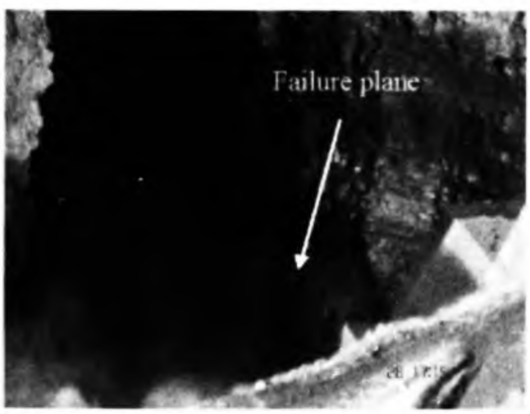

Photo-5: Scoured pit D/S of dam/ plunge pool area

- The falling water continuously for over 6 months, further eroded the D/S vicinity of the right abutment of dam for a depth of +50m in to the abutment and created about 25m deep (conjectural) scoured pit (Photo-5) in the downstream reach/ plunge pool area.

The impact of mass movements on the project was so grave that the work, which was in full-swing at dam site, came to a grinding halt for over 3 months and it is still to pick-up. Alternative make shift arrangements of concrete pouring system were made besides, design reviews for the dam. The staggering loses have been estimated to be about Rs. 250 crores, which includes the increase in the estimated quantity of concrete by over 2 lakh m^3 and a delay of over two years. Nature has put the project far from the essence of time schedule and economy of an EPC contract, in spite of all possible efforts. The project is a victim of the rarest demonstrations of nature.

Hydrology

Analysis of the available daily discharge/ hydrological data at Baglihar dam site indicated the flood discharges in Chenab River during the period from 23.06.2005 to 15.08.2005, to be around 3000 cumecs. There has been a sharp peak with river discharge rising above 6000 cumecs on 6^{th}/ 7^{th} July '05. Just before the peak the river discharge got reduced, which could be attributed to blockades of some tributaries with big slides, avalanches. The subsequent sudden breaches due to increase in river discharge, could have brought in the sharp rise in water levels in the Chenab river resulting into high floods.

Geology

Quartzite (Rm1), thinly foliated phyllitic quartzite (Rm-2) and slates (Rm-3), of Salkahala Group of rocks is exposed at the dam site (Ahmed, 2002). The close proximity of the project to the Muree thrust has posed poor geological conditions. High volumetric joint count (Jv >20), clay-in fillings in joints, presence of shear joints, shear seams, invariable slate partings are some of the striking geological features which has influenced the stability of deep rock cut slopes, foundation for the dam and appurtenant structures. The old/ dormant landslides, in the project area have significantly influenced the stability of cut slopes and in future will influence the siltation of reservoir. Over 55 % of the tail track foundation was on the +35 m thick overburden material of an old slide, on the higher reaches of the right abutment.

The dam seat rests partly on a 80 m wide quartzite band cutting skew to the dam axis by about 20° and partly on the thinly foliated/ phyllitic quartzite with slate bands exposed on the left abutment, in a ratio of 65:35 respectively. Four plus two random sets (Fig 1) of joints noticed at the dam site render a high degree of jointing (Jv) of +20 to the rock

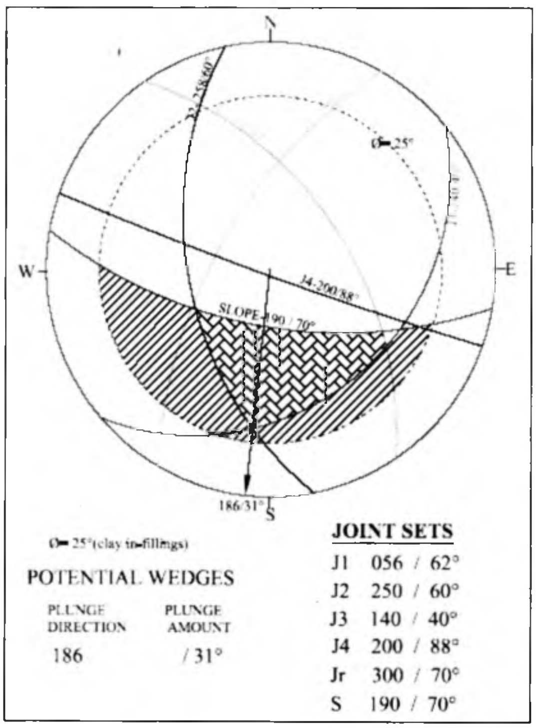

Fig. 1: Stereo-plot of joint sets showing potential wedges

mass, which has not been a favourable feature for the competent rocks like quartzite (Rm-1) (*Op. cit.*, 2002). The steeply dipping foliation joints (+70°) towards the valley have been instrumental in affecting the stability of left abutment hill, in the down stream reaches.

The slope stability analysis has been carried out using FWEDGE and is based on general principles of wedge analysis as laid down by Hoek & Bray (1981).

The right abutment with predominantly Rm -1 rock mass had a natural slope angle of ± 75°. The J_2, J_3 & J_4 joints form wedges (Fig. 1) with a plunge of + 31° towards the valley. Any excavation at the toe of the slope day lighting the J_2 shear joint with slate partings affected the stability of the slope. In order to maintain the stability of the cut slopes, measures like mesh reinforced shotcrete and tensioned rock bolts were taken up progressively with excavation. The right abutment, excavated for housing the auxiliary channels and trough, was fully protected, based on the stability analysis carried out during excavation, with 6 - 8m long Fe 415 and 18m & 25m long high tensile (DWYDAG), pre-stressed, rock bolts in the intake area, downstream reach of dam and higher reaches of abutment (Photo -6).

The poor strength characteristics of slates with shearing, at the contact with the relatively competent quartzite have

Photo 6: View of right abutment showing slide scars and effects on tail track

influenced the stability of slopes in the intake area of diversion tunnels.

It is perhaps one of the rare case of events in the history of river valley development, where a project is the sole victim of mass movements.

Conclusion

Looking at the need of the hour for an accelerated power development programme of our country, the slide events of natural hazards like high floods have posed questions as to how best the site specific mass movement activities for the river valley projects can be studied and measures taken, particularly in the Himalayan region, to minimize the losses and accelerate the completion of project.

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