Geotechnical Evaluation of Dibang Multipurpose Project, Lower Dibang Valley District, Arunachal Pradesh

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Abstract

For generation of 3000 MW of hydroelectric power, a 288 m high rock fill / concrete dam across Dibang River was proposed alongwith a 150 m wide chute spillway, six head race tunnels and underground powerhouse on the right bank. The site under study is located over tightly folded quartzo-feldspathic gneiss and amphibolites belonging to Ithun Formation. Due to polyphase deformation, foliation shows variation. Rocks are highly sheared and closely jointed. This write up describes the geotechnical aspects of the various components of this megahydel project.

Introduction

Dibang Multipurpose Project envisages construction of a 288 m high rock fill/concrete dam across Dibang River, a right bank tributary of Brahmaputra at Munli (28°20'15":95°46'15", 82 P/15) with a 150 m wide chute spillway, six head race tunnels and an underground powerhouse on the right bank for generating 3000 MW of hydroelectric power. Earlier dam axis was suggested at 450 m downstream of Munli (Axis I) – where gneissic rock had been met at both the banks of the river. Subsequently, the dam axis has been shifted further upstream of Munli to accommodate spillway intake, (Axis II). But due to presence of about 70 m thick overburden on left bank (DDH-13), as evidenced from drill data, Axis II has been shifted at about 500 m downstream of Munli (Axis III). The present dam axis (Axis-III) under consideration has been mapped geologically and subsurface exploration in the form of drilling and drifting was carried out for assessing the feasibility of the scheme.

Geology

Quartzofeldspathic gneiss, amphibole gneiss with patches of amphibolite and minor granite comprising the "Ithun Formation" are exposed at the areas around the project site. In general, foliation swings from N 35°W-S 35°E to N 70°W-S 70°E with moderate to steep dip (50°-70°) towards northeast i.e., upstream. However, due to tight folding, foliation dips are highly variable. Rocks of this area bear imprints of three phases of deformation. First generation of deformation (DF_1) affected the compositional layering/banding (S_0) generated during regional metamorphism. Strong transposition lead to parallelism of S_0 to foliation (S_1). Whereas due to second generation of deformation (DF_2) – minor crenulations in schistose rocks and fracture cleavage in gneisses (S_2) have been produced. At places, refraction cleavage was noticed – where alternate competent and incompetent layers are present. Compositional layering in quartzo-feldspathic gneiss exhibit slips along schistosity plane – which suggests strain slip nature of clearage. S_2 plane trends in NW-SE direction with 65° to 80° dip towards SW. Third phase of deformation (DF_3) has produced widely spaced, subvertical to vertical fracture cleavage trending NE-SW to ENE-WSW, with steep (65°-85°) dip towards NW-WNW.

Folds

Three phases of folding are noticed in this area. First generation of folds (F_1) is tight to isoclinal with long drawn out hinge and very high amplitude to wavelength ratio with penetrative axial planer schistosity. Superposition of second phase of folding has caused strong curving of both hinge and axial plane – thus giving rise to hook shaped folds. Second phase folds are open to tight symmetrical to asymmetrical and overturned with broad to straight hinge zone. These folds show variable interlimb angle and wavelength / amplitude ratio. Overturned steeper limb of asymmetrical folds (F_2) are sheared and exhibit dextral to sinistral slip movement. Dibang river flows along the axis of an asymmetrical overturned plunging antiform. The left bank lies on the normal limb, while the right bank is on overturned limb of this fold. Third phase folds (F_3) are open, symmetrical to asymmetrical warps. These folds have variable interlimb angle and very high wavelength to amplitude ratio.

Shears

Axial plane shears and shears parallel to steeper overturned limb of F_2 folds are very common in the area. One major shear zone occurs along the right bank of Dibang river – near Laskar Camp, 0.5 km upstream of proposed underground powerhouse location. Strike length of the shear zone is 80 m and width of this shear zone varies between 20 m – 30 m respectively. Shear planes trend in N 30°W-S 30°E with 50°-55° dip towards SW. Strike continuity on both the directions could not be traced due to thick talus and debris cover. This shear zone is characterised by development of s-c fabric, strong preferred orientation of amphiboles/biotite, development of chlorite and clay, elongated boudinaged and fragmented lithoclasts aligned parallel to shear planes. Slickensides parallel to strike of shear planes are conspicuous in quartzofeldspathic gneiss.

Joints

The following joints have been noticed in these rock masses:-

a) N 35°-70°W-S 35°-70°E strike with 50°-70° dip towards NE, persistent, spacing 10 cm – 1 m, rough, planer, tight, filled with rock fragments at places.

b) N to N10°W-S to S 10°E strike with 60°-80° dip towards W, persistent, spacing 20 cm – 50 cm, rough, planer.

c) N 30° to 70°W-S 30° to 70°E strike with 60°-70° dip towards NE, spacing 20 cm – 40 cm, smooth, planer.

d) N 45°-55°E-S 45°-55°W strike with 50° dip towards S 45°W, spacing 20 cm – 1 m, smooth, planer.

e) E-W strike with 20°-35° dip towards south (Minor).

Geotechnical appraisal

Dam

The proposed dam axis trends in N 68°E-S 68°W and the Dibang river flows in S 22°E direction. Thinly to thickly foliated quartzo-feldspathic gneiss will be the foundation rock for dam and its appurtenant structures. However, thin bands of granite gneiss, amphibole gneiss and pegmatitic gneiss are also present. All the rocks bear imprints of low-grade metamorphism and multiple deformation. A major asymmetrical plunging anticline (45° towards NW) is interpreted along Dibang River, where left abutment falls over normal limb and right abutment over the overturned limb. Seven boreholes were drilled along the dam axis and four drifts alongwith the crosscuts have been excavated to assess the foundation depth and stripping limits. Synopsis of subsurface exploration results are given below.

Subsurface exploration data in the form of drilling and drifting indicate that thickness of overburden are 25 m in riverbed, 3-4 m in left bank and few cm to 13.5 m in right bank. Stripping limit of left and right abutment will vary between 12 m – 20 m and 12 m – 30 m respectively. Joint frequency in bedrock of both abutments are J_4 and J_5. Permeability varies between 1.5 lugeon and 25.32 lugeon indicating mixed flow to turbulent flow condition. Several free flow zones characterised by presence of brecciation,

Boreholes

Hole No.	Location	Ground elevation (m)	Depth Drilled (m)	Bedrock level (m)	Rock type	Features
DDH-18	Left abutment (5203.02E: 4502.79 N)	411.05	80.5	408.05 (3.0)	Quartzo-feldspathic gneiss, amphibolite	Fault at 4 m depth. Brecciation 12-16.5 m Shearing 16.5-21 m Brecciation 28.5-30 m.
DDH-19	Left abutment 5315.39E: 4577.28 N	524.12	90.0	521.12 (3.0)	Granite gneiss with thin bands of amphibolite	Shearing 34.5-43.5 m. Foliation parallel shear.
DDH-20	Riverbed 4998.87E: 4463.04 N	288.60	100.00	263.60 (25.0)	Quartzo-feldspathic gneiss, amphibolite	Highly fragmented rocks 67-71.5 m, 75-77.5 m, 85-87 m, 90-93 m, 94-99 m
DDH-21	Right abutment 4890.87 E: 4409.24 N	306.83	75.0	293.33 (13.5)	Quartzo-feldspathic gneiss with thin bands of amphibole gneiss	Highly shattered rock between 42-46.5 m, 59-60 m
DDH-22	Right abutment 4696.81 E: 4329.77 N	528.86	80.0	515.86 (13.0)	Quartzo-feldspathic gneiss with thin bands of amphibole gneiss	Four brecciated zones 18-19.5 m, 22.5-24 m, 25.5-27 m, 57-58.5 m
DDH-24	Spillway bucket 3800.19E: 3796.34 N	293.297	52.5	284.297 (9.0)	Schistose metabasic rock	Sheared rock. 24.5-31.5 m
DDH-17	Left bank 5040.465 E: 4455.380 N	290.294	42.0	281.874 (8.42)	Quartzo-feldspathic gneiss, amphibole gneiss, schistose amphibolite	

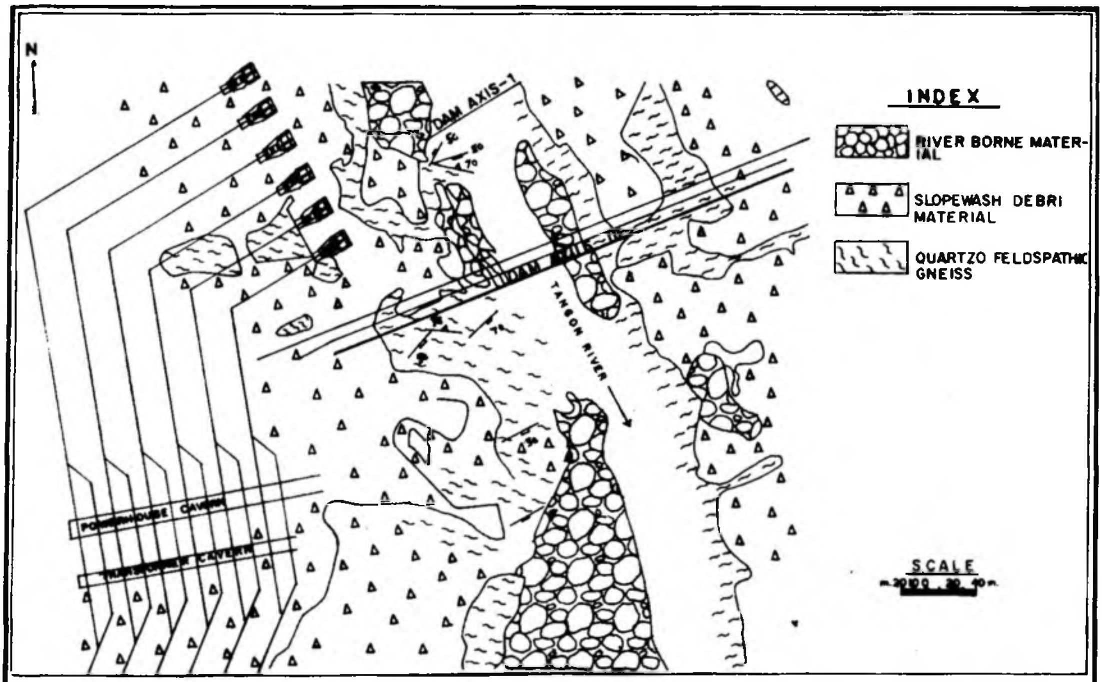
shearing, pulverized / shattered zone and high joint frequency are recorded. Rockmass in left abutment falls in poor to fair category (RMR=29-52) and 'Q' values range between 0.04 and 1.36. Rock condition deteriorates from lower to upper drift. Rockmass in right abutment falls in poor to fair rock category (RMR=29-52) and 'Q' values range between 0.10 and 2.51. Rock condition deteriorates from lower to upper drift. In case of rock fill dam of 288 m height – a central core will be advantageous – as it can provide higher pressure at the contact between core and foundation reducing the possibility of leakage and piping. Fresh rock should be exposed at the core contact area. Positive cut-off upto 1 m depth in fresh rock is to be provided. This holds also good for concrete dam also. It has also been suggested to extend cut-off in abutments upto top of fresh rock. Slopes of both the abutments are to be excavated from top to form moderate slopes by providing

Drifts:

Drift No.	Location	Elevation (m)	Length (m)	Direction	Rockmass characteristics
LDR-3	5160.118E: 4500.832 N	373.905	70	N85^{0}W- S 85^{0}E	Gneissic rock (0-44 m), amphibolite (44-59m), Highly sheared pegmatite (59-63 m), quartzo-feldspathic gneiss (63-70 m). RMR 45-55, Class III, Q=0.464-2.05
U/s crosscut of RDR-3			20	N05^{0}W-S05^{0}E	Quartzo-feldspathic gneiss. Foliation perpendicular to crosscut. RMR 48-64 Class-II/III, Q=0.736-8.580
D/s crosscut of RDR-3			20	N12^{0}W-S12^{0}E	Quartzo-feldspathic gneiss with 20-30% amphibolite. RMR=44-60, Class III, Q=0.398-4.64
LDR-4	5242.012E: 4532.213 N	462.376	103	N80^{0}W-S80^{0}E	Quartzo-feldspathic gneiss (0.38 m), amphibole gneiss (38-100 m), felsic volcanics (100-103 m). RMR 29-48, poor to fair, Class III-IV, Q=0.34-0.736
U/s crosscut of LDR-4			20	N24^{0}W-S24^{0}E	Amphibole rich quartzo-feldspathic gneiss. RMR 42-53, Class-III, Fair, Q=0.293-1.59
D/s crosscut of LDR-4			20	N24^{0}W-S24^{0}E	Amphibole rich quartzo-feldspathic gneiss
RDR-3	4717.518E: 4322.526N	370.403	100	N80^{0}W-S80^{0}E	Quartzofeldspathic gneiss. Shearing noted between 3-7 m, 18-22 m, 27 m, 30-41 m, 55-63 m. Class III-IV. Poor to fair rock Q=0.136-3.41
U/s crosscut					Same rock. Slabbing/overbreak common due to intersection of shallow dipping cross joint and steep dipping foliation joint. Fair rock. Class III Q=0.34-0.681 RMR 43-47
D/s crosscut					Same rock. RMR 38-64 Q=3.42-8.58
RDR-4	4717.518E: 4322.526N	478.932	100	N80^{0}W-S80^{0}E	Quartzofeldspathic gneiss. Shears noted between 18-26 m. Rock highly sheared at places. RMR 30-47, Fair to poor rock, Class- III-IV Q=0.046-0.63
U/s crosscut				N03^{0}W-S03^{0}E	Quartzofeldspathic gneiss RMR 42-48, Class III, Q=0.293-0.736
D/s crosscut				N02^{0}E-S02^{0}W	Same rock. At places ferruginated. RMR 34-48, Fair (III) to poor rock (IV) Q=0.086-0.736

berms in order to get good contact between core and fresh rock and also to minimise the effects of cross valley load transfer. Curtain grouting below cut-off trench will be required for arresting seepage through cracks, sheared and jointed rockmass. Contact face of the abutment has to be prepared by removing the overhangs and rock pinnacles to eliminate surface stress concentrations, possible differential settlement and strains in the core that could lead to cracking. Trimming back of overhangs and flattening of vertical faces without resorting to blasting for minimizing formation of cracks is suggested. Conventional dental treatment is to be provided for shear zone of less than 2m width and for shear zone for more than 2m width, concrete plug may be preferred. Geological setting prevailing here favours for construction of a concrete dam, as hard and fresh foundation grade rock is available at reasonably shallow depth. Shears occurring in quartzofeldspathic gneiss can be effectively treated. If a suitable seismic resistant concrete dam can be designed taking into consideration of the seismicity of the area, option of rockfill dam need not be pursued. In that case, spillway is to be located within dam body and huge cutting of 150m-200m can be avoided.

Spillway: A 150 m wide chute spillway has been planned on right abutment at the dam body earlier – for which huge rock excavation would be required. This may lead to problem of instability of the cut face on both sides. Presence of foliation shears and cross shears also pose a threat in terms of seepage and erosion along spillway. So it has been suggested to consider shifting of spillway from dam body by about 160 m towards N 35^0 W and pass the same through the saddle zone to minimise rock cutting by 35 m to 40 m. Thickness of overburden is 9 m and joint frequency in bedrock is 'J$_5$'. Permeability value ranges between 2.31 and 5.18 lugeon. Adequate measures should be taken to dissipate the energy of the spillway discharge, as it will channelled over highly fractured rock.



SKETCH GEOLOGICAL MAP OF DIBANG MULTIPURPOSE HYDROELECTIC PROJECT
LOWER DIBANG VALLEY DISTRICT, ARUNACHAL PRADESH

Power House

The earlier proposed surface powerhouse (at 8 km d/s from Munli) is located on the river terraces near Nizamghat. Tipam group of rocks are exposed to the south of the project area – overlain tectonically by Miri Formation along Mishmi Thrust. In the case of surface powerhouse, a 7.2 km long HRT through fractured / sheared rocks was required. A Dam -toe powerhouse was also not feasible due to fluctuating periodic discharge of Dibang river, uncertain flood character and rapid change in main course. Hence it was decided to construct an underground powerhouse at 1.5 km downstream from Munli at the right bank of Dibang river, also in view of the high seismic activity in the region. Rock cover above the powerhouse cavern is about 400 m. For assessing the rock mass condition at the proposed underground powerhouse site, a 270 m long S 80°E-N80°W trending exploratory drift has been geotechnically assessed. The drift makes an angle of 75°-80° with foliation strike. Presence of three sets of joints and shears in quartzo feldspathic gneiss and amphibolite have rendered the area vulnerable to failure due to formation of wedges. RMR varies between 30 and 7 1 (Class II and IV) and 'Q' value ranges between 0.17 and 6.6 indicating very poor to fair categories of rocks. Wedge analysis indicates that the rock failure may take place due to wedging – if angle of friction (30°) and slope (40°) is disturbed. Excavation parallel to steep dipping foliation (NW-SE strike with

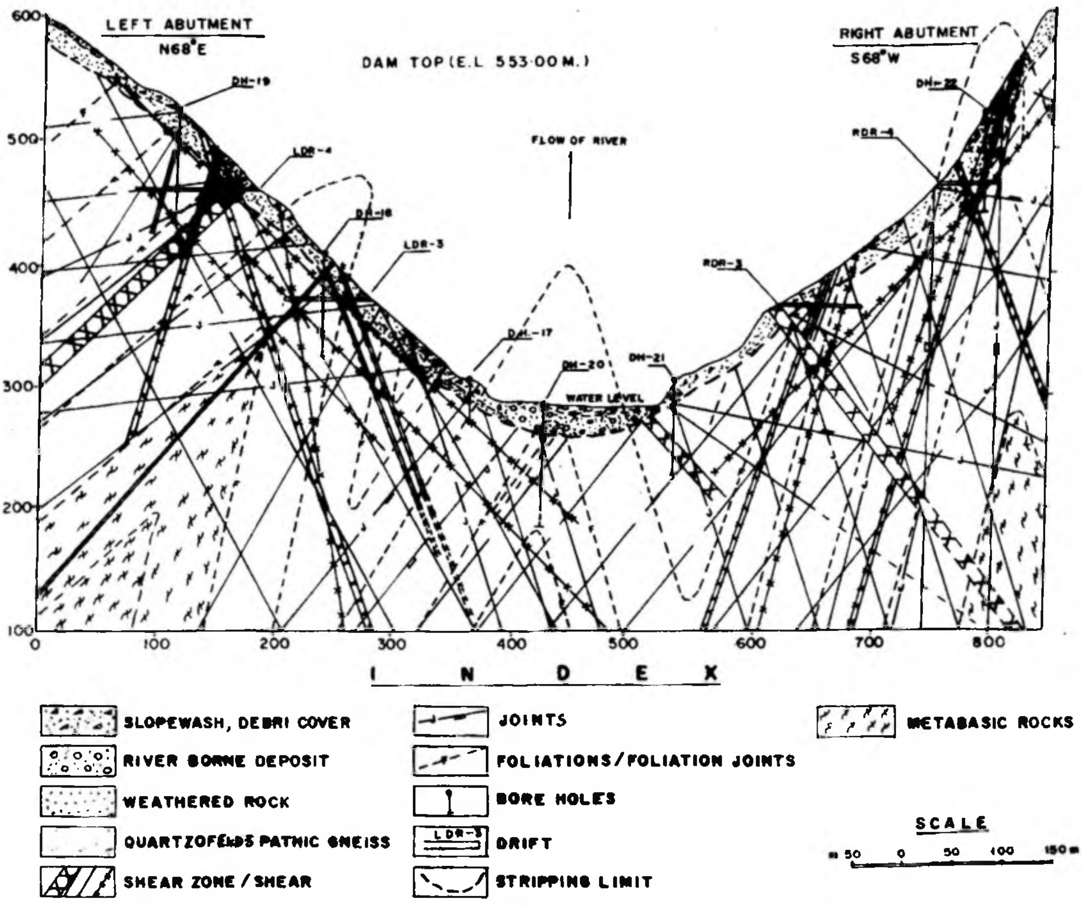


Plate - 2 Geological section along the proposed damsite

56^0-70^0 dip towards NE) are expected to have higher rock pressure with very limited bridging action. To avoid the excavations parallel to foliation joints and expected collapse along the wedges, it is suggested to shift the powerhouse alignment to N 64^0W-S 64^0E direction from the proposed N 80^0W-S 80^0E direction. N 30^0W-S 30^0E trending and southwesterly dipping shear zone located at 500m upstream of this proposed powerhouse site is assessed to be intersected at the proposed transformer hall drift.

Recommendations

The project site falls in the most vulnerable seismic zone (Zone V) and is encompassed by Mishmi Thrust (MBF), Lohit Thrust and Tidding suture. Impounding of huge water column in reservoir may cause induced seismicity and triggering movement of tectonic planes. Before constructing such a huge dam, proper MEQ study around the project site is needed. Rock Mechanical properties may be assessed through block shear, plate load, Good man jack, blasting and groutability tests to determine the strength parameters.

Acknowledgement

The authors are thankful to the DG,GSI for his kind permission to publish the proper. They are also thankful to the officers of Engineering Geology Division, GSI, NER, associated with Dibang Project.

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