A Glimpse Through Hydroelectric Projects of North Eastern Region

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Abstract

Recently special emphasis are given in development of sustainable renewable ecofriendly energy resources in the form of hydroelectric power. North Eastern India is the storehouse of water resources available for hydropower generation. A large number of Hydel projects are coming up in recent times. Variable geological milieu ranging between Archaeans/Precambrians of Meghalaya massif, the Gondwanas, the Tertiary and Pleistocene deposits in Himalayan foothills in a highly seismotectonically sensitive region pose challenging geotechnical problems which needs to be properly addressed through systematic geotechnical explorations. This write up embodies some case histories of the hydropower projects already constructed or under construction in this region, which may be proved to be helpful in future for taking up the more projects.

Introduction

North Eastern India, with immense potential region in hydel power generation-possesses 40% of total potential of the country out of which only 2% has been exploited so far. Water resources in this part of India are abundant and adequate for sustaining development. Recently there is an urgent need for developing the vast hydel potential. Though the North East is blessed with plentiful of water resource, the region faces several geotechnical problems in harnessing the potential. Most of the region is covered by soft sedimentary rocks of Tertiaries causing problems in selection of project sites. The sites are characterised by geotechnically complex geological settings showing multiple episodes of folding, faulting and thrusting. Numerous shears & thrust zones are conspicuous throughout the region. These types of complicated geological setup warrant elaborate and detailed insight. Highly disturbed rocks are the main constraints for searching available sites for concrete dam. Foundation grade rocks are available at higher depth leading to selection of rock fill dam in place of concrete dam. Water Conductor System in the form of Head Race Tunnel passing through most soft sedimentary rocks with heavy seepage belonging to Class-IV & V require heavy concurrence supports. Locating shear shaft, penstock and powerhouse in a suitable safe and techno-economically feasible site is a serious challenge. Landslide is a major hazard in this part of India due to heavy rainfall, soft, weak fragile lithology with unfavourable disposition. Proper protection for arresting the natural and induced landslides are required to stabilize the rockmass. Moreover, North East India and its vicinity are known for a very high level of seismicity. Two major earthquakes with a magnitude of more than 8.5 have been recorded in this region. The Great Indian Earthquake of Magnitude 8.7 in 1897 occurred in Meghalaya massif. Great Assam earthquake recorded from Mishmi Block was recorded in 1950. Most of the Project areas lie in the region of collision tectonics, demonstrated by N-S compression stress field. Major earthquakes in this region are related to northerly dipping detachment surface. In view of high seismicity in the various seismotectonic domains of NE India, the highest hazard zone V has been given to this area and thus suitable and safe seismic resistant design are to be applied here. Due

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to these odds, geotechnical investigation in the region is a challenging one. GSI is intimately associated with the development of hydel power and conducting geotechnical investigations for identifying suitable sites for locating dams, powerhouses, selecting tunnel suitable alignments, suggesting suitable remedial measures during construction and providing geotechnical advice as and when needed all through. In North East India, GSI have made immense contribution in promoting the hydel projects braving the hostile terrain and remoteness of sites. In this present write up, an attempt has been made to highlight some of the major constructed projects and ongoing projects in seven states of North Eastern Region. Case histories of these projects will be helpful for further taking up geotechnicall investigations of other projects in this region.

1) Ranganadi Hydroelectric Project, Arunachal Pradesh.

The Ranganadi Stage-I Hydroelectric Project envisages construction of 68m high concrete dam across Ranganadi river at 9 km from Yazali, a 253.5m long diversion tunnel of 6.8m dia on its left bank, 10.2 km long water conductor system including 9.2km long HRT and 0.93 Km long penstock. with 94m deep surge shaft, 5.8m dia pressure shaft and surface powerhouse on left bank of Dikrong river at village Hoz for generating 405MW power (135MWx 3). The area mainly belongs to Bomdila Group consisting of Ziro gneiss, Potin Formation and Khetabari Formation. Potin and Khetabari Formation consists of pelitic schists and psammitic rocks. Gondwanas also consist of calcareous and carbonaceous shale, sandstone, coal seams and volcanics. Siwaliks overthrusted by Gondwanas mainly consist of soft, grey coloured, medium grained sandstone with thin clay bands and coal streaks. At the damsite, granite gneiss with thin quartz veins parallel to foliation form the foundation rock. Pegmatite veins are also common. These rocks have been traversed by a number of closely spaced joints. Besides, the rock is dissected by a number of shear zones. Prominent shear zones are present along foliation plane (N20° E- S 20°W strike with 70°-80° d/s dip). Thickness of shear zone varies between few cm to 0.5m . Sudden change in dip of bed rock from 10° to about 85° indicates the river flows along a fault. In view of thick riverine material in river bed and terraces on bank and its highly permeable nature on right bank, problems of leakage from reservoir was anticipated. Moreover huge excavation caused the problem of slope stability. Heavy retaining wall in right abutment, deep positive foundation along with grouting was suggested in dam foundation. Right abutment comprised slope wash material, a series of slope failures occurred along dam axis and terminal block no. 19 had to be extended below tail car tract to abut in the rock in downstream with a kink from Block no. 17 towards downstream. Another slope failure occurred in right bank endangering tail car tract, for which a masonry breast wall and dry masonry wall in 5m segments in pyramidal form has been provided. Cover for HRT ranges between 17m and 7800m with low cover along some drainage crossings. Precambrian Khetabari and Potin Formation and gneisses encountered between 0-4.437 km, Gondwana sandstone between 4.5 – 5.625km Siwalik sandstone between 5.79 – 8.637 km. Thrusted contacts noted between Gondwanas and Precambrian at 4.437-4.500 km and between Gondwana and Siwaliks at 5.625 – 5.79km . HRT passes through gneiss, schist parallel to foliation whereas running askew to strike of bedding of Gondwanas and Siwaliks. Thrusted contacts are characterized by crushed zones. Heavy over breaks were found (10-15%). Heavy seepage was also a main problem in tunneling. Methane gas explosion was also encountered in some stretches. Over breaks and cavity formations were conspicuous . In most of the stretches, steel rib support at 1m c/c provided and rock – steel rib space filled with concrete. Seepage in HRT was controlled by providing drainage holes. Surge shaft was located in Siwalik Sandstone where adequate lateral ground cover as well as space of construction of expansion chambers was available . For ensuring stability of vertical excavated section by grout anchors/rock bolting and shotcreting depending on geological condition were recommended. In view of insufficient cover along proposed expansion chamber – it was suggested to resort to safer excavation technique to avoid problems of roof collapse. Rocks of high pressure tunnel (Siwalik Sandstone) behaved as good tunneling media and light supports were recommended. Penstock anchor blocks were located on fresh rock after easihg of slope and providing drainage. Powerhouse location has been shifted towards approach road in order to avoid the flat terrace where bed rock was not available upto 19m depth. In the present location, Siwalik sandstone were exposed. Rocks show low UCS and bearing capacity and hence raft foundation was provided. Stability of slope made vulnerable by 70° southeasterly dipping joints as excavated profile of back slope of powerhouse was steeper than bedding joint. 90m stretch of Pitapool-Diversion Dam road was sinking badly between ch. 5.25km and ch 5.34km where maximum depth of subsidence recorded was 1.83m. Main causative factors of subsidence were non maintenance of road side drain, construction of road over slided debris material, presence of a fault etc. Sealing of cracks, repairing of road side catch water drains and provision of cross drainage were suggested as remedial measure.

2) Loktak Hydroelectric Project, Manipur

Loktak Hydroelectric Project uses natural potential of Loktak Lake by diverting 42 cumecs of regulated discharge to power house located on right bank of Leimatak river, a tributary of Barak system to generate 105MW of power at 60% load factor. Diversion of water from this lake is achieved through a 10 km long water conductor system (Partly open channel and partly tunnel). A barrage of 10.72m height across Imphal river at Ithai regulates pondage of Loktak Lake from which the water is drawn for power generation. The area is bounded by lake sediments and foothill zone by terrace deposits. Lower Tertiary rocks of Disang and Barail Groups occupy adjoining the hill ranges. Power channel is aligned over lake sediments with progressive increase in coarser fractions towards tunnel intake. Tunnel cuts across unconsolidated sediments, terrace deposits and Tertiary Group of rocks along its alignment. Extensive geological mapping followed by limited drilling were carried out at the project site for identification of structural parameters and related tunneling problems. Slope failures with heaving of channel floor caused major set back in channel excavation in lake sediments due to inherent weak nature of clay and artesian pressure acting from below. Cut and cover duct was designed in stretches having more than 15m depth of cutting with relief wells to counteract such phenomenon. Flowing ground condition, roof collapse, sqeezing of supports and occurrences of methane entrapped in fissures in rocks considerably slowed down the tunneling progress and also created problems of personnel hazards. Introduction of New Austrian Method of tunneling, improvement of ventilation and adherence of strict regulation as adopted in gassy mines proved effective and helped in excavation of tunnel through such geological condition. Slope stability along penstock alignment was another features which needed design modification to keep anchor blocks in position.

3) Gumti Multipurpose Project, Tripura

A 31.4m high diversion structure across Gumti river was constructed for diverting 12.46 cumecs of water through a 2411.3 m long power channel to the powerhouse for generating 8.6 MW of electricity at 50% load factor availing 40.8m head. At the diversion structure, soft argillaceous sandstones-interbanded wit shale and siltstone was found in river bed and abutments. As the beds show upstream dip, no seepage was anticipated.

No significant structural disturbances were noticed. Along power channel, sandstones and shales are exposed, folded in an anticline. Within shale zone-where the slopes are covered with plastic clayey soil, slope failures were very common. Protective measures against rock slides along NW-SE trending joint within sandstone were taken care by removing overhanging blocks with well developed open joints. At forebay site, no rock was exposed. From forebay, water has been diverted to powerhouse through 70.7m long penstock having diameter of 2.13m. Upperpart of penstock slope exposed bedding plane of argillaceous sandstone – dipping at 60° towards west. Lower part of penstock slope is soil covered where small slope failures have been noticed. Benches at lower part of slope and retaining wall at the toe of slope were provided. Powerhouse has been constructed on a flat terrace on the right bank of Gumti river.

4) Kopili Hydroelectric Project,Assam

Kopili Hydroelectric Project was constructed to harness the power potential of Kopili river in two stages. Khangdong Dam was constructed on Kopili river to create Kopili reservoir from where water is drawn by Khangdong water conductor system to run Khangdong (2 x 25MW) and stage – II (1 x 25MW) power stations. Tail discharges of these power stations are collected in Umrong reservoir, which was created by constructing Umrong dam on Umrong nala. Umrong water conductor system takes off from Umrong reservoir and feeds Kopili power station (4 x 50MW) which discharges tail water into Kopili River. A major part of the water spread would lie on limestone and shale of Eocene age. Limestones in reservoir area constitute about 67.7% have undergone extensive Karstification and thus it was apprehended that after impounding water there might be subterranean flow from Kopili reservoir to adjacent lower valleys of Umrong and Diyung , lying in the east. Nearly 200 sinking holes were detected in Kopili reservior area – which lie between elevation 707m and 792m. Many of the sinkholes would be submerged under water at the proposed FRL (789m) in Kopili basin. Out of these maximum number of sinkholes are located in Lumkinday valley – which is apart of Kopili reservoir. Surface and underground geological mapping have established connections between various solution channels having inlet and outlets in same basin. Parts of solution cavities are chocked up by clay and sand. This material may be washed away due to hydrostatic pressure under a new hydrological regime resulting a free flow. There is also possibility that the caverns may be connected with open/enlarged joints which would also caused loss of water from reservoir. Clusters of sinkholes are conspicuous at or near the boundaries of Kopili shale and Sylhet limestone. Most of the sinkholes are confined to the top 40m thickness of limestone. Many caverns probably close to this depth, but same caverns also exit at lower levels. Groundwater movement in caverns occurs in ENE-E, NNW directions – indicating joint control. Most of the exploratory holes in reservoir area and on water divide ridge indicate presence of cavities/ open joints in limestone at depth. Geophysical survey along the Khangdong dyke also suggest probable existence of solution cavities in limestone at depth. Presence of compact limestone occur at SE corner of Kopili reservoir. Water divide ridge between Kopili and Umrong basins is composed of prominent Karstic limestone on its northern part. During flood in Kopili river, greater extent of Karstic limestone submerged. After detailed study of reservoir competency, plugging of sink holes by soil/clay/cement to prevent direct ingress of reservoir water, construction of small earthen dykes to isolate the sinkholes, provision of grout curtain in dyke area upto basement gneissic rock, gradual filling of reservoir were suggested.

5) Doyang Hydroelectric Project, Nagaland

Doyang Hydroelectric Project envisaged construction of 90.16m high rock fill dam across Doyang river along with 12m dia 633m long diversion tunnel at left bank, 60m wide

357.52m long Chute spillway for discharging 5977 cumecs of flood water and a right bank dam toe powerhouse for generating 75MW of power. Sandstone and siltstone of Surmas Group of Teritary age are the main rock types exposed in the project area. Major part of the dam site were covered with overburden material and medium grained, grey, soft friable sandstone with thin bands of siltstone and shale along the river banks. Excavation of dam foundation to the tune of 21m – 22m was required. Suitable treatment was suggested for arresting seepage from right abutment after impoundment, through a nala cutting in downstream of dam axis. Along diversion tunnel, soft stratified friable micaceous sandstone, thinly bedded greenish to grey laminated siltstone, sandstone and shale of fair, poor, exceptionally poor grade rockmass were found. Roof support pressure were assessd as 2 Kg/cm^2, 3-3.5kg/cm^2 and 7.5 kg/cm^2 for fair, poor and exceptionally poor rock mass. Chute spillway has been located in left bank hill slope-where sandstone and mudstone were exposed at the foundation level. Clayfilled joints were very common. For achieving foundation, 80m deep excavation created huge slope stability problem. For avoiding slope stability problem, stable slope f 1(H): 0.85 to 1 (V) in overburden/weathered rock, 1 (H): 2 to 4 (V) in fresh rock, shotcreting with wiremesh, grouted anchor,

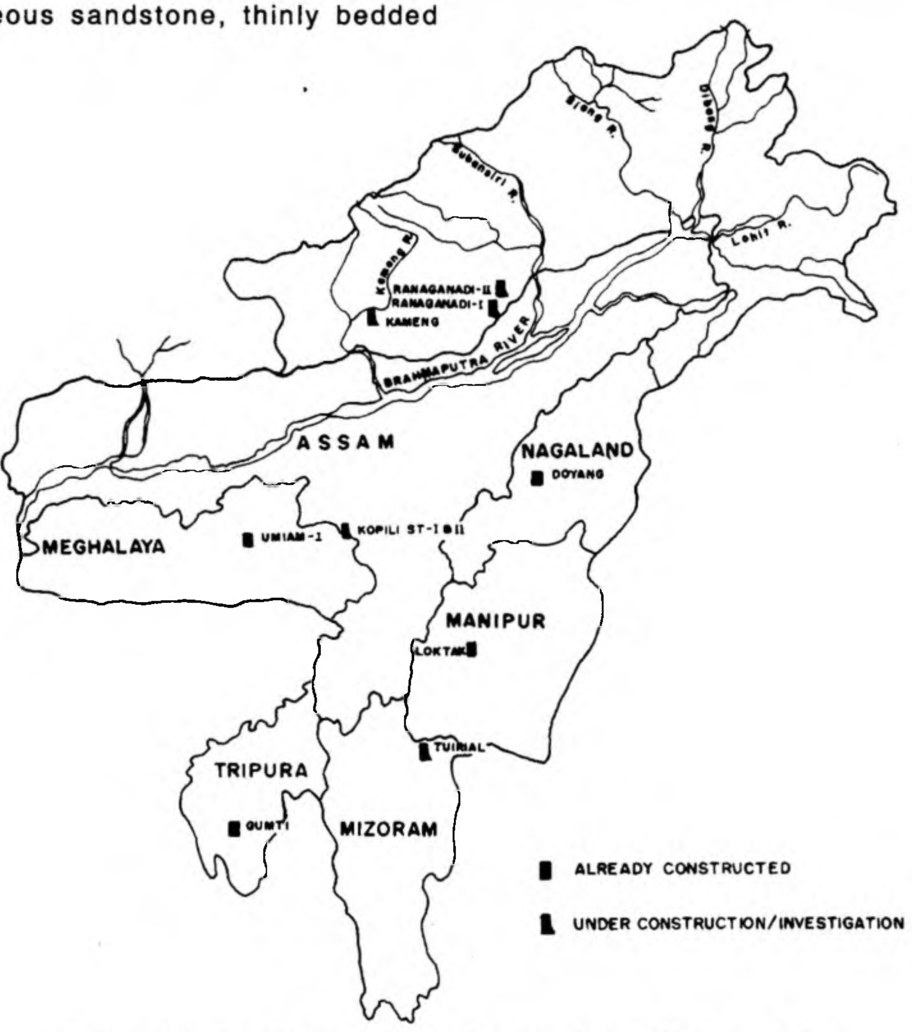

Fig. 1. Location of important hydroelectric projects in Northeast India

provision of suitable drainage arrangement, provision of cut off and dividing wall were suggested. Moreover for the swelling nature of clay in mudstone, modification of design of control structure was suggested for taking care from upheaval presure caused by rockmass on saturation. At the powerhouse site, grey to buff coloured soft, friable, medium to fine grained micaceous sandstone with intermittent thin laminations of shale, siltstone were found. These lithounits show difference in bearing capacity and thus raft foundation was provided.

6) Tuirial Hydroelectric Project, Mizoram

Tuirial Hydroelectric Project envisages construction of 76m high earth dam across Tuirial river near village Saipum for impounding 1400 cum of water (at FRL 90.5m) with reservoir spread of 53.8sq.km at 94.2m E.L. Water from reservoir would be diverted through 9m dia tunnel to generate 60MW of power –using 61.2m gross hydraulic head, at a surface powerhouse located on the left bank of dam toe. A 45m long chute spillway with radial gates(10m x 14m) is located on right bank of dam site to pass 4450 cumec of design flood. At the project site, siltstone, sandstone, shale and its variants belonging to Surma Group (Mio – Pliocene) are exposed. These lithounits in the project area are part of N-S to NNW-SSE trending folded sequence. In dam site, mainly sandstone and siltstone is available along core below 6 m thick soil and weathered rock. In riverbed, about 30 m deep alluvial deposit is present. Explorations indicated liquefaction potential of fine sand and silt deposit due to very low range of 'N' values and its depth persistence. This thick sedimentary deposit may require Vibrocompaction and sheet piling or diaphram wall type of cut-off Excavations in chute spillway area exposed numerous shears and faults for which formula and dental treatment were recommended. Major rock types in the diversion tunnel are weathered sandstone, siltstone and shale. These rocks when excavated appear to be self supporting, but within a short duration on exposure to atmosphere and seepage water, disintegrated and crumbled. Hence fairly hard rock reaches were immediately covered by shotcrete with wire mesh and failing reaches were provided with rib support. Powerhouse site is marked by thick overburden which collapsed on cutting, ultimately cut slope is being eased to improve its stability. Moreover, proper strengthening of foundation grade rockmass available in powerhouse site is required due to their inherent poor Uniaxial compressive strength (5-25 mpa). This project faced acute shortage of construction material for coarse aggregate which are being brought from about 100 km distance for tunnel lining and other civil works.

7) Umium Stage – I Hydroelectric Project, Meghalaya

The project with a 78m high concrete gravity dam across Umium river and a surface powerhouse with an installed capacity of 36MW was constructed in 1965. Damsite of this project is occupied by quartzites and phyllites of Shillong Group showing NE-SW strike with 65° – 88° dip towards SE. Dam site is traversed by a NE-SW trending and 70°-85° southeasterly dipping fault – which gave rise to 0.9m to 3m wide zone of shattered rock and gougy material. This cuts dam axis and passes through Block nos. 4 to 10 – finally emerges at Blocks 1,2, & 3 in left bank. In treatment of fault zone, clay gouge and shattered rocks were scooped out to depth equal to two or three times of width of fault zone. Fractured and broken rocks adjacent to fault zone were also removed completely. Excavated zone was then filled with concrete of high strength and grouted through inclined holes. Leakage through fractured/jointed rock in left bank was tackled by low pressure grouting. Before grouting, clay in joints and slip planes was flushed out with air and water jets. Soft phyllite also have been removed. Contacts of phyllite and quartzite were strengthened by forcing lean cement grout at low pressure. Shear zones of bucket were also strengthened by

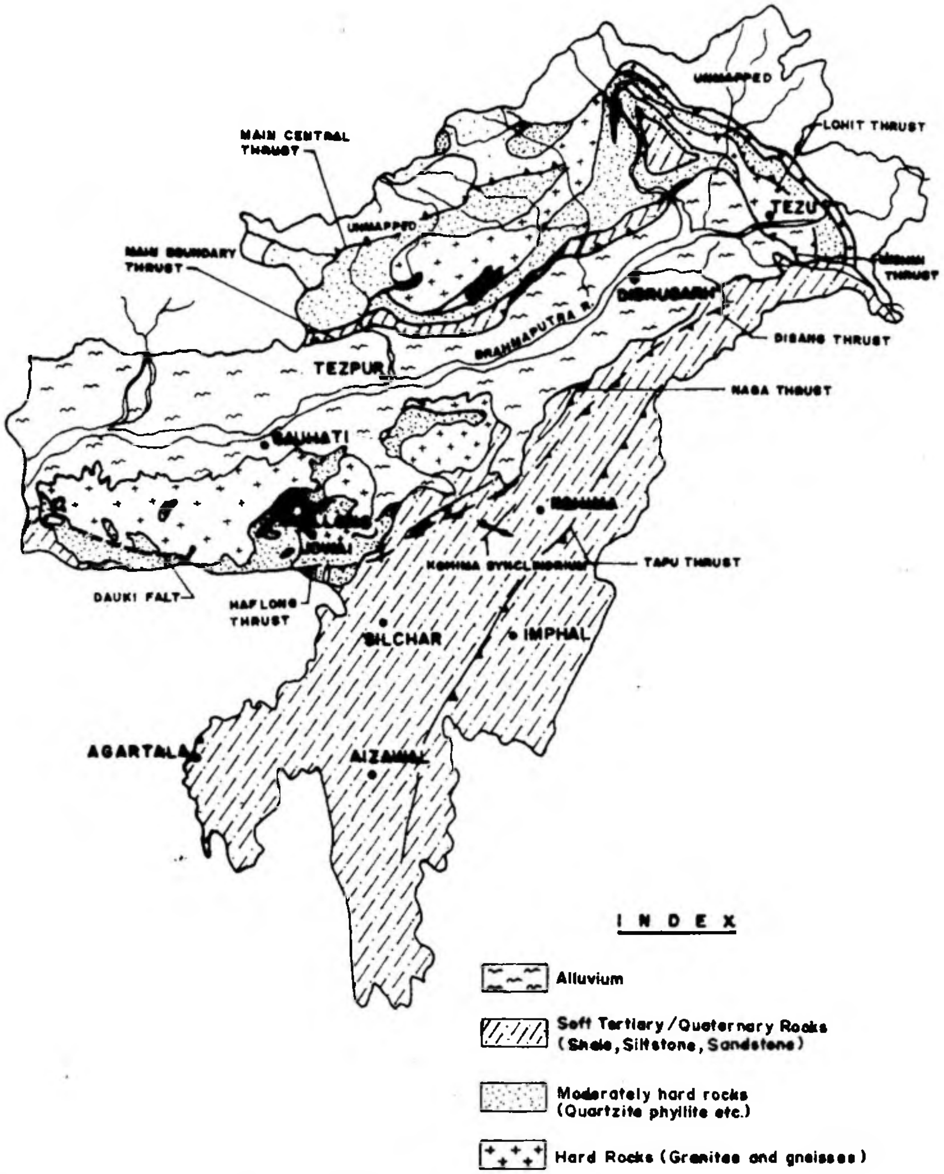

Fig. 2. Generalised Geological map of Northeast India showing the Structural elements

extensive grouting.

8) Kameng Hydroelectric Project, Arunachal Pradesh

Kameng Hydroelectric Project envisages construction of two 75 m and 25 m high concrete dams across Bichom river and Tenga rivers and two tunnels between – Bichom-Tenga and Tenga-Kimi totaling 16.76 km length for supplying water to generate 600 MW of power. Bichom dam site is located within quartz-biotite gneiss and chlorite schist of Bomdila Group of Precambrian. Left abutment of the dam will be entirely on rock and bedrock is available within reasonable depth in dam foundation and energy dissipation structure. Entire right abutment is covered with terrace deposits. Tenga dam site is located in quartzitic sandstone and carbonaceous shale of Lower Gondwana Group. 8.75 km long Bichom-Tenga tunnel passes through Precambrian porphyroblastic granite gneiss, chlorite sericite phyllite, quartz muscovite sericite schist, quartzite and Gondwana shale, sandstone. This tunnel is expected to negotiate two major thrusts and few minor dislocation zones – where stress release and heavy seepage is anticipated. 7 km long Tenga-Kimi tunnel will pass through mainly quartzitic sandstone, carbonaceous shale with thin bands of coal of Lower Gondwanas and enter with Siwalik rocks for about 200 m upto surge shaft. This tunnel will negotiate through a NW-SE trending steep north-westerly dipping thrust plane and some local folds and faults where tunnelling hazards are anticipated. Originally proposed surge shaft and powerhouse sites were located in the Siwalik Group of rocks and very close to thrusted contact between Gondwana Super Group and Siwalik Groups. Hence an alternative powerhouse site at RL 285 has been selected at Kimi, 2 km downstream of earlier powerhouse site on a very big flat terrace surface where bedrock in the form of alternate sequence of sandstone and carbonaceous shale of Gondwanas is available at 20 m – 25 m depth below terrace material. During excavation, thickly bedded sandstone has slumped and open steep cracks were developed. Cracks were sealed by sand cement slurry and followed by 7 m long grouted rock bolt at 2-2.5 m centre to centre.

Conclusions

North Eastern India is blessed with immense potential of hydroelectric power – of which a very small part has been exploited so far. High rain fall, snow fed rivers and mountainous topography form an enviable wealth of this Sub Himalayan terrain. Notwithstanding these limitations, cheap electricity available from the environment friendly and renewable source cannot be ignored any more considering the pace of development of country and shortage of power.

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