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Director's Report

The National Institute of Rock Mechanics (NIRM) has been carrying out research and consultancy work in the areas of rock mechanics and rock engineering. The Institute has unique expertise in the key areas of rock mechanics and rock engineering. We are extending our R&D support to whole of the mining industry, civil engineering projects involving underground caverns and tunnels, and to infrastructure projects like underground metros, LPG/crude oil storage caverns, etc. in the country. With a proven track record of over two decades, the Institute is entering its Silver Jubilee Year in July 2012.

During the year 2011-12, NIRM carried out investigations for 65 research projects out of which, 30 were successfully completed, and 35 were continued to next year. NIRM Scientists contributed total 26 technical papers in various national/international journals and symposia. For the year ending March 2012, THE Institute registered an internal revenue generation amounting to Rs. 1010 lakhs, and received a Non-Plan grant-in-aid of Rs. 10 lakhs. The external cash flow from the projects was Rs. 931 lakhs. The R&D activities and achievements of the Institute during the last one year are listed below.

Detailed engineering geological investigations were carried out by NIRM for the preparation of Detailed Project Report for Bunakha Hydro Electric Project (Bhutan). Extensive geotechnical investigations were carried out at Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme-II (Mahboobnagar District, AP), Rajasthan Atomic Power Project (RAPP) Units 7&8. NIRM has been involved in the review of the geological mapping works and design of rock support systems for the underground crude oil storage cavern at Padur and Mangalore (Karnataka).

In-situ stress tensor and deformability parameters were measured at Shongtong Karchham Hydro Electric Project (HP), Pare Hydroelectric Project and Dibang Multipurpose Project (Ar.P.). Using geophysical cross-hole seismic survey methods, NIRM investigated the extent of suspected shear zones in the dam foundation of Koteshwar Hydroelectric project (UK), and the likely tunneling medium on the re-drawn Katra-Qazigund and Dharam-Qazigund rail lines (J&K). Similarly, investigations using seismic refraction method were carried out for Chennai Metro Rail Project to know thickness of soil, subsurface rock and their profile.

Using 3D numerical modeling, NIRM carried out back analysis of powerhouse complex behaviour at Tapovan Vishnugad Hydroelectric Project (UK), and Tala Hydroelectric Project (Bhutan), and the stability analysis of landslide area of Varunavat Parvat UK). In a multi-disciplinary role as a reviewing authority, NIRM has been carrying out the assessment of tunnel design, blast design, efficacy of support system and stability of cut slopes near twin tunnels in the Hungund-Hospet section of NH-13 (Karnataka)

The Scientists of NIRM provided technical advice and guidance for rock blasting close to structures and green concrete at Unit 7 & 8, Nuclear Plant (Kota, Gujarat), and for the Chinnaswami Stadium-to-City Railway station stretch of the Bangalore Metro Rail.

The Institute has entered into an MoU with the Uranium Corporation of India Limited, and has been providing solutions to the rock mechanics problems being faced at their Tummalapalle mine (Kadapa district, AP). To assess the stability of sub-level stopes at Hutti Gold Mine, NIRM has installed a number of instruments in different regions of the mine and has been monitoring the area during the extraction.

Strata control investigations are in progress in the underground mines of Mathani (Pench Area), Tawa and Sarni (Pathakhera Area), Mohan (Kanhan Area) and Saoner (Nagpur Area) of Western Coalfields Ltd (WCL), to design appropriate method of partial extraction and proper support system to work the coal seams under difficult conditions like Deccan Trap rock, surface structures and forest area. NIRM designed rock bolting systems for development of roadways at Durgapur Rayatwari colliery (WCL) under high horizontal stress conditions, and at Kakatiya Project (SCCL) for the 2.5 to 4 km long longwall gateroads, based on geological hazard map.

NIRM formulated a methodology for grading of granite quarries, and implemented it in the mines of the Mysore Minerals Limited. NIRM Scientists suggested eco-friendly quarrying methods at the quarries in Kerala. Slope stability studies have also been carried out at Pandarathu Limestone Mine of M/s Malabar Cements (Kerala).

At the request of NPCIL, NIRM carried out seismo-tectonic evaluation of the area around Kudankulam Atomic Power Station complex (TN), and the area near Pudimadaka (near Visakhapatnam, AP. Another major project undertaken by the Institute is the establishment of a nano-seismic monitoring in the powerhouse of Tapovan-Vishnugad hydroelectric project. On similar lines, the Druk Green Power Corporation (Bhutan) have asked for setting up of a system to monitor the likely seismic events in the powerhouse area.

As an accredited test laboratory, NIRM has carried out non-destructive and proof load testing of ropeway wires, winder/hauler systems and mining machinery parts for National Aluminium Company Ltd, Khetri and Kolihan mines (Hindustan Copper Ltd), Rajpura Dariba mines (Hindustan Zinc Ltd), and in the different areas of SCCL.

The diverse projects briefed above reflect the vision of the Institute for quantum growth, and its resolve for self-sustainability. We draw our inspiration for this from the advice and guidance from the Peer Review Committee, and the support from the Governing Body and General Body of the Institute, and the Ministry of Mines, Govt of India. While various agencies and industries have reposed faith in our research activities through sponsored projects/ assignments, the Scientists and staff of the Institute did commendable job in executing the projects to the satisfaction of the clients and in the best interests of research and development.

1. ENGINEERING GEOLOGICAL INVESTIGATIONS

Geological and Geotechnical inputs are pre-requisite for economic and safe designing of construction projects related to power sector (hydel, thermal, nuclear), communication sector (metros, rails, tunnels, roads, bridges), mining sector, and also for geohazard assessment and mitigation. The department undertakes works related to detailed geological investigations in various stages of the project developments. The department also undertakes seismotectonic evaluation of the region around major developmental projects. During 2011-12, The Engineering Geology Group completed four projects, and four projects are in progress.

1.1 Engineering geological investigations for preparation of DPR for 3x60MW Bunakha Hydroelectric Project, Bhutan, Project No. EG1002 & EG1103, Completed.

(A.K. Naithani, L.G. Singh, Devendra Singh, A. S. Negi, P. S. Varma and P.C. Nawani)

Detailed engineering geological investigations were carried out by NIRM for the preparation of Detailed Project Report (DPR) for Bunakha Hydro Electric Project (BHEP), Bhutan. It is a storage project utilizing the head upstream of the existing Chukha HE Project and the confluence of Paro Chhu and Thimphu Chhu. This project is expected to generate 180 MW of hydropower. This scheme envisages construction of important structures such as 198 m high roller compacted concrete dam, spillway, pressure shafts (penstock), dam toe surface power house and tail race tunnel. The proposed dam and surface power house facilities at BHEP can utilize a head of 155 m. Site investigations were carried out at the request of the THDC India Ltd. The main objective of the investigations was to provide the adequate geological and geotechnical data input to prepare a bankable DPR for BHEP. The broad scope of work was:

- Detailed geological mapping of the dam site, spillway, intake, pressure shaft, power house and tail race channel on 1:1000 scale.
- Geological logging of exploratory drill holes and exploratory drifts on 1:100 scale.
- Preparation of geological section of all the project components.
- Geological mapping of the reservoir area on the scale of 1:10,000 and identification of landslides in the vicinity of reservoir using high resolution satellite imageries and field traverses.

Detailed engineering geological investigations at the dam site were carried out to bring out a detailed report on the rock mass characteristics of the foundation of dam, spillway (Fig. 1.1) and powerhouse. Additional subsurface explorations by drilling and drifting were also planned by NIRM. Water percolation tests were conducted in drill holes, at increasing and decreasing cycles of pressure, to determine rock mass permeability values. Geological mapping of reservoir area were carried out from the landslide and slope stability point of view. Landslide inventory map, drainage map, landuse/landcover map for the reservoir area with the help of Satellite Image (Cartosate-1) and limited field verification were prepared. The basic purpose of these investigations was to identify / map different rock types and structures like joints, shear zones, fault, fold, fracture zones etc and also to comment on reservoir rim stability and reservoir competency. A comprehensive geological and geotechnical report was submitted to THDC in two volumes.

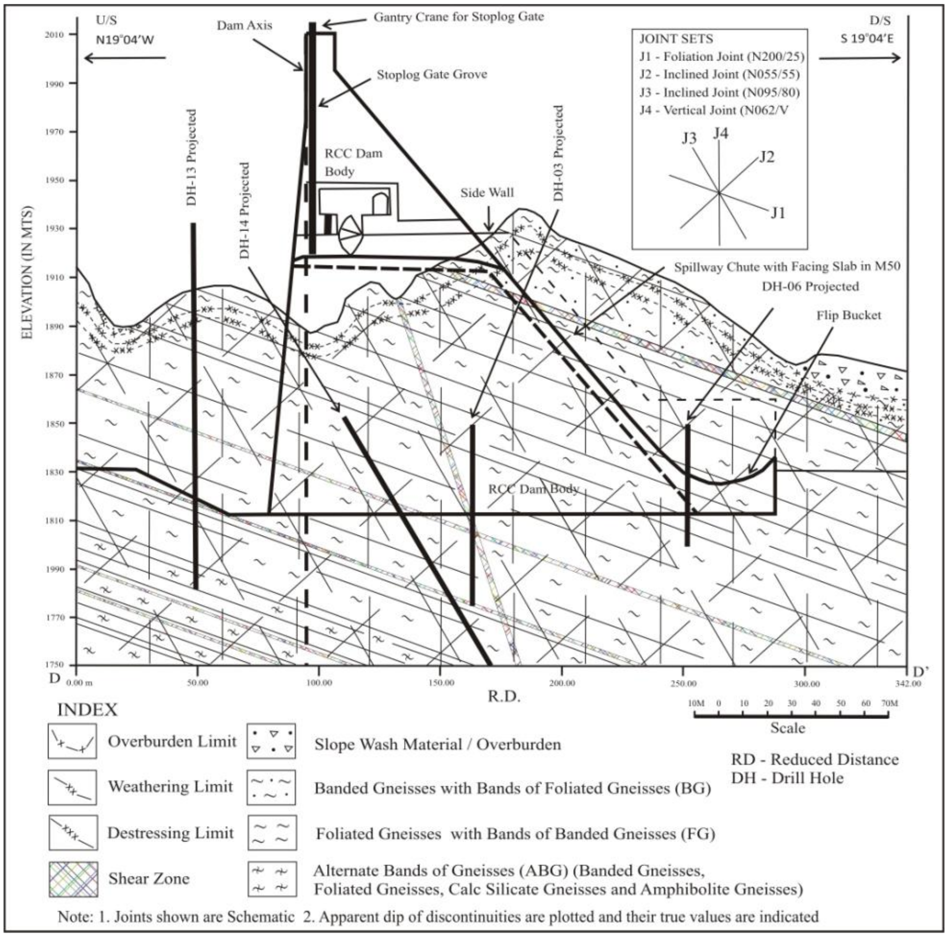


Fig. 1.1 Geological section along the right bank of spillway, perpendicular to the dam axis

1.2 Construction stage engineering geological mapping of foundation of Rajasthan Atomic Power Project (RAPP) Units 7&8, Rawatbhata in Chittorgarh District of Rajasthan, Project No. EG1003, Completed

(A.K. Naithani, Rabi Bhusan, Prasnna Jain and P.C. Nawani)

Engineering geological foundation mapping for the of foundation of Rajasthan Atomic Power Project (RAPP) Units 7&8, Rawatbhata in Chittorgarh District of Rajasthan 7&8 was carried out by NIRM. This work was sponsored by Hindustan Construction Company Limited, Mumbai. This project consists of two units of 700 MWe each PHWR type Nuclear Reactors, adjacent to the operating RAPP-1 to 6 units. The site is on a gently sloping terrain and bed rock is present within few centimeters from the surface.

The investigations included engineering geological mapping on 1:100 scale of strata at foundation levels of buildings and cut slopes (walls); identification of geological defects and recommendations of suitable engineering measures. The project area is occupied by very hard and competent fine to medium grained sandstone of Kaimur group of upper Vindhyan Super

Group of Proterozoic age. The total geological mapping covered of 45,579.676 sq.m., including vertical, inclined walls and horizontal foundations of various structures.

The floors, inclined walls and vertical walls of Nuclear Building -7, Nuclear Building -8 ,Station Auxiliary Buildings, Control Building and Waste Management Plant of RAPP Units 7&8 were mapped on a grid pattern (1 m x 1 m) (Fig.1.2). All the lithological and structural features were observed and mapped using Total Station surveying equipment and are shown in the final foundation grade geological plan map and maps of vertical sides. Different grades of rockmass observed in vertical walls. Classification of rock mass by Rock Mass Rating (RMR) was done and based on the investigations, recommendations were given for the treatment of foundations and vertical walls. Three geological reports for different component of the project were submitted by NIRM.

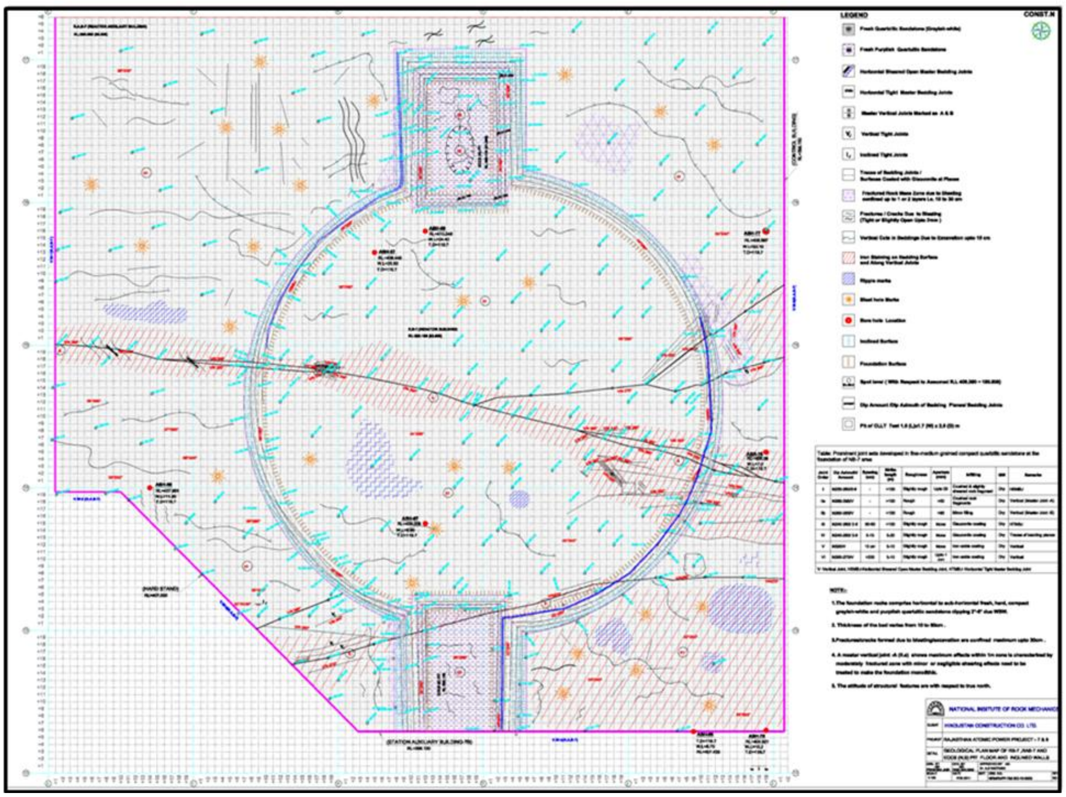


Fig.1.2 Geological mapping of horizontal surface of NB-7 showing the vertical master joint

1.3 Engineering geological investigations of rock mass from the excavated north wall face in the pump house of Mahatma Gandhi Lift Irrigation Scheme-III, District Mahaboobnagar, Andhra Pradesh, Project No. EG1101, Completed
(A. K. Naithani, Manoj Kumar, Rabi Bhusan, and P.C. Nawani)

The Mahatma Gandhi Lift Irrigation Scheme (MGLIS) is being constructed in three stages for lifting the Krishna water from Srisailam reservoir to Gudipallygattu balancing reservoir through channels and tunnels to cater the needs of irrigation in the drought prone upland areas of Mahaboobnagar District of Andhra Pradesh. The major components of MGLIS-III are: i) 6.0 km long gravity canal, ii) 6.156 km long and 6.85 m finished diameter horseshoe shaped tunnel, iii) surge pool (80 m long x 20 m wide x 110 m high), 55 m long five numbers of draft tube tunnels, iv) pump house (80 m long X 20 m wide X 116 m high) and v) five numbers 15 m long horizontal & 163 m long inclined having 2.6 m finished diameter delivery main tunnels.

Due to the intersection of joint planes and shear zones, slips had occurred on the northern wall of pump house of Lift-III. Deepika inftatech requested NIRM to undertake geological investigations in this area. After the site inspection and discussion, geological mapping on 1:200 was carried out in a total 6445 sq.m. area (Fig.1.3) to suggest remedial measures. Rock type exposed on the wall section and the foundation level is medium grained, hard compact and jointed granite.

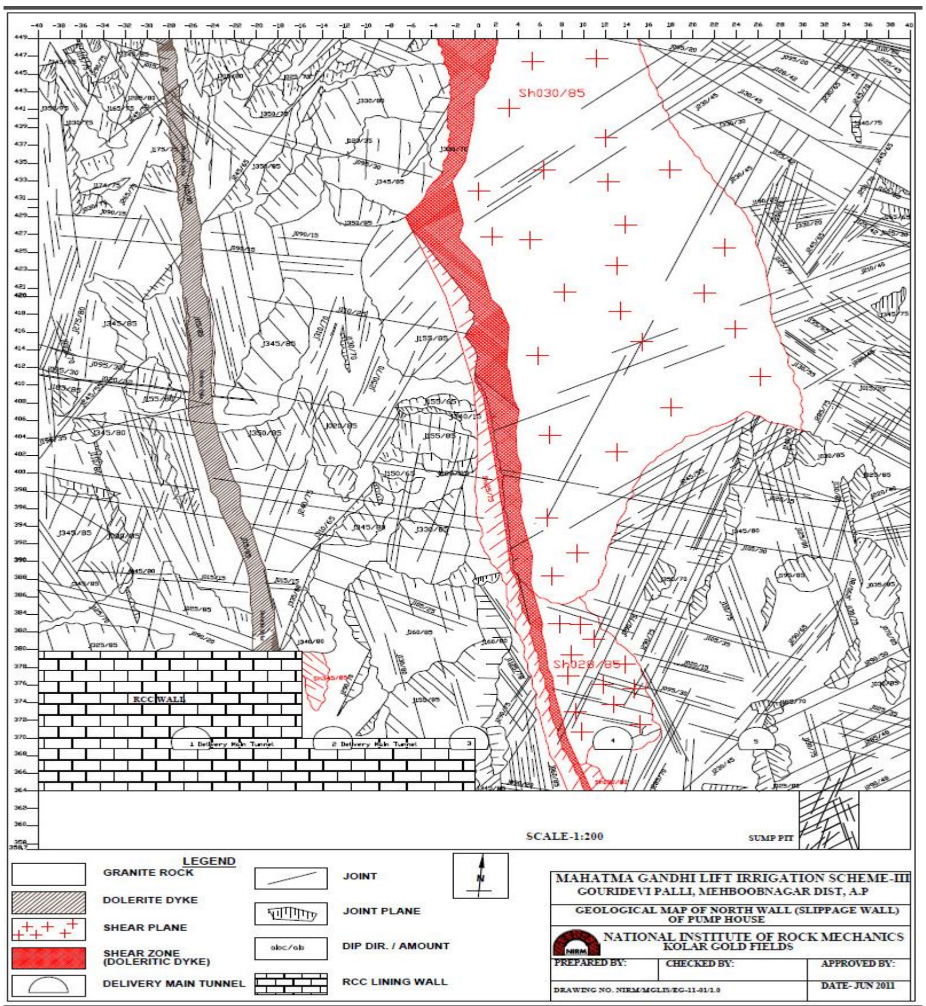


Fig. 1.3 Geological map of the North wall pump house of MGLIS-III

Granite is generally fresh to moderately weathered (WI – WIII) in nature. It belongs to Eastern Dharwar Craton of Indian Peninsular Shield of Late Archaean age. The rock mass is characterized by six number of joints, which are continuous and persistent, rough and irregular to slickensided and undulating to planar with unaltered joint walls. Staining was recorded along the joint surfaces where the joints are tight and where opening is up to 10.0cm, soft clay mineral filling was recorded. In general, the rock mass is characterized by dry condition or minor inflow (< 5.0 l/min). Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. The rock on north vertical wall of pump house is intersected by a vertical dolerite dyke (N115^{o}/85^{o}) and shear zone (N030^{o}-028^{o}/85^{o}-80^{o}) containing clay gauge material and disintegrated rock fragments. ISRM classifications for weathered mass were used to characterize the rock mass into different grades. All the lithological variance and the structural discontinuities in rock mass of the wall were identified and mapped. The assessment of Tunnelling Quality Index 'Q', based on the rock joints characteristics and shear zone were done. Based on detailed engineering geological investigations, permanent support measures was recommended for the treatment of north vertical wall in the pump house area of MGLIS-III.

1.4 Review of construction stage engineering geological excavation mapping at crude oil strategic storage project, Padur, Karnataka, Project No. EG1105 (Phase-I), <u>Completed</u>
(A.K. Naithani, Manoj Kumar and Prasnna Jain)

The Government of India is constructing underground rock cavern storage for imported crude oil at Padur, Karnataka with significant storage capacity 2.50 MMT. Indian Strategic Petroleum Reserves Limited (ISPRL) is to implement, maintain and operate the strategic storages on behalf of the Government. Engineers India Limited, the Project Management Consultant for the project approached NIRM to review construction stage engineering geological investigations. The crude oil storage facility at Padur is designed for two crude qualities (high sulphur and low sulphur), and consists of two separate storage units in the proportion of 3:1. The crude oil storage facility consists of four U – shaped units with two legs each resulting in eight caverns, six for high sulphur crude oil and two for low sulphur oil storage unit, oriented approximately in N060^{o}E direction. Two independent portals and access tunnels are located in the valley, located in either side of the facilities. The principle for storage of crude oil in underground unlined rock caverns essentially makes use of confinement by ground water pressure for containing the products within.

The main objective of this work is to review engineering geological excavation mapping works and recommendation for temporary and / or permanent rock support system as per design. The scope of the work includes rock matrix description; rock discontinuity orientation & description, ground water condition, rock mass quality assessment and permanent support recommendations based on rock support categories as mentioned in Basic Engineering Design after every drill & blast-mucking-scaling cycle. Other scope of works are: permission for the bench excavation, hydrogeology i.e. water curtain management, review the ground water level through the monitoring borehole and sustain the water seepage in cavern and accesses tunnel.

The investigations were carried out in shafts, tunnels and storage caverns after every drill & blast-mucking-scaling cycle to acquire the geological and/or geotechnical data (Fig. 1.4), i.e.

rock description (structure, color, grain size, name, weathering grade and strength); rock discontinuity orientation (dip amount and direction) & description (type: joint, foliation, shear, fault, fold and fracture zone; persistence, spacing, volumetric joint count, roughness, alteration); ground water condition, etc. for rock mass quality assessment. Based on rock support categories, as mentioned in Basic Engineering Design, permanent rock supports were recommended.

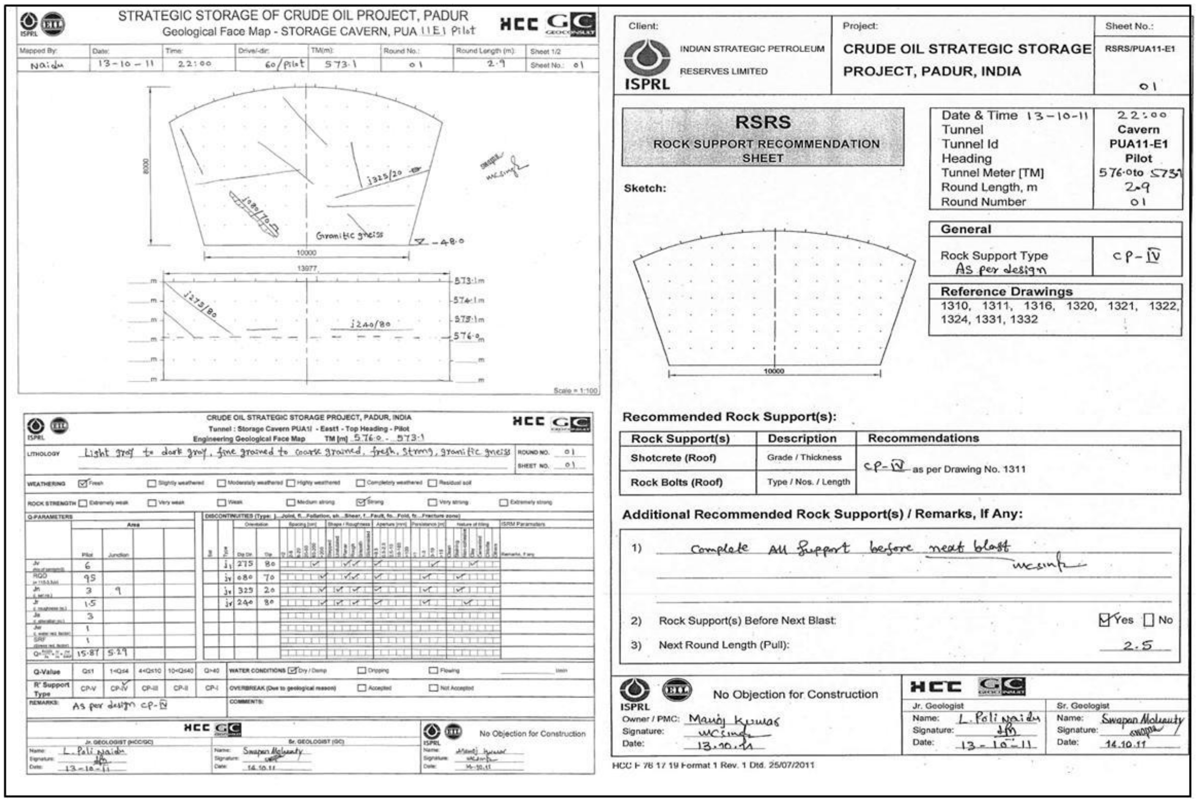


Fig. 1.4 Geological face map of Storage Caverns-PUA reviewed by NIRM

1.5 Construction stage engineering geological investigations of surge pool and pump house (5x30MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme-II, Mahaboobnagar District, Andhra Pradesh, Project No. EG1104, On-going

(A.K. Naithani, L.G. Singh, Devendra Singh Rawat and A.S. Negi)

Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme-II (MGLIS-II) is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir to cater the needs of irrigation in the drought prone upland areas of Mahboobnagar District, Andhra Pradesh. The major components of the project are: one 4.0 km long gravity canal, D-shaped tunnel (4.553 km and 6.85 m diameter) surge pool, draft tube tunnels and pump house. So far most of the part of surge pool and pump house has been excavated. But the rock on all the sides of the surge pool and pump house partly slided due to presence of shear zones and uncontrolled blasting. NIRM studied suitable measures for stabilization for all the walls of surge pool and pump house of Lift-II.

MGLIS-II form a part of Eastern Block of Dharwar Craton mainly comprised of Archaean granites which are intruded by mafic dykes age ranging from Archaean to Upper Proterozoic. Engineering geological mapping on 1:200 scale of the pump house and surge pool walls was carried out by NIRM. Detailed examination of rock types in each grid was carried out which includes mineralogical composition and texture. Fracture filling that have taken place in the study site were examined and recorded. The attitude, degree/grade of weathering, structure of the rocks, fractures and joint pattern present in the walls were mapped. The assessment of rock mass classification 'Q' for the walls of surge pool and pump house is based on the joint characteristics, while rock mass classification of rock ledge is based on RMR.

Three to five prominent joints set are developed along the walls of surge pool and pump house and clay coating was also recorded. Joints are irregular in pattern (Fig. 1.5). Granites are generally fresh to slightly weathered (WI–WII). Dykes are generally sheared along the contact at the surge pool and pump house area. Dykes are generally moderately to highly weathered (WIII – WIV).

Based on investigations, geotechnical problems were identified and remedial measures viz. stabilization of slopes of the vertical walls, patterns of rock bolts, treatment of shear zones, consolidation grouting, Spot rock bolting and 100 mm thick reinforced shotcrete with chainlink and weep holes was recommended for various slopes walls of surge pool and pump house. To preserve the rock mass strength and minimize the damage/overbreak, smooth blasting practice should be adopted for rock excavation at all locations of the project. At the time of foundation excavation of surge pool and pump house, a floor level geological plan depicting all the shear planes and other discontinuities should be prepared and accordingly treatment plan should be given.

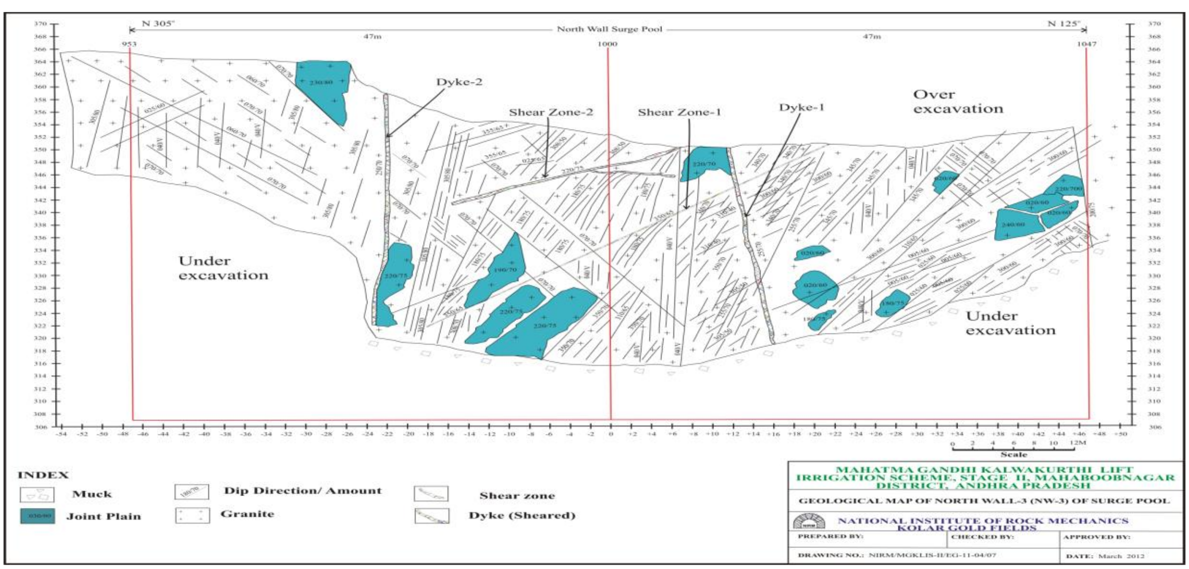


Fig. 1.5 Geological map of North wall of Surge Pool, MGLIS-II

1.6 Review of construction stage engineering geological investigations of twin tunnels on the Hungund-Hospet Section of NH-13, near Hospet, Karnataka, Project No. EG1106, On-going
(A.K. Naithani and L.G. Singh)

GMR-EPC, Bangalore are the contractors for construction of 4/6 laning of the Hungund-Hospet section of NH-13 (km-265 to 299) in the state of Karnataka. This work is being executed on DBFOT basis to National Highway Authority of India by GMR, Bangalore. In the above stretch, twin tunnel tubes (D-shaped, 15.5 m diameter and 300 m length) are required to be constructed for up and down traffic near Hospet. RCC cut and cover exists at both the approaches of 15 m length. The clear spacing between the tunnels is 20 m. There is a railway line passing on the hillock with a clear distance of 15 m from the roof of the tunnel. The width of 3-lane carriageways inside the tunnel is 14.5 m.

The scope of the work of NIRM is to review the geological / geotechnical mapping of the twin tunnels, estimated rock mass quality and suitable support measures as per design. The rocks exposed in the project site are banded hematite rocks, basalts, metabasics, banded ferruginous cherts, phyllites and mica schists. Banded hematite is the major rock type in this area. Prominent joints are developed and the rock shows weathering grade of W-II to W-III (Table 1.3). This rock is oldest sedimentary deposit of Archaean age. Other different rock types also shows different joint pattern and weathering grades (Table 1.4). The open cut area of RHS from the entry and exit was excavated through the jointed and weathered banded hematite rocks and metabasics up to the required level while cut and cover portion from the entry side was excavated through metabasics, mica schist, phyllite and banded hematite rocks. On the back slope of south of RHS, moderately weathered, jointed rocks are exposed and overburden up to 2 m was recorded during the site visit. Three benches were made along this slope and the individual slope angles for first, second and third bench above the portal are 52^o (0.8:1), 59^o (0.6:1) and 22^o (2.5:1), respectively, with an overall slope of 45^o (1:1). For bench 1 and vertical face above the portal, 80 mm thick shotcrete with chain link/wire mesh and weep holes are given in the drawing. M25 grade concrete is being used for the plain shotcrete. The size of the chain link being used at the site is 100 mm x 100 mm x 3 mm (diameter). Rock reinforcement given in the drawing is fully grouted (resin capsule) 4.5 m length rock bolt, 25 mm diameter and 2 m c/c spacing. The weephole executed at the site is 100 mm diameter drainage hole at 2 m cente-to-centre spacing, 1 m depth perforated PVC pipe. The support design was found to be adequate for the current slope.

It was recommended that the main drain constructed above the portal should be lined properly to prevent any water flow into/on the slope coming from the uphill slope. Plantation of grasses and shrubs was recommended to restore the vegetative cover on these cut slopes in other to arrest the surface erosion. Before opening the portal from the entry side of RHS, it was recommended that the vertical face should be logged and shotcreting should be done only on completion of geological logging. After reinforcing the face of the portal, it can be opened immediately. After construction of portal, forepoling up to 6.0 m was recommended. On the basis of rock mass characteristics, “Excavation of Tunnel by Centre-Heading Method” was recommended.

1.7 Construction stage engineering geological mapping of various building floors and walls of Rajasthan Atomic Power Project Units 7 & 8, Rawatbhata, Rajasthan, Project No. EG1107, On-going

(Rabi Bhusan and A.K. Naithani)

Rajasthan Atomic Power Project (RAPP) Units 7&8 consists of two types of building i.e. Nuclear Building and Non-Nuclear Building. Engineering geological foundation mapping of non-nuclear buildings of RAPP units 7&8 has been carried out by NIRM at the request of the Hindustan Construction Company Limited, Mumbai. The non-nuclear buildings for which the mapping has been done include Safety Related Electrical Houses, Safety Related Pump Houses, Fire Water Pump House, Diesel Oil Storage Areas, Ventilation Stack and Stack Monitoring Room and D_2O Upgradation Plant. The project site is exposed of fine to medium grained sandstone of Kaimur group of upper Vindhyan Super Group of Proterozoic age.

The major objective of this study was to carry out engineering geological investigation of foundation levels and vertical surfaces of non-nuclear buildings. Foundations and walls mapping has been done on the grid pattern on 1:100 scale using Total Station surveying equipment. The site is on a gentle sloping terrain and rocks are available within few centimeters from the surface. In this area, hard, massive and competent sandstones are exposed just below the 20cm from the ground surface. The total area mapped including vertical walls and horizontal to sub-horizontal foundations was 10954.088 sq.m.

Due to high weathering grade at the foundation of few buildings, extra excavation were recommended up to fresh and competent rock mass before the final foundation mapping. A detailed lithological characteristics and geological structural features were mapped (Fig.1.6). In this area, particular on the walls, different weathering grade of rock were mapped. Hard, massive and competent rock masses are exposed in the entire foundation surfaces of non-nuclear buildings. Classification of rock mass using Rock Mass Rating has been done. Based on the detailed investigations, recommendations of the remedial measures for the foundations and vertical walls are given as the excavation progresses.

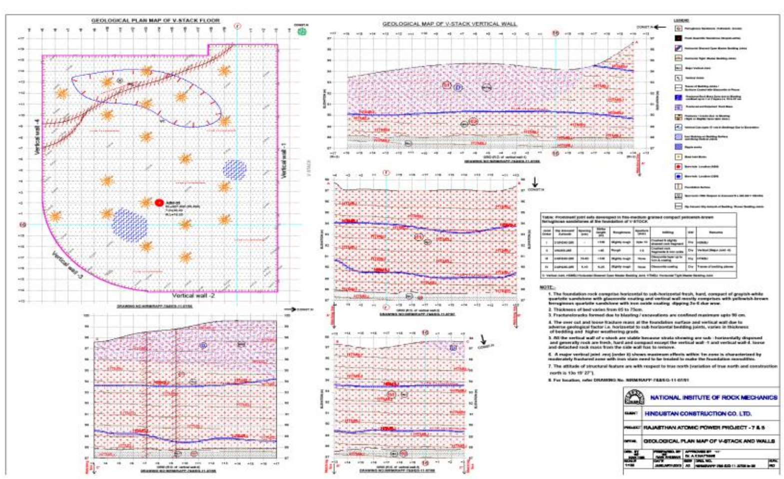


Fig.1.6 Geological Mapping of foundation floor and vertical of V. Stack building of RAPP 7&8

1.8 Review of construction stage engineering geological mapping at crude oil storage project, Mangalore, Karnataka, Project No. EG1108, On-going
(A.K. Naithani and Devendra Singh Rawat)

Indian Strategic Petroleum Reserves Limited, on the behalf of the Government of India, is constructing underground unlined rock cavern storage of imported crude oil at Mangalore. The main project components include a portal, access tunnels, water curtain tunnels, shafts and four numbers of storage caverns. The total capacity of the project is 1.50 MMT for two crude oil qualities (high sulphur and low sulphur). Engineers India Limited, who is the Project Management Consultants, requested NIRM to provide and deploy engineering geologist at project site to review geological mapping works and recommendations for temporary and/or permanent rock support systems as per design.

The area exposed laterite of Quaternary period and peninsular gneissic granitic complex includes gneissic granites, biotite-hornblende gneisses and biotite gneisses of Archean age. The rock type of the project area is basically granitic gneiss with standard granite zone and locally banding (gneissic structure) with alteration of mafic bands and felsic minerals. Mafic dykes are also present at the site and the thickness is < 1 m – 20 m. The five prominent joint sets recorded in them have the following attitudes: 260°-280° (dip amount) /80°-88° (angle of dip), 355°-020°/70°-80°, 170°-200°/60°-80°, 190°-210°/5°-10° and 010°-025°/5°-10° the surfaces of the all joint sets are rough-undulating.

NIRM is involved in review work for the geological face mapping, 3D logging, estimation of rock mass quality based on Q- value and recommendation of rock support (temporary and permanent) as per approved engineering design. Presently, review work is being carried out for shafts and storage caverns after every drill-blast, mucking and scaling cycle to acquire the geological/geotechnical data, rock description, dip direction/dip amount and ground water condition.

Mangalore site comprises four parallel caverns, two 913 m long and two 873 m long. Each cavern width is 20 m and height is varying from 23.8 m to 31 m.

2. ENGINEERING GEOPHYSICAL INVESTIGATIONS

Engineering geophysical investigations are carried out either as part of engineering geological studies being by NIRM or independently for a number of trouble-shooting operations for mining, civil and other infrastructure projects. With the state-of-the-art facilities for surface and borehole geophysical investigations, the Institute is carrying out mapping of the subsurface using refraction, reflection, sounding and cross-hole tomography techniques using seismic, electrical and GPR survey techniques. During 2011-12, this department took up five sponsored research projects which pertain to geophysical investigations for bed rock profiling and assessment of the rockmass in the foundation regime at various hydroelectric projects.

2.1 Cross-hole seismic profiling and tomography at Koteshwar Hydroelectric project, THDC, Rishikesh Project No: GP1002, Completed.

(P. C. Jha, V. R. Balasubramanaim, N. Sandeep, Y. V. Sivaram, D. Joseph and B. Butchi Babu)

Koteshwar Hydroelectric project is in the downstream of Tehri hydel project. It was at the stage of commissioning when the present investigation was carried out. As a part of stabilisation measures for the dam, grouting of the dam foundation to pack suspected shear/ weak zones was being carried out. While drilling, the drilling barrels were getting stuck in a number of holes and grout mix poured from one hole was coming out from other holes. In order to find out the longitudinal and the lateral extent of the suspected shear zone(s) in the foundation, THDC India Ltd. requested NIRM to investigate the dam foundation using geophysical methods.

After discussion with the local authorities, NIRM suggested to go for cross-hole seismic survey. Accordingly, it was suggested to drill 10 holes from the bottom-most inspection gallery up to a depth of 60 m so as to cross the desired feature. It was expected that cross-hole survey across these pair of holes will be able to map the extent/trend of fracture zone/ weak zone, present if any.

When the survey team first reached the site in September 2010, the drilling work was still in progress. While waiting for the drilling to be completed, sudden spate of rainfall in the region caused the river to overflow and the entire area got submerged and hence, the planned work could not be completed. The survey was taken up in February 2011 after clean-up and completion of drilling operations. Initial data collection with the cross-hole seismic survey revealed that the shear zone was too small to be discernible by this method. Hence we resorted to cross-hole seismic tomography which has higher resolution. The objectives of this tomography exercise was to

- map the subsurface of the dam foundation.
- identify and map the extent/trend of fracture zone/ weak zone
- access the overall condition of the foundation regime

In total, 11 holes were drilled at roughly 10 m spacing. Accordingly, cross hole seismic tomography was done at 1 m interval across ten pair of successive boreholes. Due to drilling constraints, only three out of eleven holes could be drilled nearer to the target depth of 60 m, while other terminated at 40-45 m which restricted data collection up to the depth of holes only.

All the ten tomograms so obtained under this survey were plotted perspectively in Fig. 2.1. Ten low velocity pockets marked 1-10 were identified in these tomograms. All locations of low velocity pockets were carved out and joined to generate the picture of the subsurface shear zone as shown in Fig. 2.2.

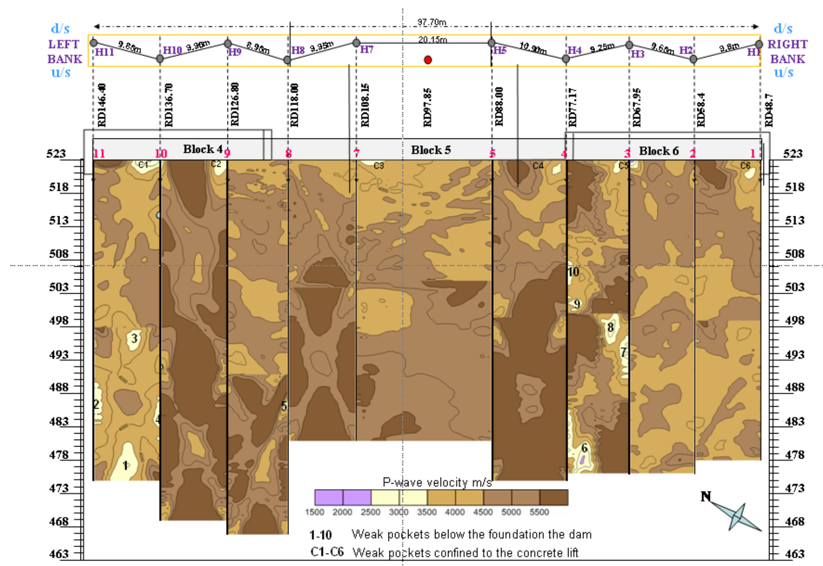


Fig. 2.1 Seismic tomography section from the bottom most gallery at EL = 523 m.

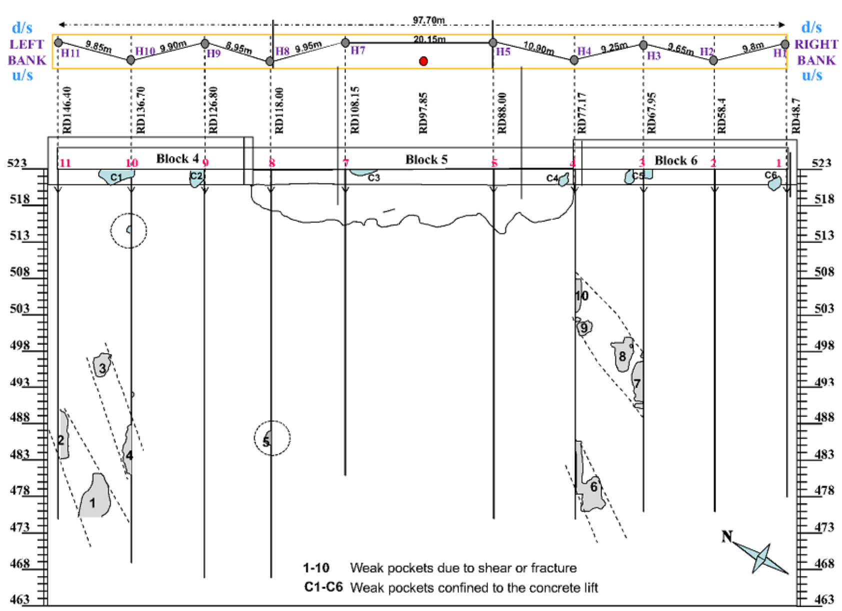


Fig. 2.2 Interpretation of subsurface from the Seismic tomography section

They represent replica of likely shear zone in the foundation area. All these shear zones were trending N-S as per normal trend of shear zones observed on the surface. Thus it was suspected that some of these zones might be continuing on the surface which might pose greater threat to the stability of the foundation. It was recommended to grout all these shear zones up to the top. Final report incorporating our findings and recommendations was submitted in May 2011.

2.2 Seismic Refraction Survey at tunnel T-74 R of Dharam-Quazigund section of J&K Rail link Project, IRCON Banihal, J&K, Project No. GP1004, Completed.

(P. C. Jha, V. R. Balasubramanaim, N. Sandeep, Y. V. Sivaram, D. Joseph and B. Butchi Babu)

Due to geological constraints, part of the alignment of the Katra-Quazigund rail link was redrawn. In order to find out the strata conditions at tunnel portal locations and bridge foundations along this revised alignment, IRCON requested for a geophysical survey along 15 discrete lines from chainage 123.5 km to 133.5 km to cover important structural locations namely Khoda-1 bridge, Tunnel-52, Khoda-2 bridge, Tunnel-53, Arpinchala station yard, south portal of T-74R and escape tunnel, Junction location at 133 km and the North portal junction location of T-74R. It was desired by IRCON to project the likely tunneling medium around portal locations and the strata conditions the bridge abutments as well as in the station yard area. Data acquisition work was carried out during March-April 12, 2011. Out of these 15 lines, seven lines were surveyed using hammer source (each lines measuring 115 m) and eight seismic lines were surveyed using explosive source (each lines measuring 230 m). Depending on the method used, the depth of investigation was up to 40 m for hammer source and 75 m for the explosive source.

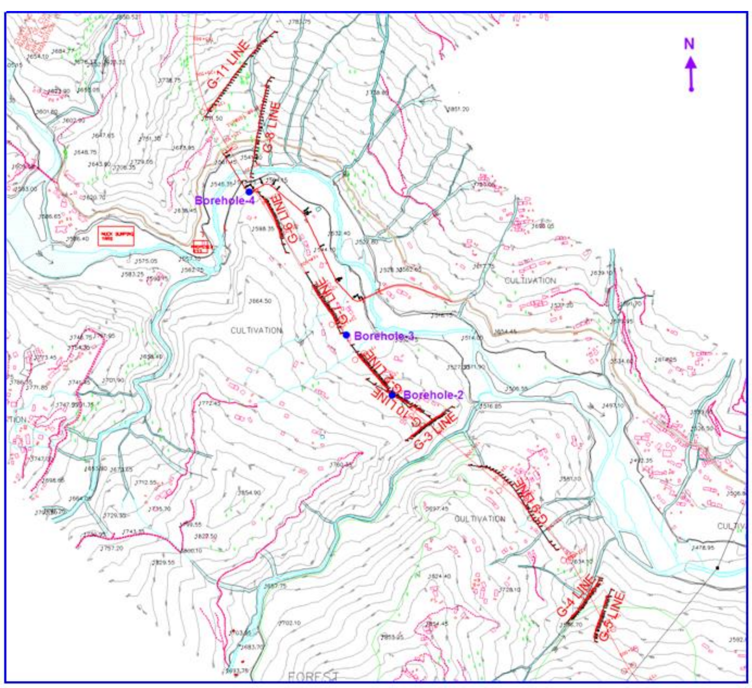


Fig. 2.3 Part plan showing south portal to tunnel T-74R

Most of these survey lines were laid on thick overburden materials. At many locations it was spread over slide debris to ascertain the depth to the bed rock. Fig. 2.3 shows the part plan of the area showing locations of 10 out 15 lines surveyed. Geologically the rock types exposed in the area are phyllitic quartzite associated with phyllite, slates and quartzite. Black coloured limestone bands are present on the right bank of the nearby nallah.

A sample seismic section along the profile G-8 is shown in Fig. 2.4. This line is trending roughly N-S between chainage 125.210-125.415 km. The survey area was a typical slide zone where the South Portal of Escape Tunnel was planned.

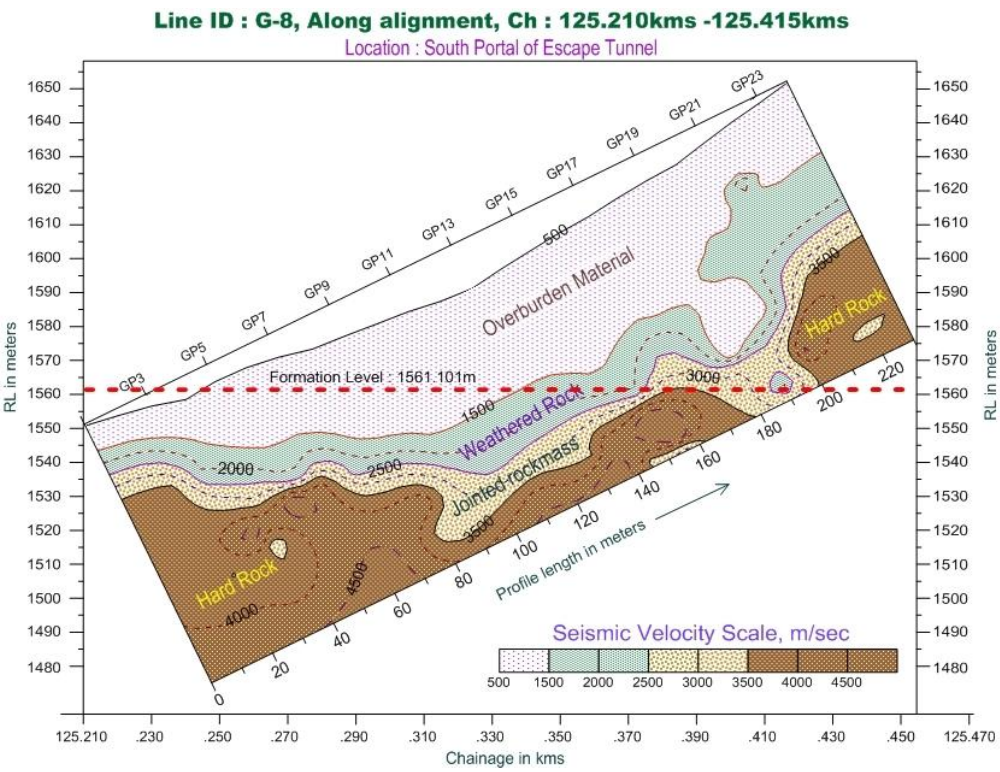


Fig. 2.4 Section along line G-8 at the South Portal of Escape Tunnel.

In this section subsurface layers indicate the presence of a dominant (8-35 m thick) overburden (loose and compact soil) layer in the central portion followed by 5-10 m thick weathered rock layer. As per plan, formation level along this line is at 1561.1 m, which is shown by dotted line. This is found mostly running in the slide material. Depth to the hard rock along this line varies from 22-70 m. There appears to be anomalous geological situation towards the end of this line (180-200 m distance), where a shear type feature is suspected but it needs to be confirmed by drilling. Though a cut and cover section was suggested for the first 125 m portion of this tunnel, the railway authorities subsequently re-located this portal considering the adverse geological conditions for tunnelling.

2.3 Seismic Refraction Survey at tunnel T-48 of Dharam-Quazigund section of J&K Rail link Project, IRCON, Banihal, J&K, Project No. GP1101, On-going
(P. C. Jha, V. R. Balasubramanaim, N. Sandeep, Y. V. Sivaram, D. Joseph and B. Butchi Babu)

In yet another stretch of the revised alignment of Dharam-Quazigund section, IRCON asked for geophysical survey for strata classification at various locations around tunnel no. 48 (T-48 area) near Sangaldhan with a view to ascertain the tunneling medium along the survey lines as well as the foundation regime at the bridge abutments. In total, ten survey lines were identified to cover various important structures like either portal locations of the main tunnel, adit portals and nallah sections.

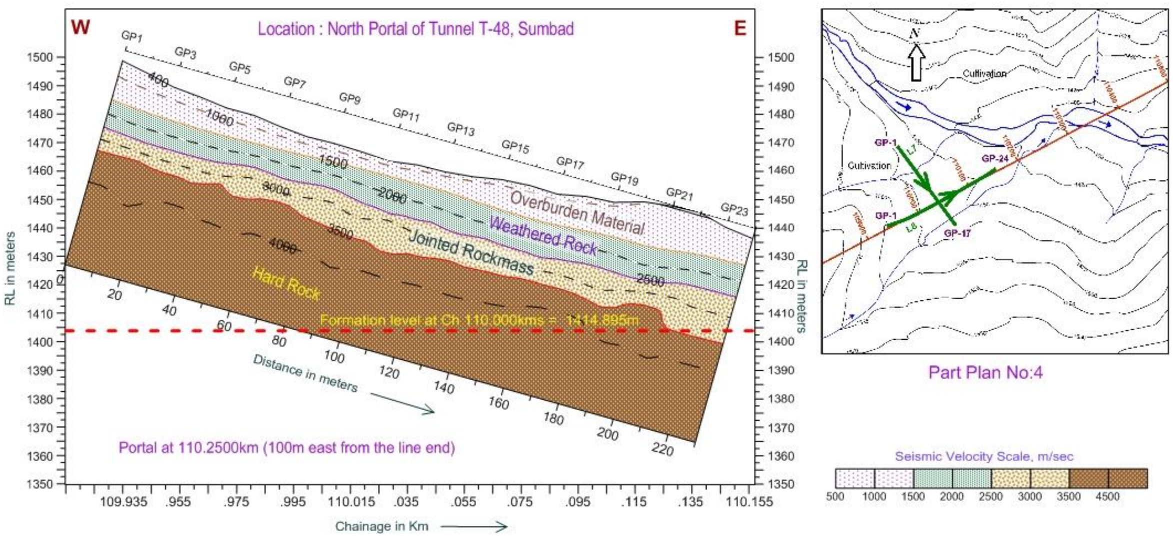


Fig. 2.5 Section along line North Portal of Tunnel-74

A sample seismic section along the North portal of tunnel-48 is shown in Fig. 2.5. This line was passing through slope wash material and cultivatable fields. The subsurface layers in this figure are almost parallel and appear dipping towards the nearby nallah. The thickness of the overburden layer along this line is 7-9 m followed by the weathered and jointed rock mass layers with even thickness of around 7-8 m. Hard rock mass layer is found at 40 m depth from the surface. The formation level of 1414.895 m along this line is passing mostly through the hard rock layer but towards the end it is in the jointed rock mass layer indicating that this portal might be in the jointed rock mass layer.

2.4 Seismic refraction survey along the power tunnel alignment at the intake area of Pallivasal Hydroelectric Project, Munnar, Kerala,Project No: GP1103, On-going.
(P. C. Jha, V. R. Balasubramanaim, N. Sandeep, Y. V. Sivaram, D. Joseph and B. Butchi Babu)

Kerala State Electricity Board is working on the prospect of the extension of the present Pallivasal hydroelectric scheme to generate additional 60 MW of water by harnessing the available waters. Under this extension scheme it is proposed to have a new head race tunnel, surge shaft, pressure shaft, two penstocks (one for the existing power house and the other for proposed power house) and a power house. The platform of a shaft being sunk in the initial stretches to drive the power tunnel collapsed under adverse geological conditions. Hence it was desired to investigate the rock mass condition around the proposed tunnel alignment.

Accordingly geophysical investigation using seismic refraction method was carried out in the Intake area as well along further stretches of this power tunnel and likely alternate route. The scope of the seismic refraction survey was to provide information on the nature and profile of overburden, weathered rock and bed rock up to a maximum depth of 80 m. In total seven lines were identified for the seismic refraction survey. While the field work was completed during the reporting period, the data processing work was still in progress.

2.6 Seismic refraction survey at the CMRL project site at the Chennai central Station, TT-AFCONS JV, Chennai, Project No. GP1102, On-going.

(P. C. Jha, V. R. Balasubramanaim, N. Sandeep, Y. V. Sivaram, D. Joseph and B. Butchi Babu)

M/s Trasnstonnelstroy-AFCONS joint venture is carrying out construction of subsurface station at Chennai Central station area as part of Chennai Metro Rail project commissioning. The subsurface station in the Chennai Central area is a two level station, wherein excavation and construction of components of subsurface station are in progress. In order to know thickness of soil, subsurface rock and their profile, geophysical survey at the construction site was requisitioned along the diaphragm wall planned for construction.

Accordingly seismic refraction survey, using 24-channel set up at 5 m interval with hammer and explosive source was carried out along the proposed diaphragm wall between Chennai Central Station and Ripon Building. The location of the seismic survey lines was identified by AFCONS.

3. GEOTECHNICAL ENGINEERING INVESTIGATIONS

Geotechnical investigations at different stages of projects are an essential and integral part for the design of civil engineering/ mining structures. In case of civil structures, the decisions for geometry, shape, dimensions, excavation sequence, orientation of the support system, acceptable water pressure for the conduits are heavily dependent upon the results of geotechnical investigations. In mining, geotechnical investigations help in mine layout, pillar design, stope design and sequence of mining for safe and economical extraction of minerals. Geotechnical Engineering department with its experienced manpower and state of the art equipment is actively involved in different geotechnical investigations of a number of projects in India and abroad. During 2011-12, the department completed four sponsored projects for hydropower sector. One S&T project sponsored by Ministry of Mines is under progress.

3.1 Determination of in–situ stress parameters by Hydrofrac method in the drift along adit to desanding chamber at the proposed Shongtong Karchham Hydro Electric Project Stage, HPPCL, Project No. GE1005, Completed.

(S. Sengupta, D. S. Subrahmanyam, R. K. Sinha, G. Shyam and Moses Immanuel)

Shongtong Karchham Hydro Electric Project, a run-of-river scheme on the river Satluj in Kinnaur district of HP, envisages construction of 102.5 m long diversion barrage, near village Powari to divert 406cumecs discharge to four sedimentation chambers, each 300 m long. For the design of desanding chambers, the in-situ stress parameters is of utmost importance considering the fact the stability of the underground cavern gets enhanced if the long axis of the cavern is oriented along or sub-parallel to maximum principal stress direction. At the request of Himachal Pradesh Power Corporation Ltd (HPPCL), NIRM carried out investigations inside the drift along the adit to the proposed desanding chamber. The scope of work was as follows:

- In-situ stress tensor measurement by Hydrofrac method using HTPF method (Hydrofrac Test in Pre-existing Fractures) inside EX boreholes in the vicinity of the proposed desanding chambers.
- Analysis of the data using software to evaluate complete stress tensors.

Geotechnical investigations were conducted at the site from 30 June 2011 to 03 July 2011. The results of the investigations are given in Table 3.1.

Table 3.1 In-situ stress by hydrofrac method

Vertical Stress (σ_v) (Calculated with a rock cover of 191 m and density of rock = 2700 kg/m^3)	5.05 MPa
Maximum Horizontal principal Stress (σ_H)	16.125 ± 2.6044 MPa
Minimum Horizontal principal Stress (σ_h)	10.75 ± 1.7363 MPa
Maximum Horizontal principal Stress direction	N 150^0 -N 160^0
K = σ_H/σ_v	3.19

The conclusions from the study are as follows:

- The maximum compression direction is N 150 - 160^0.
- A high K-value indicates influence of tectonic stress at the site.
- The long axis of the proposed desanding chamber is preferred to be oriented along maximum compression direction i.e., N 150 - 160^0 for optimum stability

3.2 Determination of in-situ shear and deformability parameters at the proposed Pare Hydroelectric Project, NEEPCO, Arunachal Pradesh for the design of Dam, Project No. GE1103, Completed

(S. Sengupta, D. S. Subrahmanyam, R. K. Sinha, G. Shyam and Moses Immanuel)

The Pare Hydroelectric Project is proposed on river Pare in Arunachal Pradesh. It envisages construction of a 78 m height concrete gravity dam and a surface powerhouse to house 2 units of turbines of 55 MW each to generate 110 MW. The shear parameters and deformability of rock mass are the two important parameters required for the design of a concrete gravity dam. In view of the importance of these parameters, North Eastern Electric Power Corporation Ltd (NEEPCO) engaged NIRM to carry out different in-situ investigations inside the drift excavated along the proposed dam axis. The scope of the work is as follows:

- To determine In-situ Deformability parameters of the rock mass inside exploratory drift at the right bank of proposed Dam axis (Fig. 3.1).
- To determine in-situ shear characteristics between concrete to rock and rock to rock interface inside exploratory drift at the right bank of proposed dam axis.
- Analysis of the data for evaluation of the peak and residual cohesion values, the angle of internal friction and the modulus of rock mass.

Different in-situ investigations were conducted on sandstone inside the exploratory drift on the right bank at the proposed dam axis (Figs. 3.1 & 3.2). The deformability modulus of the rock mass (determined by plate load test method) in the right bank at EL 220 m (E_m) is 0.08 GPa to 0.66 GPa. The other results are given in Tables 3.3 to 3.4.

Table 3.2 Shear parameters of the rock mass (Concrete-rock interface)

Peak shear parameters		Residual shear parameters	
Cohesion (c) kg/cm^2	Angle of internal friction (Ø)	Cohesion (c) kg/cm^2	Angle of internal friction (Ø)
1.057	49.81	0.023	46.73

Table 3.3 Shear parameters of the rock mass (Rock-rock interface)

Peak shear parameters		Residual shear parameters	
Cohesion (c) kg/cm^2	Angle of internal friction (Ø)	Cohesion (c) kg/cm^2	Angle of internal friction (Ø)
1.217	49.92	0.591	49.33

It is concluded that the peak could not be achieved as the rocks have undergone shearing by natural process. The rock mass can be categorized in poor category.

Fig. 3.1 Plate load equipment set-up at the site

Fig. 3.2 Direct shear test set-up at the test site

3.3 Determination of In-situ stress, Deformability and shear parameters at proposed Dibang Multipurpose H.E. Project NHPC Ltd, Arunachal Pradesh, Project No. GE0810 & GE0811, Completed

(S. Sengupta, D. S. Subrahmanyam, D. Joseph and R. K. Sinha)

At the proposed Dibang Multipurpose H.E. Project NHPC Ltd, Arunachal Pradesh, for the optimum design of the powerhouse along with the support system, different in-situ investigations inside an exploratory drift at the proposed powerhouse chamber were conducted by NIRM to obtain in-situ stress and in-situ shear and deformability parameters. The scope of the investigations is as follows:

- In-situ stress measurement by Hydrofrac method inside a NX size borehole
- Deformability moduli of the rock mass encountered inside exploratory drift to the Powerhouse at five places by plate loading method
- Shear parameters of the rock mass encountered inside exploratory drift to the Powerhouse at five places by direct shear test method

The results of the investigations are given below in Table 3.5 to 3.7 and the comparison of various results given in Figs 3.3 to 3.4.

Table 3.5 Stress tensors derived from by Gensim analysis

Vertical Stress (σ_v) in MPa (Calculated with an overburden of 400 m and density of rock = 2700 kg/m3	10.58
Maximum Horizontal principal Stress (σ_H) in MPa	13.22
Minimum Horizontal principal Stress (σ_h) in MPa	8.81
Maximum Horizontal principal Stress direction	N 150^0
K = σ_H/σ_v	1.25

Table 3.6 Deformability modulus of the rock mass by Plate load test method

Em (RDR-8)	0.213 GPa to 1.398 GPa
Em (LDR-5)	3.71 GPa to 4.33 GPa

Table 3.7 Deformability parameters by Pressure meter method

Mean with S.D. (E_d)	8.62 ± 5.18

Table 3.8 Shear parameters of the rockmass (Direct shear test method)

Location	Peak shear parameters		Residual shear parameters	
	Cohesion (c) kg/cm^2	Angle of internal friction (Ø)	Cohesion (c) kg/cm^2	Angle of internal friction (Ø)
Left bank	Peak could not be achieved Might have already sheared by natural process		1.857	25.6
Right bank	Peak could not be achieved Might have already sheared by natural process		1.367	21.3

The conclusions drawn from rock mechanics investigations are as follows:

1. The rock quality at the right bank drift is poor
2. The rock quality at the left bank is fair to poor inside the drift.
3. But the rock encountered deep inside the foundation rock is good to very good as revealed by pressure meter test

Peak could not be achieved probably the rocks have undergone shearing by natural process. The rock mass can be categorized in poor category.

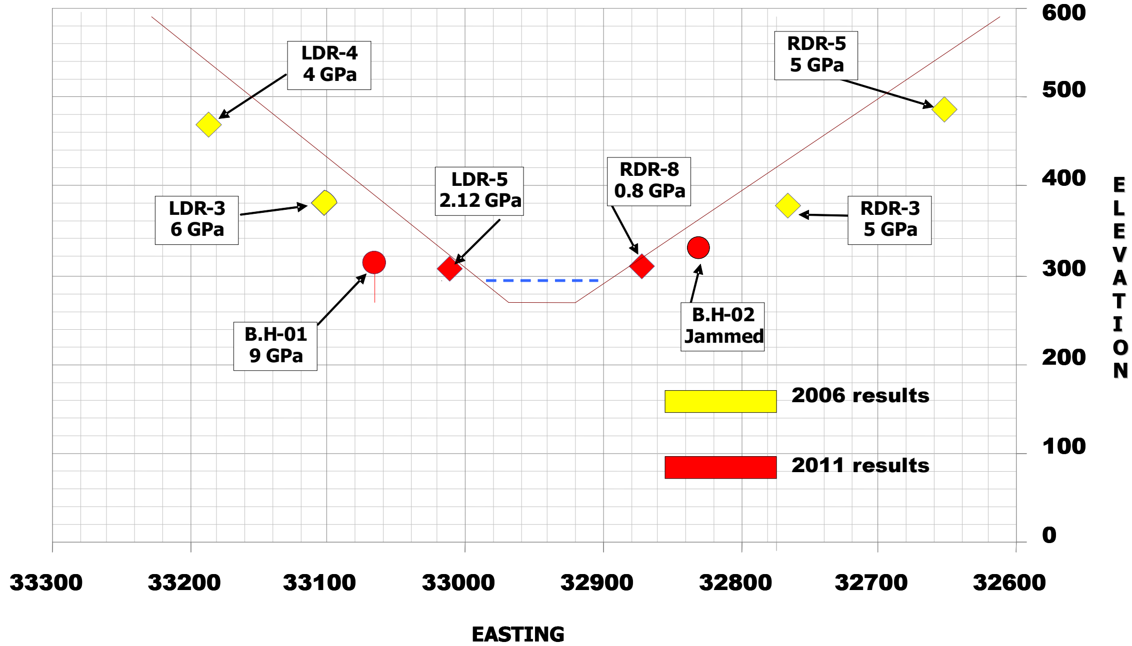


Fig 3.3 Comparison of results for deformability parameters conducted at various locations at Dibang Hydroelectric Project, Arunachal Pradesh

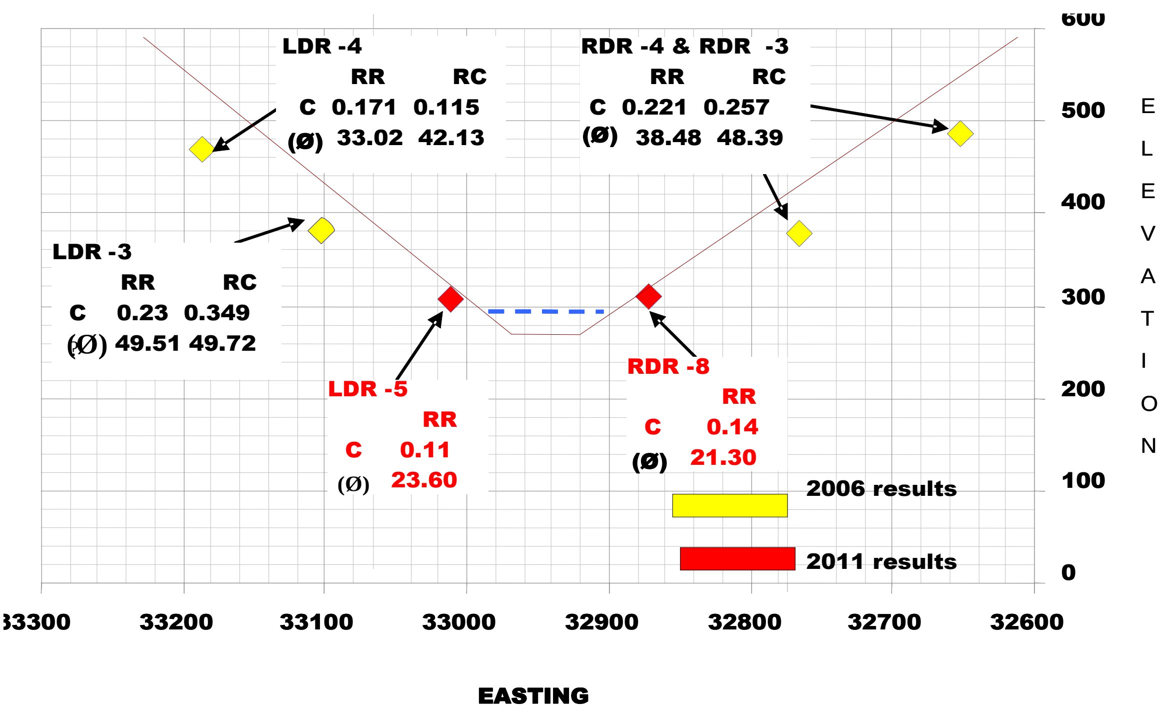


Fig 3.4 Comparison of results for conducted at various locations at Dibang Hydroelectric Project, Arunachal Pradesh

3.4 Development of state of the art Facilities for In-situ Stress measurement by Hydrofracture Method in Porous and Fractured Rock Mass, S&T Project No. GE1003, <u>On-going</u>
(S. Sengupta, D. S. Subrahmanyam, D. Joseph and R. K. Sinha)

The S&T Project, titled "Development of state of the art Facilities for In-situ Stress measurement by Hydrofracture Method in Porous and Fractured Rock Mass", was sanctioned by SSAG under Ministry of Mines during 2009-10 and financial assistance was received for the 1st year. Global tender notice has been floated for the procurement of Hydrofrac and CSIRO Overcoring equipment with accessories. Suitable Mines for conducting the investigations have been identified both in Western coalfields and Singareni collieries. Field investigations will commence very soon.

4 ROCK FRACTURE MECHANICS

Rock Fracture Mechanics laboratory has the facility and expertise to carry out basic research and to determine the properties of both intact and jointed rocks. The laboratory is also well-equipped to determine the properties of dimensional stones as per ASTM and European standards. During 2011-12, laboratory investigations were conducted for two projects besides regular testing of rock samples.

4.1 Laboratory rock mechanics investigations for Chamkharchhu-I Hydroelectric Project, NHPC, Project No. RF1101, Completed.

(G. M. Nagaraja Rao and S. Udayakumar)

Rock samples, obtained from the dam site, power house, pressure and surge shaft, power house drift and Head Race Tunnel of Chamkharchhu-I Hydroelectric Project, were investigated at NIRM. The test samples were prepared from the cores and the rock blocks collected from the blasted debris. The rock type included garnetiferous quartz mica schist, granite gneiss, schistose quartzite, quartzite, phyllite and micaceous quartzite. Most of the rock samples contained foliation planes at an angle to the core axis.

The test results are given in Table 4.1 and 4.2. In the case of dam site, the samples from inclined borehole show higher strength than those from the vertical bore hole. Granite gneiss has higher strength than garntiferous quartz mica schist. Dry and water saturated samples show inconsistent trends due to highly heterogeneous nature of the samples. There is a perception that water affects the strength of all rock types. In general, it is observed that water affects the strength of sedimentary rocks, not the strength of igneous and metamorphic rocks. Due to some reason, if the igneous and metamorphic rocks contain a large number of micro and macro cracks, water decreases the strength for these rocks. In the case of sample of power house drift, the rock type is quartzite. The table shows that the strength of quartzite decreases with the presence of water. Quartzite is a high strength and very compact rock (Fig. 4.1). Water cannot decrease the strength of a high strength rock without the presence of defects. For water saturated samples, strength decreases due to the combined action of microcracks and water.

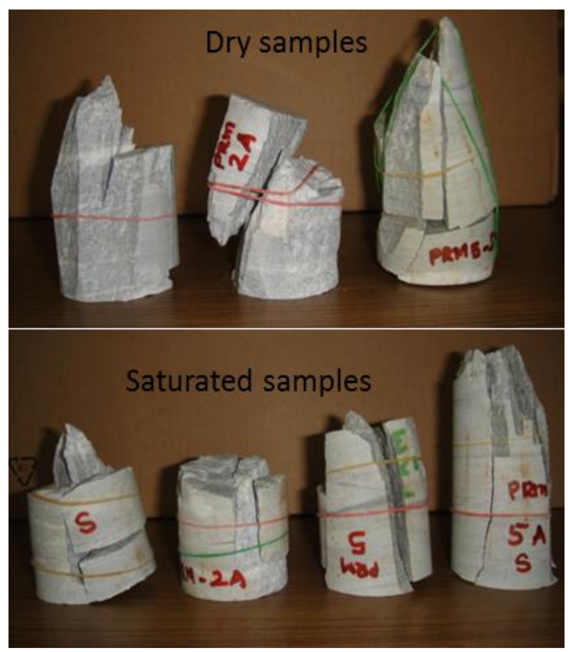


Fig. 4.1 Fractured samples of quartzite rock

4.2 Laboratory rock mechanics investigations for Tawang Hydroelectric project, stage 1 & 2 NHPC, Project No. RF1102, Completed

(G.M. Nagaraja Rao and S. Udayakumar)

Rock samples were investigated from desliting chamber, power house cavern, pressure and surge shafts and Head Race Tunnel of Tawang Hydroelectric project, stage 1 & 2. Rock properties for biotite gniess, quartzo-biotite gniess, quartzo-feldspathic gniess, quartz mica schist, quartz biotite schistose gniess and mica schist were determined under dry and water saturated conditions. Test results for the water saturated conditions show lower uniaxial compressive strength, young's modulus, tensile strength and cohesion than for the dry conditions. However, the trend was inconsistent for Poisson's ratio and friction angle. The inconsistency in Poisson's ratio is due to unusual lateral deformation at low stress levels. Friction angle is largely influenced by the nature of interface at the fracture plane and the orientation of failure plane to the principal stresses, which varied from sample to sample and is responsible for its erratic trend. In the case of biotite gneiss the friction angle for dry sample is 31.97^{o} whereas for water saturated sample it is 5.22^{0}. Such a large difference is attributed to the orientation of foliation plane to the core axis (Fig. 4.2).

Fig. 4.2 Foliation planes with respect to core axis

4.3 Physico mechanical properties of dimensional stones and rocks

(G.M. Nagaraja Rao and S. Udayakumar)

Physico mechanical properties of dimensional stones and rocks were also determines for different granite / felsites rocks from Karnataka.

5. ENGINEERING SEISMOLOGY

Continuous monitoring of seismic activities is essential to understand the seismotectonics of the region and to assess the stability of underground and opencast excavations. During 2011-12, the Engineering Seismology Department had one S & T project and one sponsored project.

5.1 Seismotectonic Evaluation of Kudankulam Atomic Power Plant within 30km Radius area, Tamil Nadu. Project No. EG0903, Completed.

(D.T. Rao, Biju John, Yogendra Singh, K.S. Divya Lakshmi, and P.C. Nawani)

The Kudankulam Atomic Power Station complex is located near Kudankulam village close to the coast of Thirunelveli district of Tamil Nadu. The seismotectonic evaluation of the area covering 30 km radius was carried out by NIRM. The study identified 54 lineaments that were grouped into 14 sets based on the trend, association and affinity and called them as systems.

The NW-SE systems constitute the major trend in the area. Field investigations identified some of these (N2 and L4) lineaments are showing signatures of neoteconism. Regionally these systems are sympathetic to Tenmali and Achankoil fault system. Earlier studies indicated the presence of NE-SW trending crystalline sedimentary contact fault which was named as L7. The present study However did not identify the surface expression of this fault. For considering the design aspect for seismic hazard of the plant the L7 was extrapolated into the sea as per the comments of Dr SK Biswas, Expert – Seismoteconics, AERB.

The seismotectonic map prepared assimilating and synthesising the different data sets (Fig. 5.1)

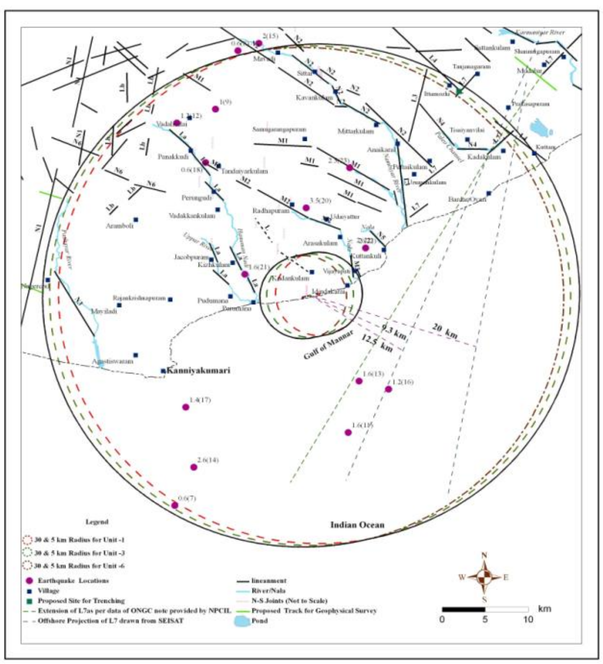


Fig.5.1 Seismotectonic map of the 30 km radius of the Kudankulam project site

There were two earthquakes of M=6.0 in the region. The earthquake of 9th February 1900 was located around Coimbatore. This event was located on the NW part of the major lineament L9 in land and is probably associated with it. This lineament was also extended up to western part of Sri Lanka. However, the recent ONGC note does not show this as extending to Sri Lanka. The same has been terminated before the NE-SW trending Gulf of Mannar and Palk Strait lineament (GM) as per NPCIL note.

Another earthquake was the 6th December 1938 which was located in Gulf of Mannar. Hence there was only one earthquake of M=6.0 in 1938. The event of 1938 was located in the offshore region. The lineament L5 with extended part up to west coast of Sri Lanka was shown in report by Ghosh and Banerjee (1989). However, its extension into Gulf of Mannar fault up to the east coast was not shown but marked as Tenmalai-Achankovil Fault/ lineament in the NPCIL note. Also there was an event of M=5.1 of 6th December 1993 located in Gulf of Mannar besides some micro earthquakes as shown by NGRI and IMD data. It appears that the spatial distribution of the events show a linear trend in L5 direction.

The final report in two volumes is submitted to NPCIL. The study recommended for further evaluating the offshore structures and other lineaments in the sea. The extensions of the land lineaments mainly L2, L3 & L7 and some lineaments, associated broad offshore structures as indicated in the NPCIL note also need to be studied.

5.2 Seismotectonic evaluation and related geological studies in Pudimadaka Achutapuram Mandal, Visakhapatnam district, Andhra Pradesh. Project No. EG1001, On-going

(D.T. Rao, Biju John, Yogendra Singh, G.H. Kotnise, K. Kanna Babu, K.S. Divya Lakshmi and P.C. Nawani)

The area located near Pudimadaka in Achutapuram Mandal of Visakhapatnam District, Andhra Pradesh covers the coastal inland portion with an area of 60 x 30 km^2 and falls in the zone II as per the seismic zoning map of India (2002).

Eighty four lineaments were marked from LISS4, cartosat and landsat data (Fig. 5.2). The features 68 and another parallel lineament in NWSE direction were delineated as discontinuous features marked by two sets of NW trending zone of width varying from 4 to 10 km. This zone was field checked and evidences of faulting were noted at three places.

Based on the association and trends, the lineaments are grouped into 8 sets. Of these, six are falling in NW-SE and three in NE-SW directions. Signature of reverse faulting observed in the khondalite rocks in the vicinity of NW2 There are black coloured vein like materials in some of the fault planes and joint planes (Fig.5.3). Thin section studies shows that this material is ferruginous breccia. More structural features associated with faulting observed in a high rock cut nearby (Fig. 5.4) where the dislocation occurred along the contact plane of pegmatitic vein. All these faults are in NW-SE direction.

Along NW5 near Kanakadurga a major reverse movement observed in the khondalite rock. The exposure exhibits distinct structural features on either side of the slip plane (Fig.5.5). At Kottavuru dominant strike slip movement also observed in a steep NE-SE trending joint indicating movement toward NE direction (Fig.5.6). Field studies identified signatures of brittle faulting through the presence of gouge and slickensides. Fracturing and associated fluid activity has also been identified. XRD analysis identified calcite and Kaolinite as the minerals in the fracture zone.

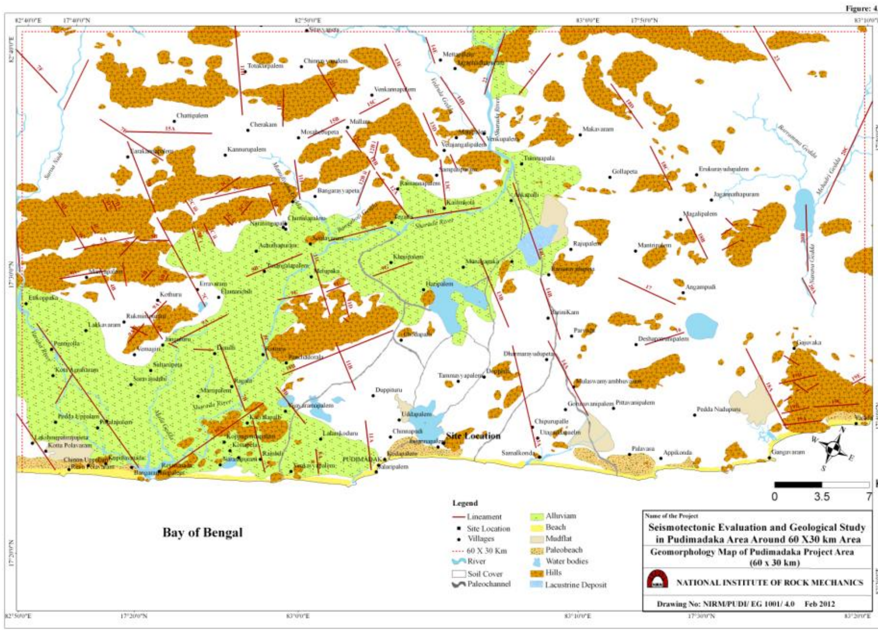


Fig. 5.2 Geomorphological and lineament map around Pudimadaka

As a part of identifying deformational features in the quaternary sediments, river sections were cleaned and exploratory trenches were made where ever the conditions for liquefaction satisfying. Sedimentary features resembling liquefaction due to seismicity has been identified in the Pudimadaka area and in the bank of Sharada River.

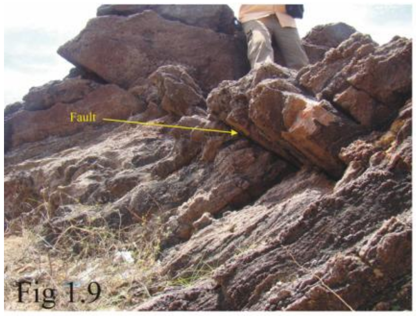


Fig. 5.3 (Top-Left) The NW-SE trending fault exposed in the Khondalite rocks. Note the sharpness of the fault plane in comparison to the weathered surface of the rocks; Fig. 5.4 (Top-Right) The black vein observed in the fault plane; Fig. 5.5 (Bottom-Left) Another NW-SE trending fault exposed in the rock section in the vicinity of the lineament NW2. Note the convergence of joints to the slip plane and discontinuous and curved joints on the hanging wall; Fig 5.6 (Bottom-Right) Photograph shows the reverse fault identified near Kanakdurga temple.

NIRM integrated the published offshore and onshore geophysical data (Fig 5.7). It is found that the features identified in land as well as offshore may have some continuity. The NW-SE lineament named as 68 by AMD was not picked up in the earlier onshore magnetic studies. This lineament is identified by NIRM from the magnetic contours.

The seismological data compiled from global, GBA and IMD catalogues contains 185 earthquakes from regional point of view for a grid between Lat 15^0N-19^0N and Long 80^0E-85^0E for the period 1063-2008 of magnitude ranging from M=2.1 to 6.0. There are about 16 earthquakes within 100 km radius with max magnitude of 4.5 located NE of site. The MEQ data within 50 km radius is not available. Only one earthquake data of M=3.1 was reported within 30 km. The major part of the work is completed and a draft report was submitted during February, 2012.

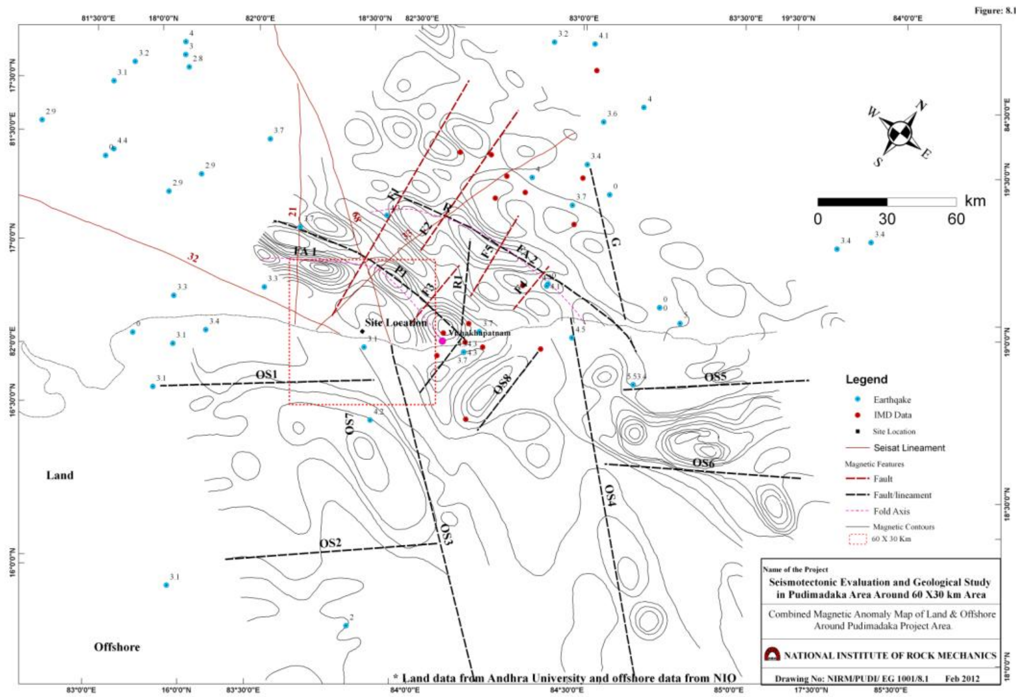


Fig. 5.7 A combined magnetic anomaly map of onshore and off shore around Pudimadaka project

5.3 Seismotectonic Evaluation of Kudankulam Atomic Power Plant within 30-50km Radius area, Tamil Nadu, Project no EG1005, <u>On-going</u>

(D.T. Rao, Biju John, Yogendra Singh, Alok Kumar Mohapatra, A.S. Negi, P.S. Varma)

This project is in continuation with the earlier studies by NIRM. During the study of Kudankulam 30 km it is found that many lineaments are having regional affinity. In order to access these lineaments NPCIL offered a second project for evaluation all the lineaments within 30-50 km. 32 lineaments were identified in this area from the analysis of satellite images. Most of them are falling in the hilly terrain and the reserve forest. L4 and N2 are the major lineaments continuing in 30-50 km. These are sympathetic to NW-SE trending Tenmalai fault system. A surface rupture zone on laterite was identified in the zone of L4 near Ittamozhi. This area was studied and documented various deformational features (Fig. 5.8). The rupture zone in general is marked by open cracks (Fig. 5.9) and reverse faults (Fig. 5.10) and is overlain by Aeolian sediments. Three faults identified in this zone show trapped sediments within laterite due to reverse movement (Fig. 5.10 & 5.11). This area has been mapped and documented the structural and stratigraphic features associated with faulting.

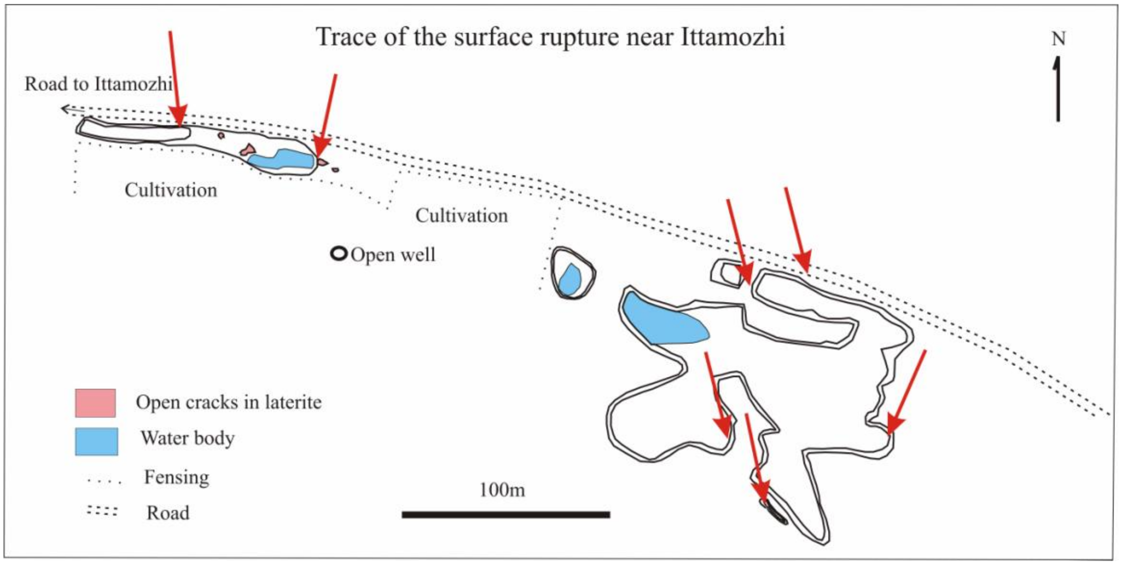


Fig. 5.8 Mapped rupture zone near Ittamozhi; red arrows shows the locations of the fault

To find out the time of deformation, OSL dating was carried out to respective samples. The age of Aeolian deposit over undeformed laterite zone is dated as 3.7±0.3. Dating of the trapped sediments within laterite due to faulting shows two different dates for the events viz., 1.73± 0.06 and 4.3 ± 0.4 ka. This repeated events indicate the lineament L4 is active. Signature of the lineament N2 is also observed in the wells (Fig. 5.12)

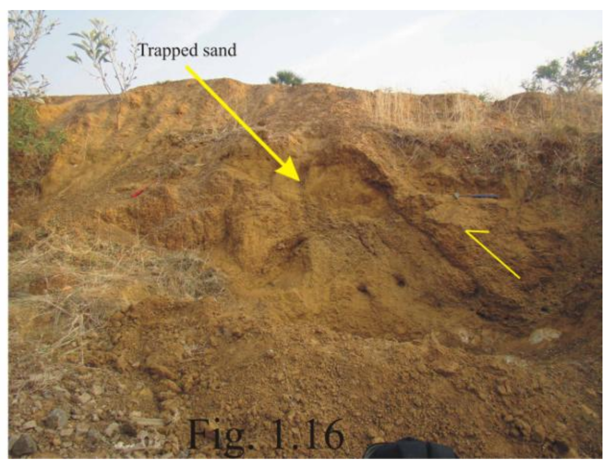


Fig. 5.9 (Left) Rupture zone at Ittamozhi being mapped; Fig. 5.10 (Right) A reverse fault showing Trapped sediments

Fig. 5.11 (Left) collection of samples for OSL dating from one of the fault zones in the Ittamozhi rupture zone; Fig. 5.12 (Right) The signature of lineament N2 observed in the open well.

5.4 Estimating the Recurrence of Earthquakes in the Central-Eastern Himalaya and Upper Assam from the Distant Liquefaction Features of the River Plains, Project No.EG0906, <u>On-going</u>

(Biju John)

The study, in collaboration with the IISc, Bangalore, is to identify paleoearthquakes from the central and eastern Himalayas through distant liquefaction studies in the Ganga-Brahmaputra basin (Fig. 5.13). The basic idea of this study is that the great earthquakes of Himalaya can trigger liquefaction even at distant locations where conditions are favorable. For example 1934 and 1988 Bihar-Nepal events induced liquefaction in the gangetic planes. Thus the study focused on these areas to find out the earlier events through trench investigations. Once the events are established the Dating of stratigraphically controlled samples would give the respective time of events and thus the recurrence interval for the earthquakes.

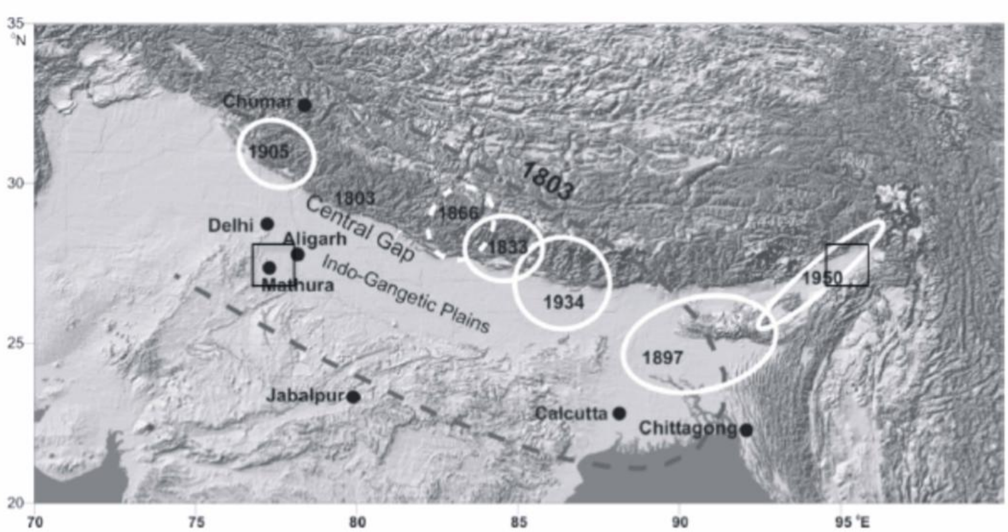


Fig. 5.13 Study sites associated with the central seismic gap and the 1934 and the 1950 earthquakes are identified by squares.

For a preliminary assessment of the sites and to understand the potential for liquefaction we used satellite photos. Further, the historical descriptions of these earthquakes were also used to identify sites affected by liquefaction. The depth to water table and the stratigraphic superpositions of various lithologies was recorded and analyzed to identify potential areas to locate the trenches. Large trenches (5-10 m long and 3-4 m deep) based on the water table and site conditions were excavated.

During this period field work was concentrated around Shravasti and Balrampur (Utter Pradesh) and Madupani, Darbhanga, and Simra (Bihar) where the phenomenon of liquefaction was reported for 1934 and 1988 earthquakes. The field locations of the phenomenon were identified through local interaction. Near Rajnagar (Madupani) a large number of creators, formed due to 1988 earthquakes, were identified. Six trenches were made in the zone of liquefaction. The studies indicated that the spouted material were of mud size. At Shravasti 2.5-3 m high the river section were cleaned for about 80 m length and identified various deformational features. Six locations of liquefaction of 1934 were identified in Simra and four trenches were made for the studies. The liquefaction features identified are typically tubular sand dykes (Fig. 5.14) as well as the creator deposits. Trench studies identified soft sediment deformations related with 1988, 1934 and older events too (Fig 5.15). Each event horizon is separated by normal sedimentary deposits. For dating the events, samples were collected from the stratigraphically controlled sedimentary layers which will be subjected to OSL and C^{14} dating. The samples are also being collected for size analysis and triaxial cyclic shear stress analysis from various horizons. Different generations of seismically induced paleoliquefaction features were identified based on their cross-cutting relations or those related to unconformities. From such an analysis, we differentiate different generations of features. Samples were collected from each of the levels, to obtain the maximum, minimum and contemporaneous ages.

Fig. 5.14 (Left) Tubular sand dyke observed in the trench wall at Simra, Bihar; Fig. 5.15 (Right) Repeated spouting observed in a trench at Simra, Bihar. Each spouting event is separated by normal deposition.

The change of sorting and compaction of the source layers of liquefaction is still not understood properly. The source layer identified in the liquefied area is below 3 m. Seismic survey, using 24 channel seismographs, was conducted at various locations of Madubani so as to understand the various compaction aspect of the liquefied layer below. The data is under processing. The results are being compiled for the second year report.

5.5 Evaluation of Neotectonic Activity of Desamangalam Fault, in the Western Terminus of Palghat Gap, Peninsular India, Project No. EG0906, On-going
(Biju John, Yogendra Singh)

The region around Wadakkancheri, which lies in the south western terminus of Palghat Gap is experiencing micro seismic activity since 1989. Most of the causative faults responsible for major earthquakes are detected only after the occurrence of the earthquakes. Studies elsewhere in the cratonic hinderland show that the damaging earthquakes occur on pre-existing faults with a recurrence period of tens of thousands of years. These long return periods facilitate weathering and erosion to destroy the physiographic evidence of faulting. However, such deformation in regard to active tectonism can be identified from careful, geomorphological studies using topographic maps, aerial photographs, satellite images and by field investigation. The present study is an attempt to demarcate such active structures, from the Precambrian crystalline terrain of Peninsular India, through remote sensing, geomorphic analysis and field verification. The west flowing Bharathapuzha river and its tributaries constitute the drainage system of the area. Remote sensing studies and field verification have discovered paleochannels south of the main trunk of the river near Wadakkancheri. These paleochannels corresponds to tributaries as well as for the main river its self. Geomorphic analysis of the area indicates anomalous nature of the drainage system, where some of the anomalies are manifested as paleochannels.

Field visits were carried out to identify and characterize the anomalies in the area. A number of brittle faults located in the quarry sections (Fig. 5.16) which are either parallel to the foliation or perpendicular to it. The faulting seems to be related with fluid activity and the secondary minerals (Fig. 5.17) are collected from the intra fracture zones. A study of this material will give an insight into the nature of faulting.

As a part of the studies GPR survey was carried out across brittle faults identified near Erumapetti (Fig. 5.18). A thin top layer of lateritic soil capped over charnockite basement rock. The study reveals that the normal faults observed are confined to upper few meters of the surface. The study is continuing to evaluate paleochannels in the area by stratigraphic studies.

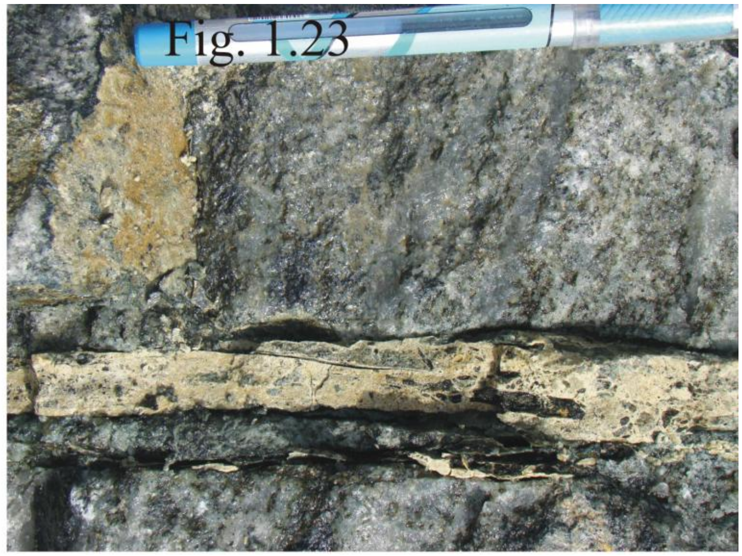


Fig.5.16 (Left) Brittle faulting observed in the charnockite extending up to the laterite cap; Fig. 5.17 (Right) Fracture fill observed in the brittle fault rock.

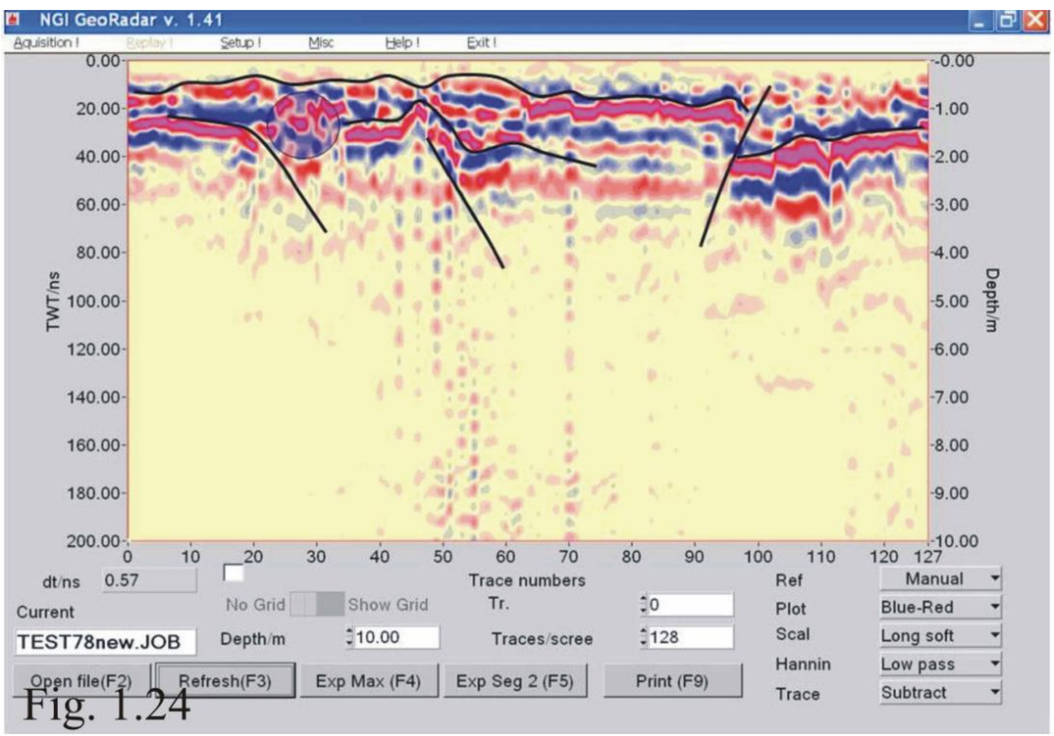


Fig. 5.18 The GPR profile showing the subsurface extension of a normal fault

5.6 Monitoring Indian Shield Seismicity with 10 BBS to understand seismotectonics of the region using V-SAT Connectivity, Project No. ES0901, On-going

(Srinivasan. C., Willy, Y.A and Carter, R.)

The KGF Broad Band Station (BBS), one of the 10 BBS installed in the Penninsular India, is supported by the Ministry of Earth Sciences to understand the seismotectonics of the region. The acquired seismic data are downloaded at the Central Seismic Monitoring Station at NGRI, Hyderabad through V-SAT connection. The retrieved data were archived and after preliminary analysis sent to the IMD, National Seismological Data Center, New Delhi for detailed analysis. The earthquake near Nellore (Lat 14.28, Long 79.56, Magnitude 3.0), Andhra Pradesh of 8th February, 2012 was recorded by the KGF Broad Band Station and also by other five observatories/BBS in the Peninsular India. The Nellore earthquake data from all the stations were downloaded and collated.

The KGF Broadband station recorded several seismic events of local, regional and teleseismic in nature during the reported period is 579. The important local and regional events were from Pernampet, Vizhupuram and Tiruchi in Tamilnadu, Nellore in Andhra Pradesh, and Gujarat.

The Strong Motion Accelerograph installed at NIRM has picked up several seismic events. It picked up 20 events from the KGF mines and three earthquakes including one from Pernampet in Tamilnadu.

The major rockburst of magnitude 2.8 from the mines of Kolar Gold Fields recorded by the Strong Motion Accelerograph is shown in Fig. 5.19. The vertical component has recorded higher acceleration compared to the horizontal components. So, it is inferred that the event has occurred right below the sensor location.

The strong motion data was used to derive ground-motion predictive equation for peak ground acceleration (PGA) for short distances and low magnitudes for KGF mines region. The dataset covered the magnitude ranging from 1.5 to 3.2 and a hypocentral distance up to 30 km. The data base suffered from near-field records for distances greater than 5 km. In order to compensate this gap, additional data for distances less than 30 km from Campania-Luciana region of Southern Italy were used to obtain the attenuation relation. The attenuation of PGA obtained is found to be logarithmically distributed with a strong attenuation for low distances and low magnitude values. The resulting equation is

$$\log(PGA) = -1.664 + 0.36075 - 1.477 \log(R) \pm 0.338$$

where PGA is expressed in ms^{-2}, M is the magnitude, R is the hypocentral distance. The sensitivity analysis of the model is performed by estimating residuals. The residual trend show that predicted PGA are quite stable with respect to reasonable variation of the model.

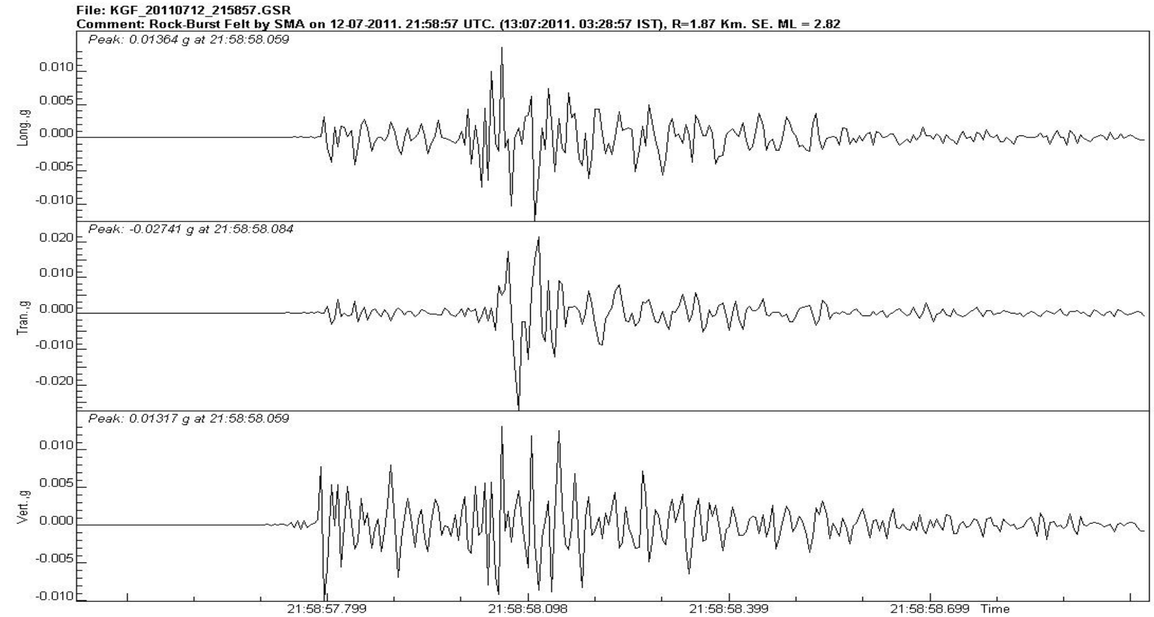


Fig. 5.19 A major Rockburst recorded at KGF during 2011-12

5.7 Analysis of Strong Motion Accelerograph Data of Wangkha Dam, Tala Hydroelectric Project, Bhutan, Part Project No. NM1002, On-going

(C. Srinivasan, Y. A. Willy and Sripad Naik)

The data picked up by Strong Motion Accelerographs installed at the Wangkha dam site, Tala Hydroelectric Project, Bhutan, were analysed. The data included seismic events such as microearthquakes, earthquakes and local activities in the vicinity of the dam site.

Fig. 5.20 shows the Sikkim earthquake of 18^{th} September, 2011 recorded by the Strong Motion Accelerograph, installed on the left bank of the dam. The time series of recorded acceleration is shown in Fig. 5.21 and the frequency spectra in Fig. 5.22. The computed magnitude of this event was 5.8 against 6.8 reported by IMD, New Delhi and the USGS. The difference in the computed magnitude could be due to the limitation that only part of P-phase signal was recorded at the Wangkha dam site.

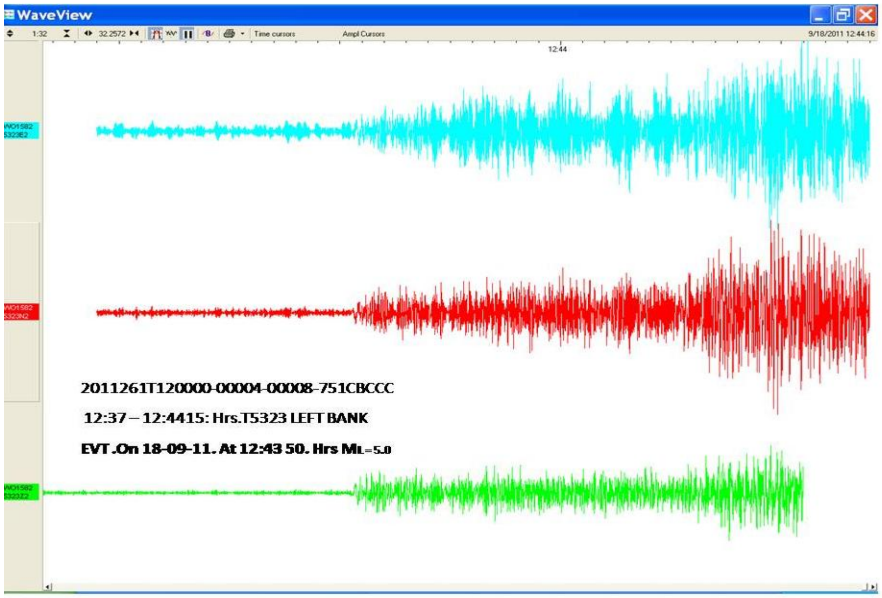


Fig. 5.20 The Sikkim Earthquake recorded at the dam site on 18.09.2011 at 12:43:50 Hrs

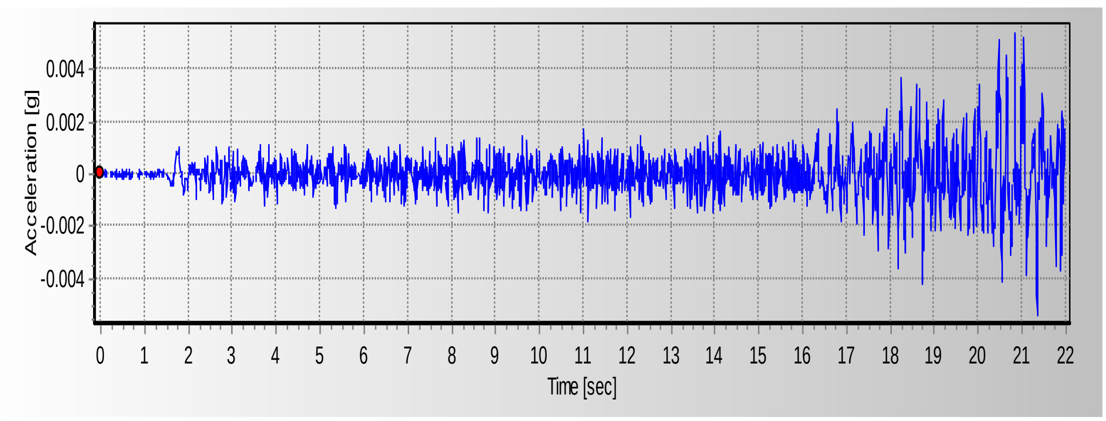


Fig. 5.21 Time series of the acceleration of the Sikkim earthquake

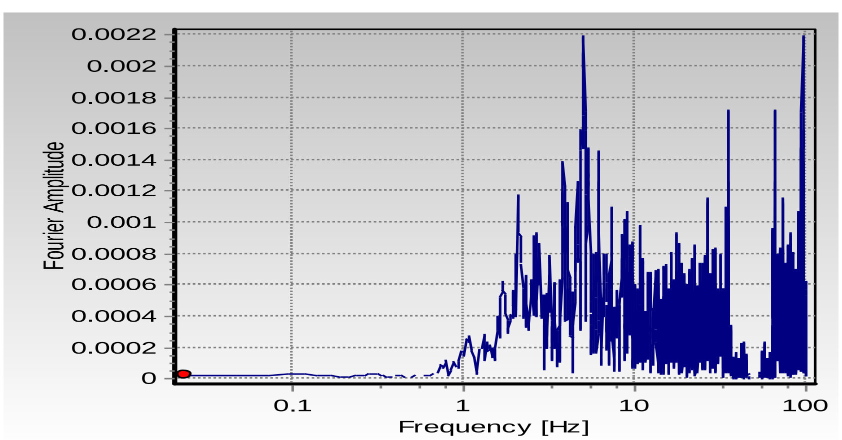


Fig. 5.22 FFT of the Sikkim earthquake

6. NUMERICAL MODELING, INSTRUMENTATION AND MONITORING

Numerical Modeling Department undertakes analysis of a wide range of rock mechanics problems in the areas of civil and mining engineering using discontinuum and continuum techniques. The department also caters to stability analysis of concrete structures and underground caverns in rock mass using the instrumentation data. Numerous rock mechanics issues in the areas of hydroelectric projects and natural slopes were addressed in the year 2011-12.

6.1 Back analysis of powerhouse complex behaviour using 3D numerical modeling at Tapovan Vishnugad Hydroelectric Project, NTPC Ltd., Noida, Project No. NM0705, On-going.

(Sripad R. Naik, Roshan Nair, K. Sudhakar and P. C. Nawani)

Tapovan Vishnugad Hydroelectric project is a 4x130 MW run of the river project on Alaknanda river, being executed by NTPC Limited in the state Uttarakhand. The underground powerhouse complex of the project consists of three main underground excavations, namely powerhouse, transformer hall, and bus ducts and other tunnels.

NIRM carried out 3D modeling studies using three dimensional discontinuum code, 3DEC, by incorporating in-situ conditions like joint sets, weak zone, shear zone and other geological materials. The model was based on the geological information given by NTPC prior to the excavation. Subsequent to substantial excavation activities in the powerhouse complex, this work was taken up based on the instrumentation data provided by NTPC. Following are the observations from the back analysis studies:

- There was significant difference in the results obtained from the initial model in comparison with the instrumentation data, requiring calibration of the model.
- According to the calibrated model, 130 m chainage in the powerhouse cavern was found to be the most critical section, where maximum displacement of 100 mm was observed after stage 10 of excavation. (Fig. 6.1)
- Maximum displacement of 75 mm was found at 50 m chainage after stage 4 of excavation in the transformer hall cavern.
- The factor of safety contours obtained from the calibrated model differed significantly compared to that of the initial model. However, out of 55 m of rock pillar, nearly 35 m of rock mass at 80 m chainage was found significantly affected due to excavation process (factor of safety less than 1.5). Hence, it was recommended to stitch the rock mass by cable bolting.
- Very low factor of safety (unstable condition) were found at the junctions of caverns and bus ducts.
- The displacements values obtained from the calibrated model compare well with the measured instrumentation data. However, there is a scope to further modify the model based on the detail geological map prepared during the excavation of the cavern.

The final calibration of the model will be based on the geological map after completion of excavation of the caverns and the instrumentation data at the time of complete excavation of the cavern.

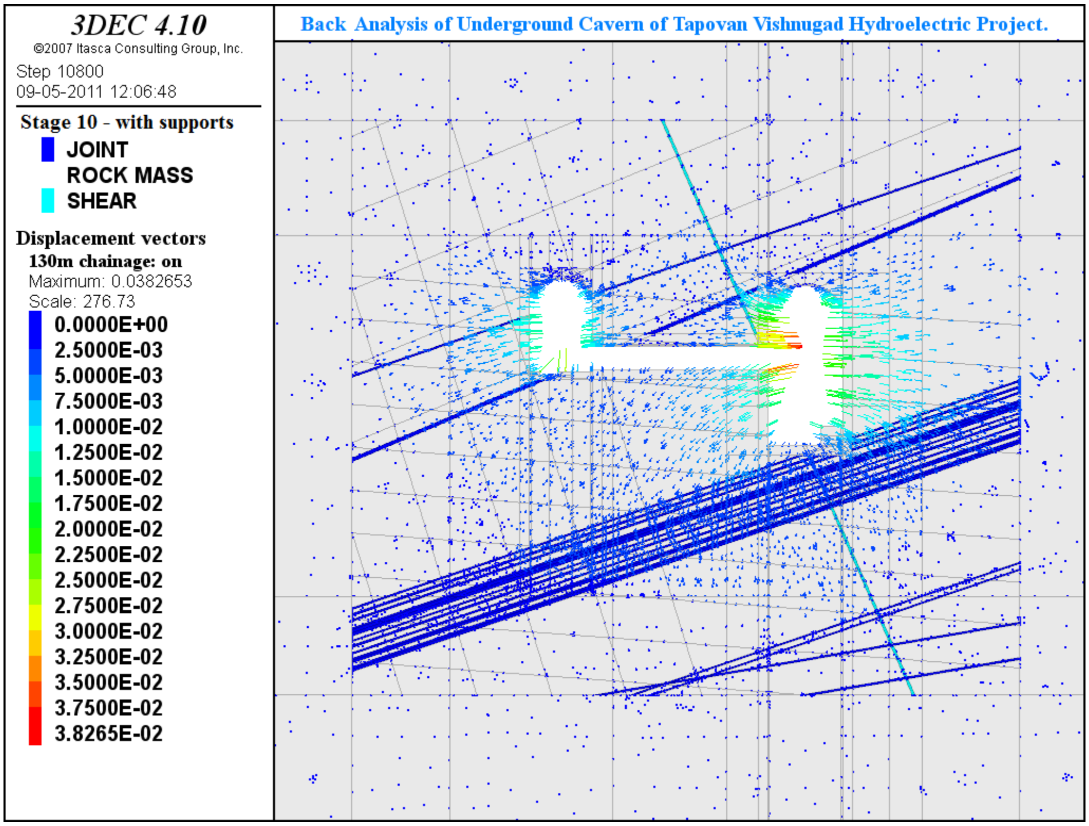


Fig. 6.1 Displacement vectors at RD 130 m chainage after stage 10 of excavation

6.2 Stability analysis of landslide area of Varunavat Parvat, Uttarakhand Project No. NM0404, On-going.

(Sripad R. Naik, Roshan Nair, K. Sudhakar and P. C. Nawani)

Varunavat Parvat is 800-900 m high hill situated at right bank of the Bhagirathi river (Ganga) in upper lesser Himalayan zone of Garhwal Himalayas, Uttarakhand, India. A landslide took place in Varunavat Parvat on 23 September 2004 causing large scale damage to property in the town of Uttarkashi lying at toe of the hill along the river bank. Post landslide, extensive stabilization measures were carried out by THDC India Ltd. based on the inputs provided by Geological Survey of India.

The stability of the treated slopes was analysed using three dimensional distinct element code (3DEC). The initial ground contour profile of the entire area was obtained from Google map. Along with the geometry of treated slopes, Varunavat Parvat was modeled using Rhinocerous software and imported into 3DEC. Detailed discontinuum analysis of the model along with the treatment measures was performed in 3DEC. Based on the geological inputs, the joints sets and different zone of rock mass (weathered and destressed) were incorporated in the model. The static analysis is complete and indicated that the treated and re-profiled slopes are stable. The data pertaining to earthquake activities in the area were collected from THDC India Ltd. and the influence of seismic conditions on Varunavat Parvat are being studied.

6.3 Back analysis using numerical modeling of powerhouse complex of Tala Hydroelectric Project, Bhutan, Project No. NM1003, Completed.

(Sripad R Naik, Roshan Nair, K. Sudhakar and P C Nawani)

Tala hydro electric project is a 1020 MW capacity project on the river Wangchu in Bhutan. The powerhouse complex consists of 20.4 m x 44.5 m x 206.4 m machine hall cavern with six units of 175 MW each, 16 m x 24.5 m x 191 m transformer hall cavern. A 40 m pillar separates machine hall and transformer hall caverns with 3 bus ducts and 2 interconnecting tunnels. The underground powerhouse is located very close to the Main Central Thrust (MCT). The rock formation in powerhouse consist of an interbanded sequence of quartzite, phyllitic quartzite and amphibolites schist partings. The rock mass are tightly folded with a general foliation trend of N49^{0}E – S49^{0}W with a dip of 41^0 in N30^{0}W direction. Maximum overburden in the powerhouse area is 1200 m, and minimum is 65 m, with an average of 400-700 m.

The machine hall cavern is experiencing failure of the rock bolts right from the construction period to the operational period, back analysis using 3DEC software was carried out with staged excavation with the supports actually installed, measured in-situ stress, and other geological and geotechnical parameters. The measured convergence and other instrumentation data were available from ongoing continuous monitoring programme undertaken by NIRM. The main objective was to study the stability of powerhouse complex by considering installed supports and effectiveness of additional supports in the form of rock bolts introduced in lieu of already failed bolts in the system. The analysis of Tala Powerhouse complex revealed the following:

- In case of model with existing supports, maximum magnitude of displacements of 1 m was observed at the roof of the machine hall cavern at chainage 140 m. However, average maximum displacements on the walls of the machine hall cavern were observed to be 302 mm and 220 mm on upstream side and downstream side respectively whereas in transformer hall, it was 263 mm and 255 mm on upstream side and downstream side respectively.
- The observed convergence values from the model were found to be in close agreement with the measured values of wall convergence at various locations in the machine hall.
- The model predicts much higher numbers of rock bolt failure than actually recorded in the powerhouse complex. Failure of 23% and 21% of rock bolts in machine hall upstream and downstream walls was observed, where as model predicts 25% and 22% of rock bolt failure on the upstream and downstream walls of transformer hall.
- Although model predicts a large number bolt failure, the factor of safety (FOS) contours around the cavern suggest that the overall stability of the cavern is not affected (section at RD 80 m shown in Fig. 6.2) with the failed zones around the caverns held in place by the rock bolts and wire-mesh shotcrete interface. Thus the rock bolts may have effectively served its purpose in controlling excessive rock mass movement during construction stage.

However, any dynamic activity in the vicinity of MCT and time dependent deformations of the caverns may affect the long term stability of the cavern.

- The overall stability of the caverns is not affected by removing the failed bolts as there was no variation in FOS values of rock mass surrounding the cavern
- No improvement in FOS values in the surrounding rock mass was observed by introducing additional bolts, revealing that there was no significant additional movement of rock mass around the caverns to initiate its mechanism.

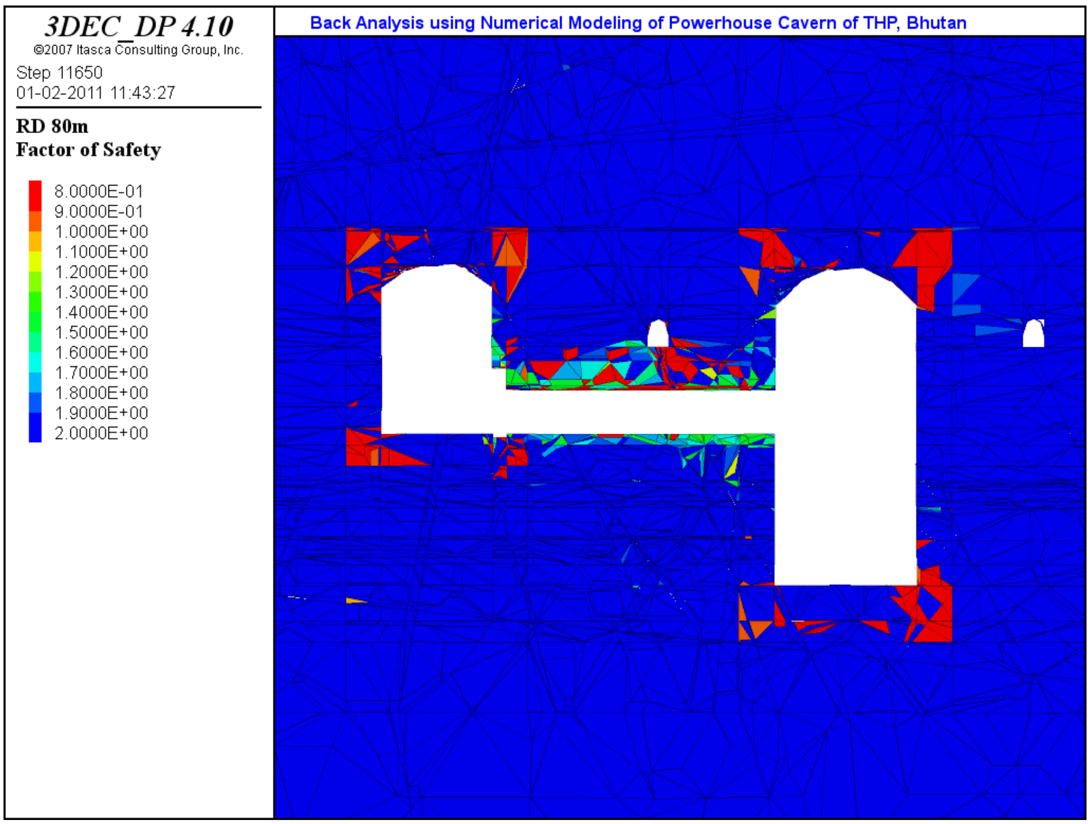


Fig. 6.2 Factor of safety contours at 80 m chainage

6.4 Instrumentation, monitoring and data analysis at powerhouse complex Tala Hydro Power Plant, Bhutan, Project No. NM1101, On-going.

(Sripad R. Naik, K. Sudhakar, Roshan Nair, P.S. Varma and P. C. Nawani)

This project is a continuation of monitoring and analysis of the existing instruments in the Tala powerhouse complex being carried out by NIRM from 2002 onwards. Different types of instrumentation actually installed in the machine hall cavern and desilting chamber is shown in Fig 6.3. During April-December 2011, about 150 instruments were monitored at power house complex, surge shaft and pressure shaft butterfly valve chamber. The stability of the machine hall cavern was assessed based on convergence observations of the side walls, load on the rock bolts, stress distribution along the length of instrumented bolts and piezometric observations in the side walls.

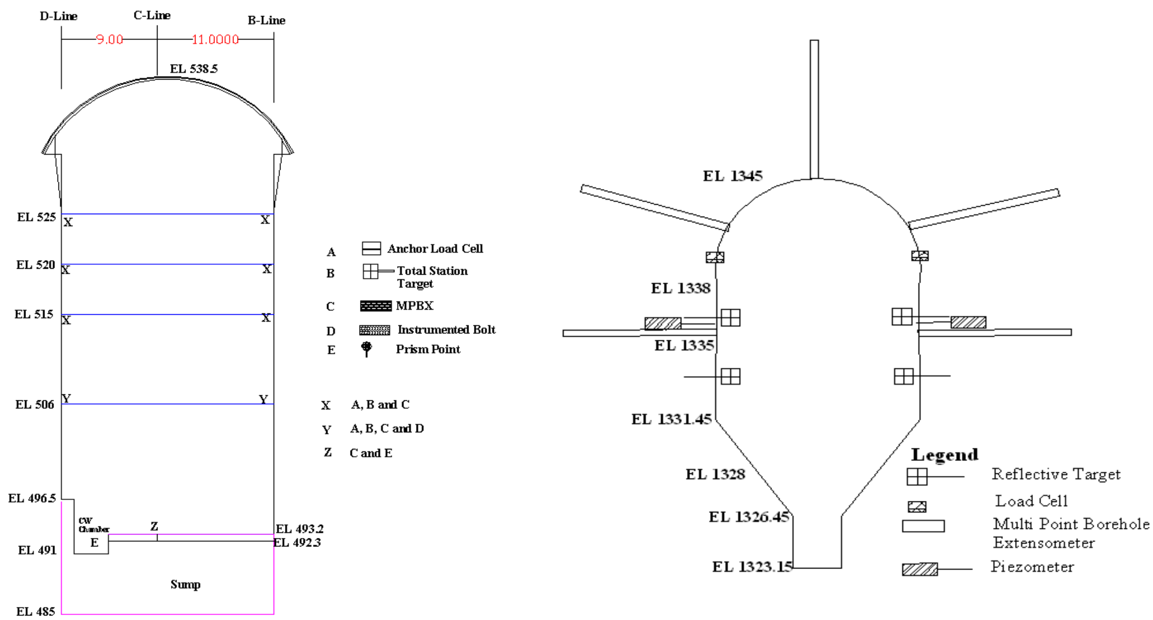


Fig. 6.3 Location of instruments in a section of machine hall cavern and desilting chamber

Measurement of load on the rock bolts indicated that some locations are still active. On the upstream side, RD 150 u/s is active from EL 520 to EL506. The increase in load varied from 5.35 t to 7.56 t at EL506 and EL 520 during the operational period. During last one year, however, there is a stabilisation trend at EL 520 and EL 515 and the change at EL 506 is ± 2 t. On the downstream side, RD 110 seems to be active at EL 515 and EL 506 with an increase of 14.27 t and 10.53 t during the operational period. In general, the increase on load on the rock bolts are reducing or maintained at the same level at higher elevations whereas below EL 515, load on the bolts seems to be increasing at slow rates at some locations or is in the process of stabilisation.

During the operational period, convergence measured at RD 65, 110 and EL 150 are in the range of 15-29 mm with a convergence rate of 0.007-0.015 mm/day. The convergence measured at additional locations (from RD 31 to RD 180) for a period of 1320 days varied from 7 to 22 mm with a convergence rate of 0.006-0.017 mm/day. These convergence rates are similar to those of the old locations.

Instrumented bolts also showed some activity during the operational period. During last one year, some of the instrumented bolts showed high values of tensile stresses on both upstream and downstream walls. At RD 65 u/s at EL 506, tensile stress was 387 MPa at 8 m depth. At RD 110 u/s at EL 506, at 7 m depth, it was in the range of 485-467 MPa. On downstream side also, the tensile stress increased at RD 110 and RD 150 and was in the range of 150-350 MPa. Other instrumented bolt locations show minimum variations of the stress levels.

In 2011, there were 15 rock bolt failures in the machine hall and only one bolt failure in the transformer hall cavern. Although majority of the instruments show a stabilizing trend, continued convergence of the side walls and failure of the rock bolts suggests that the cavern is still in the process of stabilization. The increased tensile stresses on some of the instrumented bolts during last one year shows that, the region is still active and some more rock bolts are likely to fail. Similarly, the transformer hall and other inter connecting bus ducts are also undergoing time dependent deformations.

6.5 Analysis of instrumentation data of dam at Tala Hydroelectric Project, Bhutan, Project No. NM1102, On-going**.**

(Sripad R. Naik, K. Sudhakar, Roshan Nair and P. C. Nawani)

Tala dam is a concrete gravity dam of 92 m height and 130 m wide. During the construction of the dam about 250 geotechnical instruments are embedded in the dam body. The data is collected through the Data Acquisition System (DAS). The personnel of the Druk Green Power Corporation Ltd. regularly store the data which is supplied to NIRM for analysis. Analysis of the dam instrumentation data is currently being carried out by NIRM. The analysis of data indicate the following:

- During each year, the temperature variation follows a cyclic pattern, maximum in the month of August and minimum in the month of January-February. The temperature variation during the monitoring period (Sep 2007 to till date) was found to vary up to 8.20^{o}C in Block-2 and 4.38^{o}C in Block-5.
- At most of the locations, the pore water pressure changes are minimum. In Block 2, the pore water pressure during the monitoring period (Sep 2007 to Nov 2010) varies by 0.7 kg/cm^2. In Block 5, the variations in pore water pressure during the same period are up to 0.48 kg/cm^2. The records of joint meter at EL 1292 of 90 d/s section in Block-5 indicated a cyclic pattern between September and August with peaking in the month of February-March. The minimum was in the month of August every year. In Feb 2011, the instrument peaked with a value of 4.5 mm. There was a steady increase in joint separation (currently 2.5 mm) at EL1304 of RD 13 d/s between block 2 and 3. In block 5, at RD 42 d/s EL 1307 there is a joint separation with a cyclic behavior and showed maximum value of 5.3 mm. The cyclic behaviour was also consistent at RD 13d/s at EL 1304 between block 2 & 3 and at RD 41d/s-EL1307 between block 4 and 5. The changes at other locations were less than 1 mm.
- The uplift pressure meters at the foundation indicated a change of pressure of about 33.3 mWc at Block 2 and about 13.5 mWc at Block 5.
- Based on the analysis of the instrumentation data the dam body appears to be working satisfactorily during the operational period.

6.6 Analysis of instrumentation data of machine hall and desilting complex of NJHEP, SJVNL, Shimla, Project No. NM1005, Ongoing

(Sripad R. Naik, Roshan Nair, K .Sudhakar and P.C. Nawani)

The Nathpa Jhakri Hydroelectric Project of SJVNL is a 1500 MW project with underground powerhouse complex at Jhakri, Himachal Pradesh. It consists of the largest underground desilting complex of four numbers of 525 m long with a cross section of 27x17 m, each separated by 46 m rock pillar located at Nathpa. Analysis of the instrumentation data of powerhouse and desilting complex supplied by SJVNL was conducted to evaluate the stability of the caverns during the operational stage. The instrumentation records consisted of data obtained from instruments like MPBX, piezometers, total station targets and crack meter at desilting chambers, powerhouse complex and TRT outfall area. The analysis of the data revealed the following:

- The displacement at RD92 crown in the powerhouse cavern varied in the range of 3-20 mm. It showed a stabilizing trend at EL 1014 of RD160, RD123 and RD41 on the downstream wall.
- MPBX at EL1014 of RD248 in the drainage gallery showed an increase in displacements at 4 m horizon. The displacements during last one year were 2-12 mm, without any definite trend.
- Displacement at EL1014 of RD 80 right side in the drainage gallery indicated development of crack (-16.26 mm at 15 m depth and 5.5 mm at 11 m depth).
- At chamber-4, no definite trend was found in displacement at EL1456.5 of RD450 right wall as variations was in the range of -15 to +5 mm. During depletion of the chamber, displacements varied between -11 to +3 mm.
- The displacements at other locations of chamber -3 showed a stabilizing trend.
- The pore water pressure distribution in the desilting chambers was normal and varied as per the reservoir level. During the depletion period, the pore pressure in Chamber-4, at RD 450 right wall and El 1446.5 increased to 9.47 kg/cm^2. However, even after refilling, the pore water pressure did not drop and same pressure is continuing since then. At RD 380 m left wall, the pore water pressure dropped to 0.54 kg/cm^2 after depletion and regained pressure of 6.12 kg/cm^2 and is at an average pore pressure of 4 kg/cm^2 since then.

6.7 Deformation monitoring of underground powerhouse cavern of Sardar Sarovar Project, Gujarat, Project No. NM1004, Completed

(Sripad R. Naik, Roshan Nair, K Sudhakar, P. S. Varma and P.C. Nawani)

The Sardar Sarovar project consists of River Bed and Canal head powerhouses with an installed capacity of 1200 MW and 250 MW, respectively. The underground river bed powerhouse complex consists of 23 m wide, 57 m high and 210 m long powerhouse along with six pressure shafts of 9 m diameter and six D-shaped draft tube of 16 m wide. On the downstream side, three D-shaped bus galleries of 12 m wide and 7.5 m high are connected to bus shafts. There are a few interconnecting tunnels and access tunnels, close to the powerhouse.

The monitoring of existing MRMPBX (Magnetic Ring Multi Point Borehole Extensometer), Total station targets in the powerhouse cavern and surface MPBX was conducted by NIRM. The following observations were made in the caverns:

- During April 2010 and August 2011, the displacements at all instrument locations were within 2 mm. Almost all the MPBX data showed a stable trend during the period.

- The displacements measured on the columns and beams are negligible and shows a stabilizing trend
- The surface MPBX data confirmed that the area between the crown and surface is stable and no movement is currently taking place there.

6.8 Assessment of tunnel design, efficacy of support system and stability of cut slopes near approaches of twin tunnels during the 4/6 laning of Hungund-Hospet section of NH-13 (km-265 to 299) in state of Karnataka, BIPL., Project No. NM1104, On-going

(Roshan Nair, Sripad R. Naik and K. Sudhakar)

Boyance Infrastructure Private Ltd. (BIPL) has undertaken the construction of 4/6 laning of Hungund-Hospet section of NH-13 in the state of Karnataka. In this stretch, twin tube tunnels (D-shaped 15.5 m diameter and 300 m long) are being constructed for up and down traffic near Hospet. RCC cut and cover is proposed at both the approaches of 15 m length. The clear spacing between the tunnels is 20 m. There is a railway line passing on the hillock with a clear distance of 15 m from the roof of the tunnel. The width of 3-lane carriageways inside the tunnel is 14.5 m including drain and service duct.

In this study, NIRM is proof checking tunnel design, efficacy of support system and stability of cut slopes near approaches of Twin tunnels. Several visits to the project sites were undertaken and the design submitted by the contractor was evaluated and proof checked. The reports were critically evaluated and suggestions were made to improve the excavation methodology and support measures. The excavation of the tunnel is in progress.

6.9 Slope stability studies at Pandarathu Limestone Mine of M/s Malabar Cements, Walayar, Palakkad Dist., Kerala, Project No. NM1105, On-going

(Roshan Nair, Sripad R. Naik, Rabi Bhushan, K. Sudhakar and V. Venkateswarlu)

Pandarathu limestone mine belonging to M/s. Malabar Cements is located in the reserved forest in Pudusserry village of Palakkad Taluk, Palakkad District, Kerala. The mine has limestone deposit of 600 m in length, 25-215 m in width and 200 m in thickness. The mining of limestone started from the initial RL of 518 m. At present pit bottom is at 356 m RL and the mining activities are planned up to a depth of 320 m RL.

This study is for evaluating the stability of rock and soil slopes of the benches at mine based on current mining sequence and for recommending the slope stability parameters to reach the final pit bottom of 320 m RL. The samples from the mine were collected after detailed geological mapping of the entire area. The testing of the samples to determine the geotechnical properties is in progress. A detailed 3D numerical model is being prepared to study the slope stability aspects.

6.10 Development of instrumentation data template for Koteshwar Dam and Tehri Dam, Project No. NM1103, On-going.

(Sripad R. Naik, Roshan Nair and K. Sudhakar)

Tehri Hydro Power Complex (2400 MW) belonging to THDC India Ltd. in the state of Uttarakhand, comprise Tehri Dam & Hydro Power Plant (1000 MW), Koteshwar Hydro Electric Project (400 MW) and Tehri Pumped Storage Plant (1000 MW).

Tehri Power Station is fully operational and recently Koteshwar Hydro Electric Project has also started the operation. Many geotechnical instruments were installed in Tehri and Koteshwar dams. In this study, a data template is being prepared for analyzing and presenting the instrumentation data for each instrument type. Discussions and site visits were made to the sites to assess the method of data acquisition, data storage, data analysis etc. Currently the development of data template is in progress.

7. ROCK BLASTING & EXCAVATION ENGINEERING

Rock Blasting & Excavation Engineering Department has an experienced team of Scientists and is equipped with latest instruments like seismographs, VOD measuring systems, laser based survey systems, digital video camera, fragmentation assessment system, vibration analysis system (signature hole analysis) and state-of-the-art software for blast design. The department has been providing innovative solutions to challenging problems in blasting for various surface and underground excavations in mining, hydroelectric, infrastructure and other civil engineering projects. During 201-12, the department completed seven industry sponsored projects and five projects were in progress.

7.1. Technical advice on scope for introduction of large diameter blastholes and monitoring blast vibrations at Aiswarya granite quarry, Kanyakumari, Aiswarya Granites, Project No. RB0901, Completed.
(H. S. Venkatesh, R. Balachander and A. I. Theresraj)

Aiswarya Granites is operating a granite quarry at Kaliyal village, Kanyakumari District, Tamil Nadu. The rock is excavated by drill blast method using 38 mm diameter jackhammer holes. To increase the existing production to 2000 t/day, the management of Aiswarya Granites sought the advice of NIRM to suggest blast design parameters and to conduct ground vibration and air overpressure. The study was taken up in two phases. During Phase 1, the existing blasting practice was studied and the flaw in the blast designs were identified and explained to the client.

During Phase 2, blast designs with 45 mm diameter, hole depth of 3 m and shock tube initiation system were suggested. In order to the efficacy of the suggested designs without procuring a new drilling machine, adaptors were used to mount 45 mm diameter bit to jackhammer rods to drill with the suggested hole diameter. Ground vibration studies were carried out using four seismographs. With the suggested designs, flyrock was restricted within the pit while vibrations were limited to 5 mm/s within 300 m, whereas all the private structures were located beyond 800 m from the quarry. The project authorities were satisfied with the suggested blast design parameters and procured a crawler mounted drill machine for drilling 45 mm diameter holes. The feedback received from the client confirmed that the desired production was achieved by following the suggested blast designs.

7.2. Controlled blast design for rock excavation close to structures and green concrete and ground vibration measurement at Unit 7 & 8, Nuclear Plant, Kota, Project No. RB1004, Completed.

(G. Gopinath, R. Balachander, A. I. Theresraj and H. S. Venkatesh)

The Nuclear Power Corporation of India Limited has awarded the work for construction of power plant (Unit 7 & 8) at Rajasthan Atomic Power Plant, Rawatbhata, Rajasthan, to Hindustan Construction Company Limited. As part of this work, about 16,00,000 m^3 of hard rock had to be excavated by drilling and blasting method for site grading and foundation excavations. The excavation site was located close to an operating nuclear plant, a switch yard etc. Moreover, blasting was to be carried out in proximity to green and hardening concrete. NIRM carried out field investigations and suggested safe peak particle velocity for different structures depending on the sensitivity of the structures and based on the DGMS standards. Blasts were designed and implemented considering the criticality of the structures. About 15,00,000 m^3 of rock was excavated within a span of one year following the suggested blast designs and keeping the vibration levels within the stipulated limits. The suggested blast design for pre-splitting and cushion blasting controlled the damage to the rock mass and ensured the stable vertical and inclined walls (Fig. 7.1). In total, about 45000 m^2 was successfully pre-split. Control of flyrock was ensured by proper blast design and suitable muffling method.

Fig. 7.1 Good pre-split blast result in hard rock in slopes

Blasting in proximity to concrete was carried out keeping the vibration levels within the permissible levels (Fig. 7.2). Periodical site visits helped to review the suggested blast designs and to ensure that the ground vibration levels were within the safe limits (Fig. 7.3).

Fig. 7.2 Monitoring of ground vibration on the concrete floor of RB7

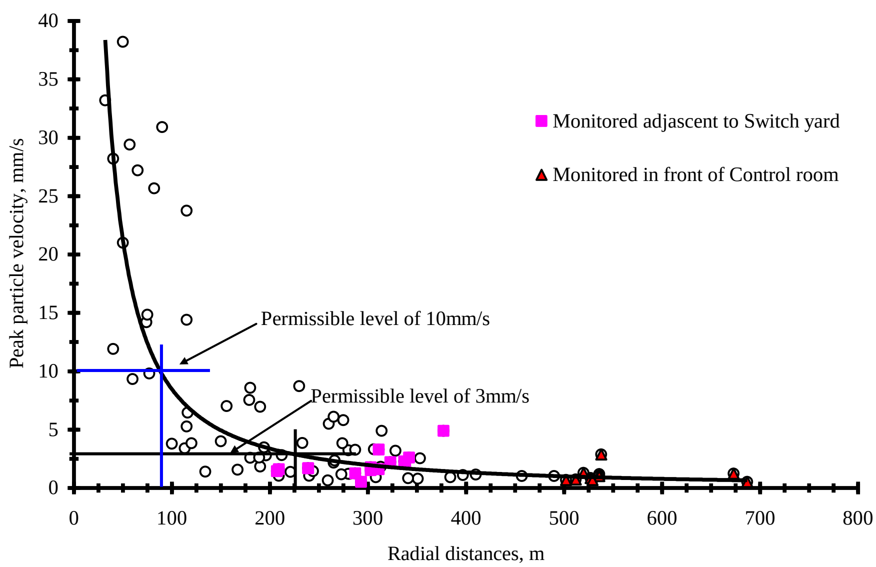


Fig. 7.3 Recorded peak particle velocity versus distance

7.3. Technical guidance for rock blasting and monitoring of ground vibration, air overpressure and flyrock during excavation at underground stations from Chinnaswami Stadium to City Railway station, Soma Enterprises Ltd, Bangalore, Project No. RB1006, Completed.

(R. Balachander, G. Gopinath, A. I. Theresraj, K. Vamshidhar and H. S. Venkatesh)

Controlled blasting operations at Sir M Visveswaraiah Underground Metro Station (MV area) were started on 12/02/2011 under the technical guidance of NIRM and continued till 12/08/2011. In addition, blasting operations at Vidhana Soudha station and City railway station areas were also conducted under the technical guidance of NIRM. In total, about 500 blasts were carried out safely during this six months period.

The blasting technique recommended for Chinnaswami Stadium, as reported last year, was extended to other station areas. Bench heights were gradually increased from 1.5 m to about 2.8 m and a production of about 450 m^3 per day was achieved against a targeted production of 300 m^3 at MV area (Fig. 7.4). About 35000 m^3 of hard rock was excavated and efforts are being made by the client to achieve consistent production rate from the suggested NIRM approach. Similarly controlled blasting was carried out for Vidhana Soudha underground station (Fig. 7.5) and City railway station (Fig. 7.6). While blasting for Vidhana Soudha underground station, ground vibration was monitored near Vidhana Soudha for all the blasts. At City Railway station since the private structures were very close, the size of the blast was reduced. Fig. 7.7 shows the daily production at this station.

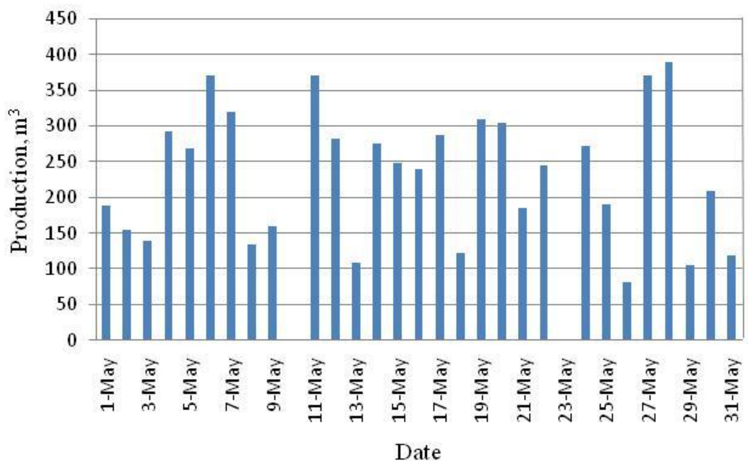


Fig. 7.4 Production details for the month of May 2011 from MV station area

Fig. 7.5 Post-blast inspection of the blast area near Vidhana Soudha by NIRM

Fig. 7.6 Controlled blasting at City railway station area

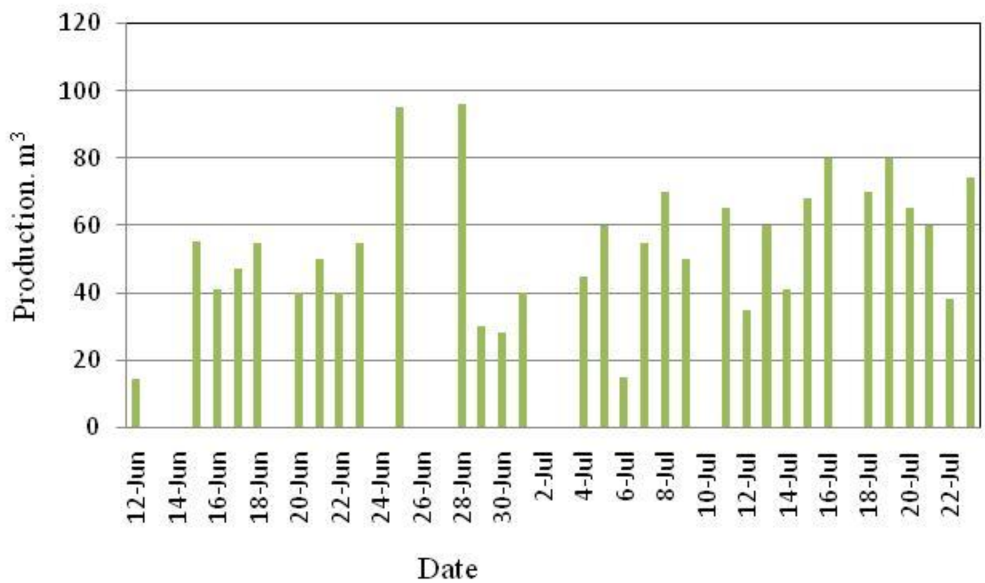


Fig.7.7 Production details at Vidhana Soudha Station during the investigation period

7.4. Methodology for controlled blasting and ground vibration monitoring while constructing two new bridges adjacent to an old bridge on NH-13 across Tunga Bhadra river, GMR Infrastructure Ltd., Bangalore, Project No. RB1010, Completed

(G. Gopinath, K. Vamshidhar, R. Balachander, A. I. Theresraj and H. S. Venkatesh)

GMR Infrastructure Pvt. Ltd. was awarded construction of 4/6 laning of NH-13 from km 299 to 265 of Hospet-Hungund project. The project involves construction of two new bridges across river Tunga Bhadra (TB), which required excavation of 36 foundations in hard rock by drill blast method. The dimensions of these foundations were 9.5 m x 5.5 m while the depth of cutting varied from 2 m to 4.5 m. As the excavation site is situated at about 10-15 m from the existing old bridges on the downstream of TB dam, controlled blasting was adopted for carrying out these excavations such that the dam, the nearby old bridges and other structures are not damaged. NIRM provided technical guidance on controlled blast design and monitored ground vibration to derive the site-specific predictor equation. The measured ground vibration level for all the blasts during the field investigation was within limits. The muffling practice suggested and demonstrated during the field investigation controlled the flyrock within a distance of 10 m. Fig. 7.8 shows the block muffled and ready for blasting near the existing bridge and Fig. 7.9 shows the post blast view. Most of the controlled blasting for the foundation excavations were completed and the concreting is in progress at different stages.

Fig. 7.8 Muffled block ready for blast adjacent to the existing bridge

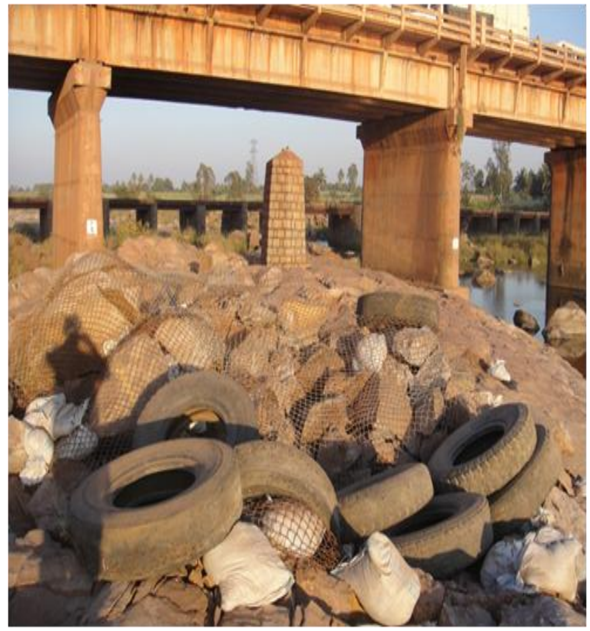


Fig. 7.9 Post blast view of the muffled blast adjacent to the bridge

7.5. Modifying blast design to improve the pull, reduce overbreak and to minimise specific charge for HeadRace Tunnel (HRT) Package, Punatsangchhu-I HEP at Bhutan, Gammon India Ltd., Project No. RB1011, Completed.

(R. Balachander, A. I. Theresraj, G. Gopinath and H. S. Venkatesh)

Punatsangchhu Hydroelectric Project Authority (PHPA-I) is constructing a 1200 MW hydroelectric project in Bhutan. The 9.07 km HRT package was awarded to M/S Gammon India Ltd. As the contractor was facing problem of less pull and high charge factor, it was referred to NIRM. The blasting method followed at different faces was reviewed. The project authorities were using wedge cut for all the faces except for one face, where burn cut was being followed due to hard rock condition. Based on the field studies, NIRM suggested and field tested the modified wedge cut and burn cut patterns at different faces of HRT. The suggested designs improved the pull and reduced the specific charge. The overbreak was controlled within in the limit. The implications of drilling errors, over-charging of holes and improper charging method of periphery holes were explained in depth to all the blasting crew. Vibrations were monitored at different distances by deploying three seismographs. The ground vibrations at different faces were found to be safe for underground structures and support systems.

7.6. Study on ground vibration and air overpressure due to blasting at quarries located around Chandragiri Fort, Chittoor District, Andhra Pradesh, Project No. RB1013, Completed.
(A. I. Theresraj, K Vamshidhar, R. Balachander, G. Gopinath and H. S. Venkatesh)

A number of stone quarries are operating in Chandragiri Taluk, Chittoor, Andhra Pradesh. In these quarries rock is being excavated by drilling jack hammer holes, charged with prilled ANFO and blasted instantaneously. These quarries are located near some villages and Chandragiri Fort area. The Fort being a monument of national importance, the Asst. Director of Mines and Geology, Chittoor approached NIRM to conduct a scientific study on ground vibration and air overpressure due to blasting operations at these quarries vis-à-vis the safety of the structures around the quarries and the Fort.

For the study purpose, the stone quarries surrounding the Fort area were grouped as two entities - Northern side of the fort and Southern side of the Fort - in consultation with the concerned officers. In total, 53 blasts were monitored for ground vibrations and air overpressure. Six seismographs were deployed at various locations around the quarries, while one seismograph was invariably placed at the fort. The study was conducted in the presence of concerned Government officials. A permissible limit of 2 mm/s as per DGMS norms was suggested for the Fort as well as for the structures in the villages. The trial blasts were nothing but the routine blasting operations in these quarries. The measured vibration levels were below the limit of 2 mm/s at a distance beyond 350 m. As the Fort is more than 1.8 km and the nearest village is 700 m, the structures are safe. The permissible maximum charge per delay was suggested for all the quarries. The air overpressure levels were well within the limit of 133 dB.

7.7. Study of ground vibration, air overpressure and flyrock distances due to quarry blasting at Banswara Limestone Mine, Rajasthan, The India Cements Limited, Project No. RB1014, Completed
(K. Vamshidhar, A. I. Theresraj, G. Gopinath, R. Balachander and H. S. Venkatesh)

The mine management of Banswara Limestone Mine, Rajasthan had plans to produce about 6000 t per day of limestone and desired to conduct a scientific study on ground vibration, air overpressure and flyrock. As per their request, NIRM carried out a scientific study.

Ten experimental blasts were monitored covering different bench heights and varying maximum charge per delay. Ground vibration and air overpressure were monitored at different locations in in consultation with mine officials. In total, 66 sets of ground vibration readings were used for regression analysis and a site-specific predictor equation was derived. Fig. 7.10 shows a plot of peak particle velocity versus scaled distance for the mine on a log-log graph. Based on the frequency of ground vibration, the permissible vibration levels were arrived for different structures as per DGMS standard. The computed safe maximum charge at different distance was suggested to keep the vibrations within the prescribed limit. The flyrock distances for the trial blasts were recorded and analysed using motion analysis software (evaluation version) (Fig. 7.11). The maximum flyrock distance observed was 88.7 m.

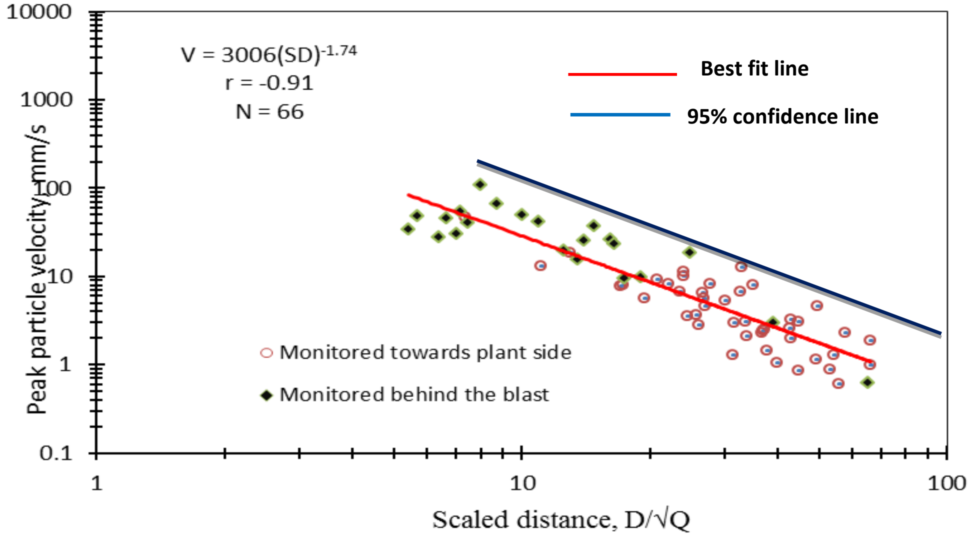


Fig. 7.10 Peak particle velocity versus scaled distance for Banswara limestone mine

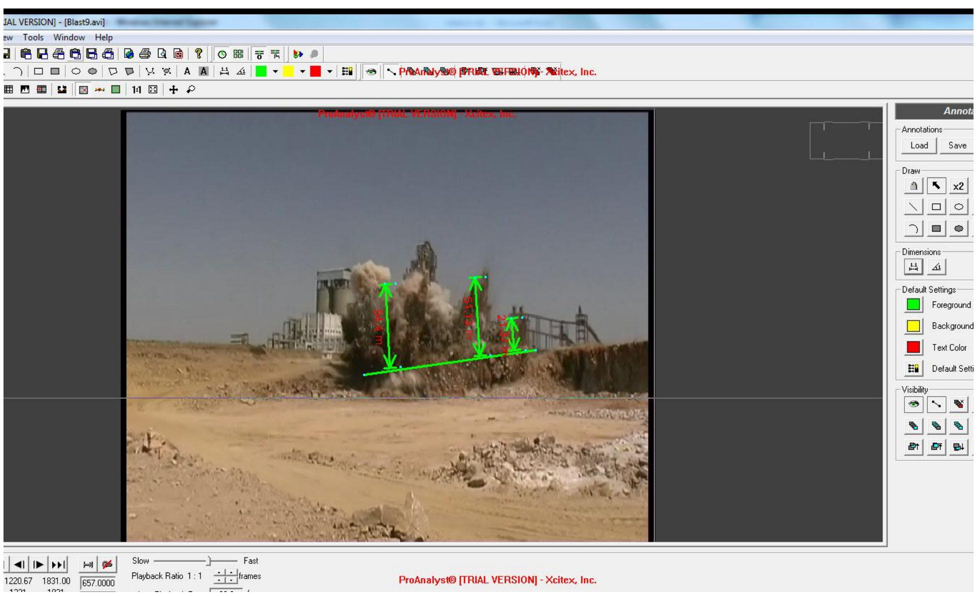


Fig. 7.11 Video observations production blast using motion analysis software

7.8. Controlled blast design for diversion weir and tunnel, and monitoring of ground vibration to study the blast effects on Kallar bridge on Alwaye-Munnar Road of NH 49, Sengulam Augmentation Scheme, KSEB, Project No. RB1012, On-going.

(A. I. Theresraj, R. Balachander, G. Gopinath and H. S. Venkatesh)

A D-shaped tunnel of 6710.44 m long, 3.5 m high, part of Sengulam Augmentation Scheme (CAS), Kerala State Electricity Board (KSEB), is under construction. It is being driven to facilitate the impounded water to Sengulam reservoir for augmenting the power generation at existing Sengulam power house by 85 Mu. It is to be excavated through two adits, from exit and intake ends.

NIRM is associated with KSEB for technically guiding the controlled blasting operations for the excavation of tunnels and open excavations. A technical note was submitted after first field visit (February 2011) and a detailed interim report was submitted after the second field visit (May 2011). The third field visit was carried out during November 2011 to monitor the ground vibration produced due to the blasting of tunnel from exit end and Adit II. All the data sets on ground vibration and air overpressure measurements carried out during the visits were analysed. In total, 65 sets of data were analysed and a site-specific predictor equation was derived (Fig. 7.12***)***. As the frequency of the measured vibrations was above 8 Hz, the permissible vibration level as per DGMS norms happens to be 10 mm/s. For the monitored blasts, the air overpressure too was well within the limits. The performance of the suggested blast design was satisfactory. A report exclusively on the study conducted at the exit end and Adit II was submitted in November 2011.

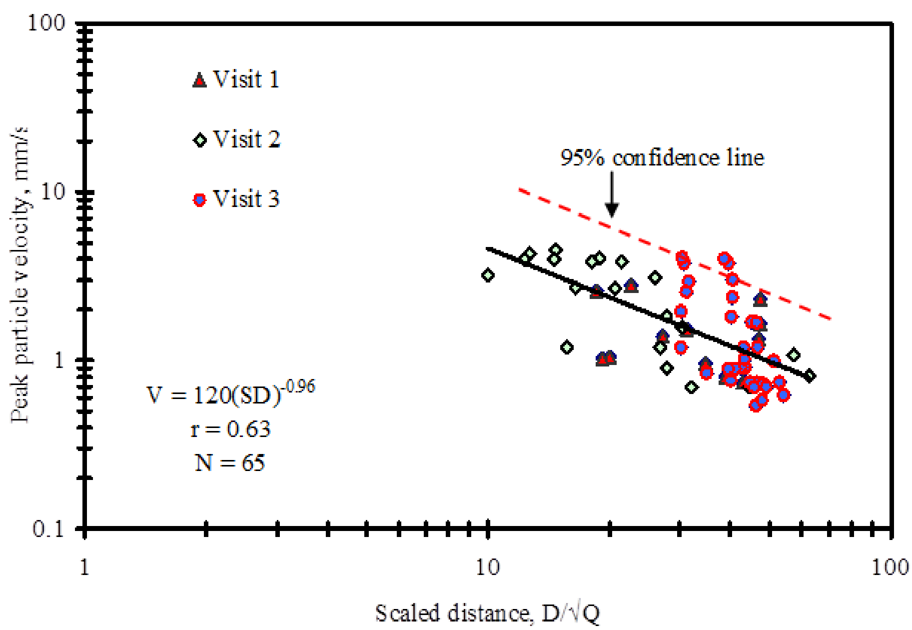


Fig. 7.12 Peak particle velocity versus scaled distance for Sengulam Augmentation Scheme

7.9. To monitor ground vibrations and air overpressure at Jambunatheswara temple due to blasting at Jambunathanahalli Iron Ore Mine, MML, Hospet, Karnataka. Project No. RB1101, On-going.

(A. I. Theresraj, K. Vamshidhar, G. Gopinath, R. Balachander and H. S. Venkatesh)

Field work will be initiated upon receiving the intimation from the client.

7.10. Technical guidance on blast design for twin tunnel tubes and monitoring of vibration near railway track while excavating the tunnels, Hungund-Hospet section of NH-13, GMR-EPC, Bangalore, Project No. RB1103, On-going.

(R. Balachander, G. Gopinath, A. I. Theresraj, K. Vamshidhar and H. S. Venkatesh)

GMR Bangalore is the contractor for the construction of the Hungund – Hospet section of NH-13. This work is being executed on DBFOT basis to National Highway Authority of India by GMR, Bangalore. In the above stretch, twin tunnel tubes (D-shaped, 15.5 m diameter and 300 m length) are required to be constructed for up and down traffic near Hospet. The constructions of tunnels are being outsourced on EPC basis. GMR requested the services of NIRM for the technical guidance on blast design and vibration monitoring. Provisional blast design (Blast Design Part 1 Approaches) proposed by SEMCON/SAMMON and submitted to GMR-EPC was reviewed by NIRM. Field visits were made to study the blast design being followed at North side of RHS tunnel and onsite suggestions were given.

7.11. Study on ground vibration and air overpressure due to blasting adjacent to powerhouse complex, head race tunnel etc., Sainj hydroelectric project, HPPCL. Kullu, HP, Project No. RB1106, On-going.

(A. I. Theresraj, G. Gopinath, R. Balachander, K. Vamshidhar and H. S. Venkatesh)

Himachal Pradesh Power Corporation Ltd. (HPCCL) is executing a hydroelectric project at Sainj, Kullu district, Himachal Pradesh. The project is a run of the river scheme utilizing water from river Sainj through a gross head of 409.6 m for generation of 100 MW of power. The various components of the projects are located along the right bank of the Sainj river valley. The project work was started in August 2010 and the underground excavation is being done in powerhouse complex, transformer cavern, head race tunnel etc. While excavation is under progress it is stated that there were complaints regarding blasting damage to the houses. Keeping this in view, the General Manager, Sainj Hydro Electric Project approached NIRM to conduct a scientific study in order to assess the impact of vibrations due to blasting operations. The field investigation has been completed and the analysis of data is in progress.

7.12. To study the impact of PSP blasting on underground structures at HPP, Tehri, Uttarakhand. Project No. RB1102C, On-going.

(A. I. Theresraj, K. Vamshidhar, R. Balachander, G. Gopinath and H. S. Venkatesh)

THDC India Limited is operating a 1000 MW (250 MW x 4) hydro power plant (HPP) at Tehri. It had planned for a second machine hall cavern at a distance of about 130 m from the existing transformer hall to be utilized for future power generation under the pumped storage plant (PSP). As the existing HPP structures and equipment are located close to the proposed PSP, the project authorities wanted to assess the impact of future close in blasting to the HPP structures while excavating the cavern, associated tunnels and shafts for the PSP. An officer from NIRM is stationed at project site to carry out vibration monitoring and to suggest suitable blast design modifications.

Blast vibrations are monitored with high frequency geophones for near-field monitoring and conventional geophones for far-field monitoring. Presently, blasting is being are carried out at adit AA1 which is approaching the upstream of the surge shaft, while adit AA2 is approaching the existing Penstock Assemble Chamber. The adit AA7 is approaching the downstream surge shaft upper level, while the adit AA11 is approaching the downstream surge shaft bottom level. Adit EA7 is approaching the Tail Race Tunnel. For all the blasts in these adits, blast vibrations, monitored at existing Transformer Hall, Butterfly Valve chamber and Penstock Assemble Chamber (Fig. 7.13) are less than 0.5 mm/s.

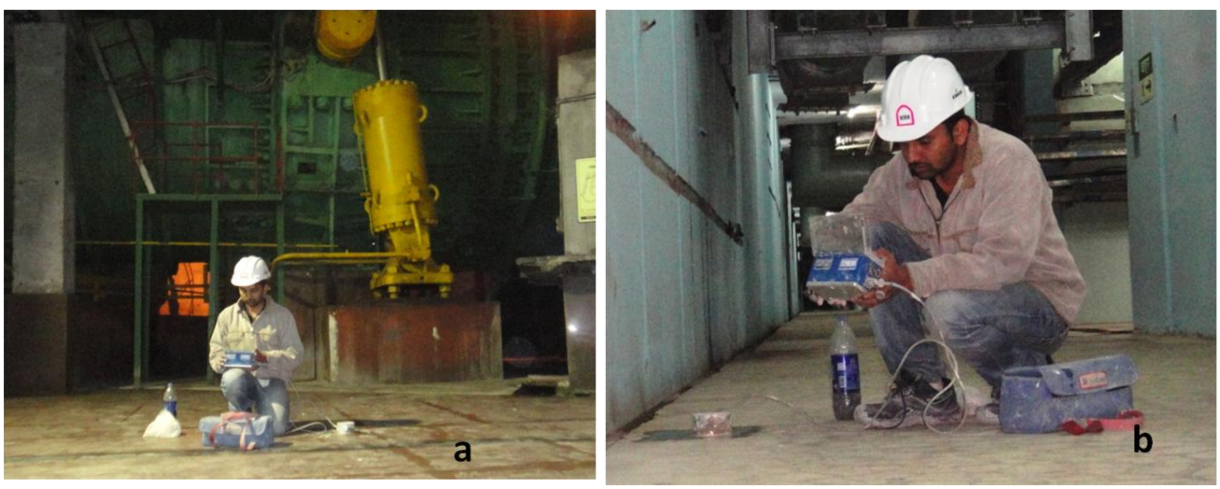


Fig. 7.13 Photographs showing monitoring of ground vibration due to adit blasting at a) Existing Transformer Hall, b) Butterfly Valve Chamber

8. MINE DESIGN

Mine Design Department is extensively involved in a number of industry-sponsored projects in the field of coal and metal mines, both underground and open pit, for the development of safe mining methods. The Department has conducted in-depth studies in ground control investigations, rock mass characterization, support design and strata monitoring, and evolved safe and innovative mining methods.

8.1 Stability of workings in hard rock mines

8.1.1 Rock Mechanics Invetigations at Tummalapalle Mine, UCIL, Project No. GC1004, On-going.

(C. Nagaraj, Amrith T. Renaldy and V. Venkateswarlu)

The Uranium Corporation of India Limited (UCIL) has opened an underground mine near Tummalapalle in Kadapa district, Andhra Pradesh, to mine the ore of uranite mineral / pitchblende. Presently, the mine is being developed through three declines, 15 m apart, in the footwall ore body. From the East decline, Advance Strike Drives (ASDs), roughly 4.5 m in width and 3 m in height, are being driven at 40 m intervals in the ore body. For connecting the ASDs, ramps are driven along an apparent dip at regular intervals of 120 m. NIRM had earlier designed the support plans and formulated the method of extraction, namely room and pillar method. In view of the strata control problems faced in the mine, UCIL entered into an MoU with NIRM, to address the different rock mechanics problems at the mine.

As a part of the MoU, field investigations were carried out at the mine to improve and optimise the roof support systems. Rook bolt anchorage tests were carried out in the roof randomly at different locations viz., ASD 8 West, ASD 8 East X-cut, ASD 3 East P1 W3, ASD 4 East P1 W2 and ASD 4 East P1 W2. The ground conditions in the deeper ASDs [ASD-4 (E & W) and ASD-8 (E & W)] were found to be satisfactory. Suitable methods were demonstrated to improve Roof Bolting techniques at the site. Further, it was suggested for introducing fully automated mechanized bolting system, with quick setting cement capsules or resin capsules for grouting the bolts.

To design support system for the 13 m x 13 m x 13 m underground Crusher Chamber core samples from ASD-8E, ASD-8E Conc.-Cut and East Decline were collected from the site, and they are being tested for their physico-mechanical properties. After the detailed study, the support system for the Crusher Chamber will be designed.

8.1.2 Instrumentation and Monitoring of Sub-level Stopes in Strike Reef at Hutti Gold Mine, HGML, Project No. GC1101, On-going.

(C. Nagaraj, Amrith T. Renaldy and V. Venkateswarlu)

The Hutti Gold Mines Limited extracts gold ore at Hutti gold mine in Raichur District of Karnataka state. In this mine, there are four reefs in which mining is being carried out. To understand the behavior of the rib pillars in Blocks A & B and to evaluate the stability of the barrier pillars, NIRM has been monitoring the sub-level stopes in Strike Reef from 2000D/L to 2200 L FE 33 region during the extraction.

NIRM took up the studies and designed the instrumentation plan for the sub-level stopes in Strike Reef from 2000D/L to 2200 L FE 33 region. The parameters being monitored are stress build-up using stress cells, and pillar movements using extensometers.

Different locations in SR-20 and SR-22 levels were identified for the instrumentation. Nine MRMPX were installed at different locations in SR-20 level (Fig 8.1). Two Stress Cells were installed in SR-22 level A & B Blocks. The strata behavior monitoring is in progress.

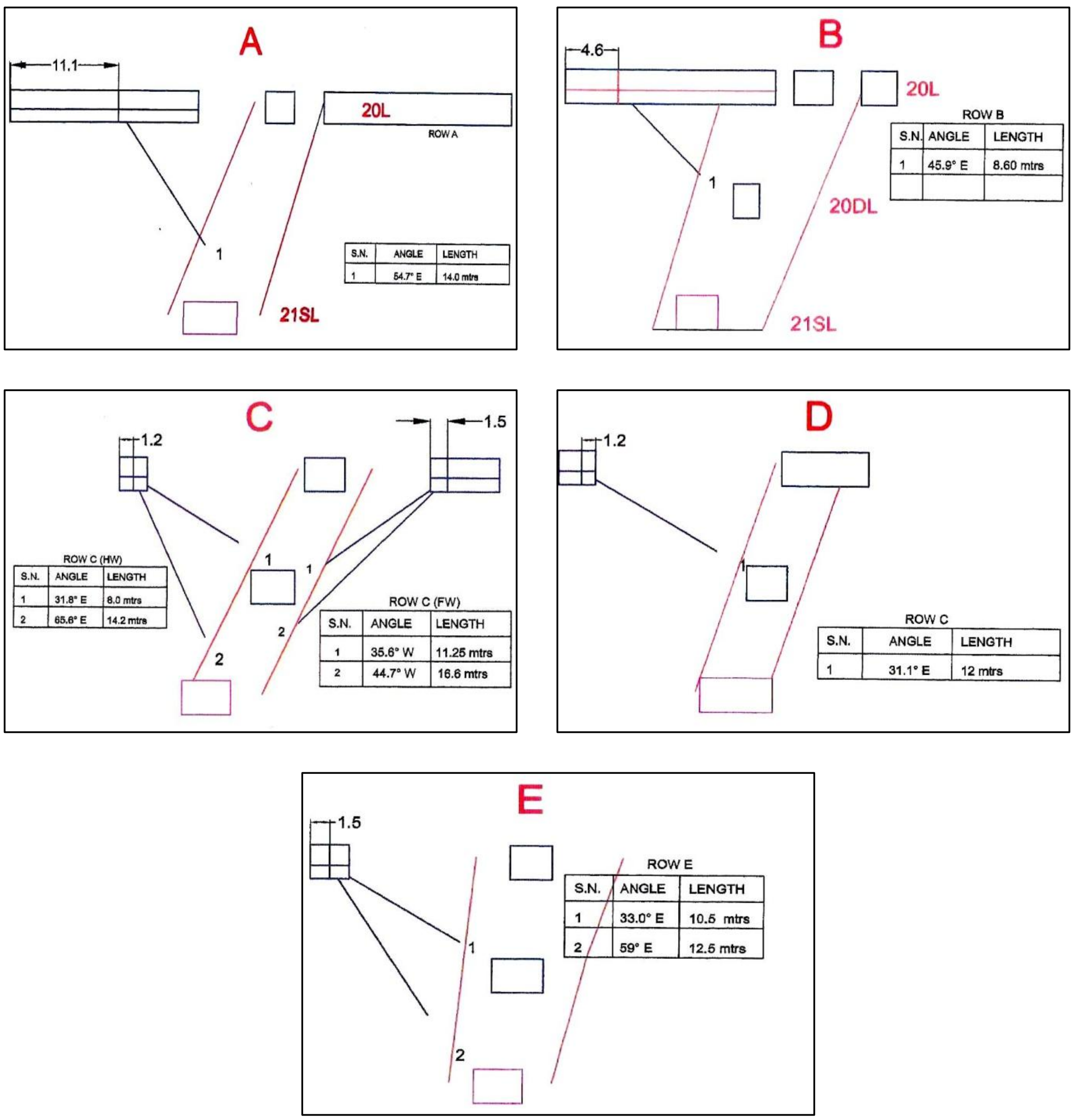


Fig. 8.1 Locations of MRMPBX installed at SR-20 level

8.2 Strata control in coal mines

8.2.1 Strata control investigations in I (B+C) seam at Mathani colliery, Pench Area, WCL, Project No. GC1103, On-going

(R.D. Lokhande and V. Venkateswarlu)

At Mathani underground mine there are four mineable coal seams which are I (B + C), II B, III B and VA seam in descending order. Out of these, the upper three seams are contiguous; however IIB seam is not being worked. Thickness of I (B+C) seam is 5.5 to 7 m, and the thickness of IIIB seam is 1.8 to 2.1 m. Presently, depillaring is going on in seams I (B + C) and III B contiguously. The existing dip-rise galleries are under dead load and at many places the height has reached up to 7 m due to roof falls. In view of the bad roof conditions in the coal seams (Fig. 8.2), NIRM took up the studies for suggesting proper method of development and depillaring.

Fig. 8.2 Bad roof conditions experienced at Mathani mine, WCL

NIRM will carry out the testing to determine the physico-mechanical properties of coal and sandstone. Based on the field and laboratory data, the appropriate method of development and depillaring will be designed.

8.2.2 Design of Method of Extraction for Tawa and Sarni Underground Mines, Pathakhera Area, WCL, Project No. GC1105, On-going

(R.D. Lokhande and V. Venkateswarlu)

At Sarni and Tawa underground mines of Pathakhera Area, WCL, three seams are being worked. They are Upper and Lower seams at Sarni mine, and Upper, Lower and Bagdogra seams at Tawa mine. Coal is being extracted at both the mines using the Wide Stall method of working. NIRM took up the studies to evaluate the feasibility of alternate methods of extraction which can give maximum production, and also to assess the impact of subsidence on the surface due to these workings.

8.2.3 Design of Partial Extraction Method in Seam no. V of Saoner Mine no. 2, Nagpur area, WCL, Project No. GC1201, On-going
(R. D. Lokhande and V. Venkateswarlu)

At Saoner underground mine no. 2 of Nagpur Area, WCL, there are four mineable coal seams, namely no. V, IV (T), IV (M) and IV(B) seams, in descending order. The seam V was developed by bord & pillar method, and it is proposed to extract the pillars without disturbance to the surface. Accordingly, NIRM took up the studies for suggesting an appropriate method of partial extraction. Preliminary investigations were carried out, and further testing and analysis are going on.

8.2.4 Assessing the Impact of Depillaring of IV (M) and IV (B) Seams, on Seam V and on the Surface at Saoner Mine no. 1, Nagpur area, WCL, Project No. GC1201, On-going
(RD Lokhande and V Venkateswarlu)

At Saoner underground mine no. 1 of Nagpur Area, WCL, there are four coal seams, namely no. V, IV(T), IV(M) and IV(B) seam, in descending order. The seam V was depillared by caving method, seam IV (M) was developed and in seam IV(B) development work is in progress. As seams IV(M) and IV(B) are contiguous. It is proposed to extract them simultaneously with caving. NIRM took up the studies for assessing the impact of depillaring of IV(M) and IV(B) seam on seam V, mainly on the isolation stoppings, and on the surface. The studies are continuing.

8.2.5 Support of Roadways at Durgapur 6, 7, 8 Incline, WCL, Project No. GC1005, Completed.
(R.D. Lokhande and V. Venkateswarlu)

At Durgapur Rayatwari mine of Chandrapur Area, WCL, the Rayatwari seam is being developed through incline nos. 6, 7 and 8, from the highwall side of Durgapur opencast mine. The thickness of the seam is 17 to 19 m, and it is being developed along the floor, with coal-shale intercalations forming the immediate roof. Most of the dip-rise galleries, junctions and some level galleries are facing the problem of cutter roof conditions. In view of the bad roof conditions in the mine, NIRM carried out studies and designed the supports.

In the mine, the immediate roof strata consist of thin and poorly bonded layers of coal and carbonaceous shale, with occasional clay. In most of the dip-rise galleries and some of the level galleries, the coal and shale layers start separating from the roof immediately after exposure, giving rise to cutter roof conditions (Fig. 8.3) within a few days of the excavation. The coal – shale layers are weak in strength. Intense ‘discing’ was observed in drill cores obtained from the mine. The poor roof strata require immediate supporting, preferably within four hours after exposure.

The coal-shale layers in the immediate roof are not capable of offering adequate anchorage for bolts grouted with cement. Further, the ‘cutter-roof’ conditions, and the ‘discing’ of the cores, are indicative of the presence and influence of high horizontal stresses in the mine. The dip-rise and level galleries are inferred to be at right angles or parallel to the direction of the maximum horizontal stress, which is unfavorable for stability.

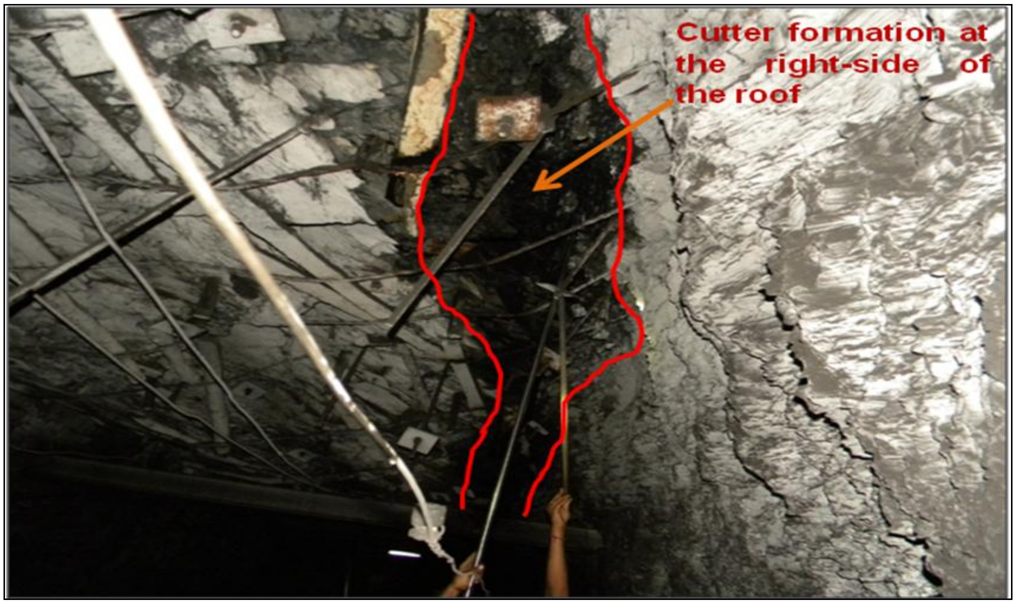


Fig 8.3 Cutter roof conditions at DRC-6,7,8 Inclines, WCL

Field investigations were made by NIRM at DRC and anchorage testing was carried out for determining bonding strength of the roof bolt. Installed roof extensometers at different locations, indicated that the roof layers are separating immediately after exposure, particularly the immediate roof strata within the bottom 2 m. Mine management has sent the core samples from the roof of the study area and laboratory test were carried out to determine the physico-mechanical properties of different litho units. Based on the field investigations and laboratory testing the roof strata has been classified as Class IV (“Poor”) rock mass with a final RMR of 32.8.

It was recommended to introduce resin-grouted bolts at the mine immediately and the direction of the drivages may be slightly altered, by driving the galleries at about 30^o to 45^o from the present direction.

8.2.6 Support of Gateroads at Kakatiya Longwall Project, SCCL Project No. GC0907, On-going.
(V. Venkateswarlu and S. Benady)

The width of the gate roadways to be developed in the four seams, namely 1A, 1, 2 & 3 seams at Kakatiya Longwall Project (KLP), Bhupalpalli Area will be of 4.2 m size. SCCL plans to extract coal by longwall method in KTK-8 Incline from all the 4 seams. Considering the longevity of the mine and presence of local geological features, it is essential to provide effective roof support for the gate roads. NIRM is designing the required roof support for these mines based on the Geological Hazard Map of the area which is being prepared by Exploration Department of SCCL.

8.3 Instrumentation and strata monitoring

Though established guidelines exist for the estimation of support requirement, the design needs to be verified based on systematic monitoring of the support behaviour in response to the strata movements. NIRM undertakes strata and support monitoring on a routine basis, and has been involved in a large number of such projects.

8.3.1 Rhombus Pillars at KTK-2 Incline, Bhupalpalli Area, SCCL Project No. GC0903, Completed.
(S. Benady and V. Venkateswarlu)

At KTK-2 incline, Bhupalpalli area, SCCL, three seams namely 1, 2 and 3 are occurring in descending order. Part of the property of the mine boundary is beneath two villages – workings in the east under Bhupalpalli village and workings in the west under Gaddiganipalli village. Upon permission granted by DGMS, SCCL undertook development in no.3 seam using scraper technology in the east side property and with SDLs in the west side property. In both workings due to steep gradient, development of pillars was taken up in apparent dip direction, forming “rhombus shaped pillars”. After the development, the two panels were depillared with stowing.

Strata behaviour studies were conducted during development and extraction in both East and West panels at KTK-2 Incline, using strata monitoring instruments. The results are summarized as follows:

- No roof movements were recorded in the workings during development and depillaring.
- No bed separation was recorded at the junctions during the monitoring period. This indicates the stability of the roof and the efficacy of supports in the galleries/junctions.
- Maximum cumulative change in stress over the pillars in the East panel (at all four locations) was insignificant with negligible rate of change of stress. The maximum cumulative stress over the pillars in the West panel (at four different locations) was between 1 and 5 kg/cm^2, which is also considered insignificant. Thus the abutment pressures recorded in the two panels during development and depillaring operations were negligible.
- The movement in the immediate roof stratum in the depillaring panel during the monitoring period was nil.

The extraction of the entire rhombus shaped pillars in both East and West panels have been completed successfully. Based on the above, it can be concluded that the extraction of the pillars by stowing in the panels progressed smoothly without any strata control problems during the monitoring period (November 2010 to November 2011). It was recommended that all future panels with rhombus shaped pillars be worked in the same manner.

8.3.2 Yield Pillars in Continuous Miner Panel at VK-7 Incline, Kothagudem Area, SCCL, Project No. GC1004, Completed.

(R.D. Lokhande and V. Venkateswarlu)

At Venkatesh Khani 7 incline, Kothagudem Area, three seams occur, namely Queen Seam, King seam, and Bottom seam, in descending order. In King Seam, Continuous Miner was introduced and the developed pillars in panels no. CMP-2 and CMP-3 were extracted successfully using the yield pillar technique. The same technique of partial extraction was continued to work the already developed pillars in panel CMP-3A and CMP-3B also. Strata monitoring studies were conducted by NIRM during the extraction of pillars in these two panels (Fig. 8.4).

Fig. 8.4 Crack observed in CMP-3B panel below the overlying longwall barrier

The strata disturbance in Panel 3B is attributable to a multiplicity of factors, such as the presence of worked out panels on the north-east, massive roof standing on partially extracted ("yield") pillars on the east and south sides, the barrier pillars of previously worked longwall panels in the overlying top seam. It is possible that the "yield" pillars have not completely yielded as designed, as a result of which the roof loads got transferred on to the pillars of Panel 3B.

The extraction in the continuous miner panel 3A progressed smoothly without any strata control problems. The maximum change in stress over the pillars recorded in this panel was in the range of 250 to 500 kPa, with a steady rate of 6 to 20 kPa per day. Only in the middle of the panel, on Pillar no. 11, there was a stress build-up of about 1200 kPa within 10 days. This is attributed to the presence of a slip plane adjacent to the pillar. The roof-to-floor convergence measured in the junctions was in the range of 15 to 62 mm, with a steep increase during extraction of the adjacent pillar. Most of the convergence was due to floor heaving.

On the other hand, the extraction in panel 3B was hampered in the initial stages due to heavy bumping of the pillars and floor heaving. Due to this, it was advised to leave the first two rows of pillars unextracted. Extraction resumed from pillar no. 9. With this, the strata conditions were normal, but it was observed that the panel as a whole was heavily stressed. The change in stress recorded in Pillar nos. 15 and 20 was more than 1 MPa, most of which occurred during the last week of April 2011. The roof-to-floor convergence in the junctions was also of the order of 160 to 180 mm immediately after extraction of the adjacent pillars. The bed separation was 3 to 6 mm within the bolted horizon, 7 to 14 mm immediately above the bolted horizon, and up to 30 mm at 10 to 15 mm height above the seam.

8.3.3 Blasting Gallery Panel at GDK-10 Incline, RG-3 Area, SCCL, Project No. GC1202, On-going
(S. Kumar Reddy and V. Venkateswarlu)

At GDK 10 incline, RG-III Area, SCCL, no. 3 seam was previously developed and is now being extracted to the full height of 13.5 m by Blasting Gallery method. A number of panels have already been worked by this method. It is now proposed to work the panel no. 3B, situated between 66 L and 70 L, and 37 D and 40 D, and having 2 x 3 = 6 pillars, by the same method. The pillars are roughly 60 m x 50 m in size, and are situated between 320 and 350 m depth. The mine management proposes to work the panels by driving two splits instead of one in each of the pillars in the BG panel.

In view of the complex geo-mining conditions prevailing during the extraction of thick seam by driving two splits in the BG method, it is essential to understand the behavior of the strata which can be done by conducting strata monitoring studies. The behavior of the strata in BG panel can be understood by measuring the diagnostic parameters such as the stress over the pillars, bed separation and convergence in galleries and load on the supports.

Accordingly, NIRM initiated the strata monitoring studies. A number of Tell-Tales, convergence points, stress cells and load cells were installed in the working areas in BG panel no. 3B in 3 seam. The strata monitoring has been continuing.

8.4 Design of slopes in opencast mines

With an increasing depth of surface mining, the slope stability problem is becoming a major concern for the mining engineers. In mountainous regions, landslides are a major safety hazard, particularly in the rainy season. The Institute has been involved in the design of safe and economic slope angles in various open pit mines. Iron ore extraction is being carried out by opencast method at a number of mines in Goa. The slopes in the iron ore (“blue dust”) mines in Goa region consist mainly of soft, soil-like and weathered schistose formations, laterites, and various types of phyllitic, ferruginous and manganiferous clays. The soft formations are characterized by the presence of tension cracks during rainy season. And the region receives heavy rainfall every year. Together, they reduce the shear strength of the slope formations, causing failures, particularly in rainy season. Due to this problem, NIRM initiated studies to investigate the stability of the pit slopes at the mines of the two companies, to suggest suitable design parameters.

8.4.1 Analysis of slope stability based on testing of dump material at Medapalli opencast mine, SCCL, Project No. GC1003, (Completed)

(V. Venkateswarlu and S. Kumar Reddy)

In order to analyse the stability of rock slopes and overburden dumps at Medapalli OCP in RG-I area, NIRM carried out the analysis of soil and clay near the dump area. SCCL identified two different sections, named as Section A and Section B, near dump no. 3 of the mine. Channel samples were collected, five each from the two sections by the mine authorities, and sent to NIRM. The material included black cotton soil (clay), alluvium soil, sandy soil, clay and sandy clay.

NIRM carried out density, void ratio (derived), moisture content, specific gravity, undrained direct shear, unconsolidated undrained triaxial (UU), and odometer consolidation tests on the soil samples. The samples were tested in as-received condition. The tests were carried out as per Bureau of Indian Standards (IS) codes.

A summary of the results of all the tests carried out on the soil samples from Medapalli opencast mine are presented below. The results pertain to samples from A and B sections, and for five samples in each section identified by the mine authorities.

Material	**Bulk Density, b (g/cc)**	**Void Ratio, e_o**	**Moisture Content, wN (%)**	**Specific Gravity**
BC clay	1.88	0.59	10.17 to 11.79	2.12 to 2.26
Alluvium	2.04	0.45	10.23 to 10.38	2.08 to 2.37

Cohesion, c (kg/cm^2)	**Angle of Internal Friction, ϕ (degrees)**	**Cohesion, c_u (kg/cm^2)**	**Angle of Internal Friction, ϕ_u**
0.3 to 0.4	34 to 47	2 to 6.6	17^o to 30^o

Section	**Sample No.**	**Material**	**Compression Index, Cc**	**Swelling Index, Cs**
A	1	BC clay	0.2637	0.0472
A	2	BC clay	0.2541	0.0432
A	3	alluvium	0.2295	0.0478
A	4	alluvium	0.2109	0.0518
A	5	alluvium	0.3124	0.0528
B	1	BC clay	0.1812	0.0335
B	2	BC clay	0.2274	0.0491
B	3	alluvium	0.3757	0.0458
B	4	alluvium	0.1706	0.0547
B	5	alluvium	0.1411	0.0869

9. DIMENSIONAL STONE TECHNOLOGY

Dimensional Stone Technology Department provides technical services to the dimensional stone industry for optimum recovery and economic exploitation. This department completed two projects during the year 2011-12.

9.1 Grading of four granite quarries of the Mysore Minerals Limited, Project No. GM1101, Completed.

(G. C. Naveen, A. Rajan Babu, Rabi Bushan, S.S. Meena, S. Udaya Kumar and S. Thobias)

The Mysore Minerals Limited (MML) has engaged NIRM to provide a procedure using scientific methods that can be adopted at the site to differentiate and establish the quality of dimensional stone granite blocks under different grades for four quarries to facilitate marketing of recovered blocks. These quarries were: 1) Punjanur Black Granite Quarry, Chamrajnagar, 2) Mallainapura Black Granite Quarry, Chamrajnagar, 3) Shivapura Black Granite Quarry, Hamrajnagar, 4) Doddamudavadi Granite Quarry, Kanakapura, Ramnagar Dist.

Field investigations at the four quarries were taken up during May-June, 2011. In the quarry area, five prominent joint sets were identified along with two random joint sets. The persistence of joints was found to be more than >10 m. The dip direction of maximum joint density varied from 030^o and 100^o and the dip amount from 7^o to 85^o. The major strike of the joints was found to be in NW-SE, N-S and WWN -EES direction. Natural defects like enclaves/xenoliths, foliation bands, pegmatite were observed in the rock mass. The presence of enclaves mainly affects the texture and appearance of the blocks. A 3D view of the granite block is shown in Fig. 9.1.

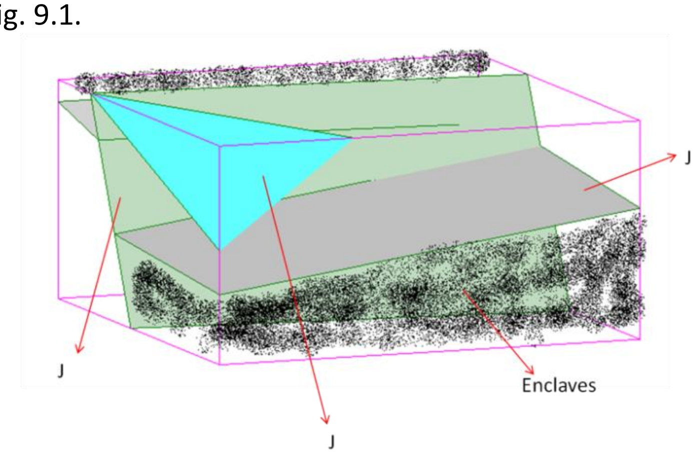


Fig. 9.1 Three dimensional view of a granite block

A methodology (Fig. 9.2) was formulated for grading incorporating geological-cum-geotechnical characteristics and physico-mechanical properties of the rock mass. The point load test and rebound hardness using Schmidt hammer were used to estimate the in-situ uniaxial strength of the rock mass. Representative blocks of samples were taken from each quarry for laboratory studies. The quarries were assessed for their overall recovery (Table 9.1) and the percentage of various grades for different quarries (Table 9.2) was projected. The overall recovery was estimated as 16% for Doddamudavadi, 18% for Punjanur, 26% for Shivapuraa and 21% for Mallaianapura.

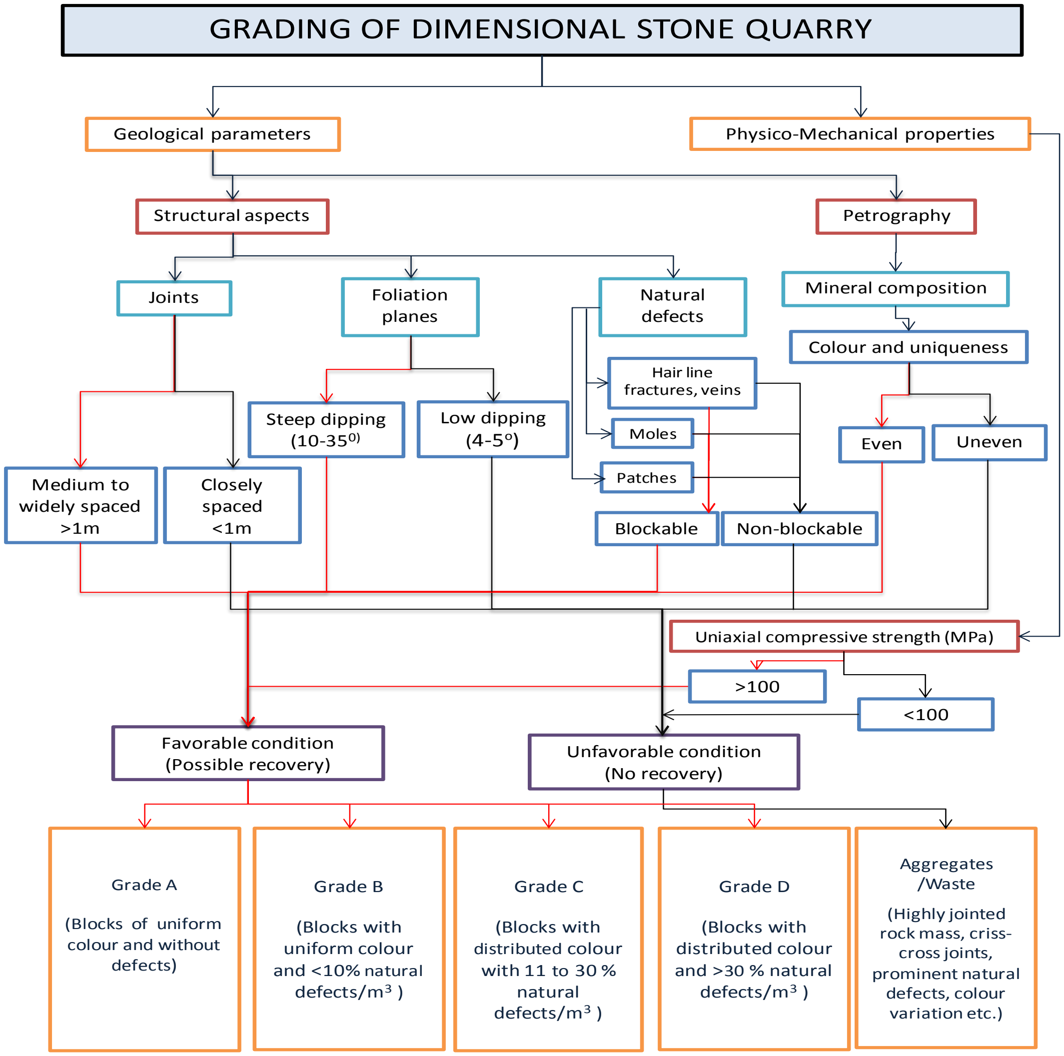


Fig.9.2 Methodology for grading of granite quarries

Table 9.1 Grading for recoverable volumes

Grade	Recoverable blocks
A	Blocks of uniform colour and without defects
B	Blocks with uniform colour and <10% natural defects/m^3
C	Blocks with distributed colour with 11%-30% natural defects/m^3
D	Blocks with distributed colour and >30% natural defects/m^3

Table 9.2 Grading of four granite quarries into four categories

Grade (%)	Doddamudavadi	Punjanur	Shivapura	Mallaianapura
A	12	4	5	4
B	32	25	39	39
C	38	41	32	33
D	19	30	24	24

The projected recoveries and grading, which can be adopted at 90% confidence level, are site-specific.

9.2 Scientific studies at the quarries of POABS Granite products Pvt. Ltd for suggesting eco-friendly quarrying methods, Kerala, Project No GM1002, Completed.
(A. Rajan Babu, S. S. Meena, G.C. Naveen, Piyush Gupta, G. H. Kotnise, S. Thobias)

The POABS group of companies, has about seven small quarries at different locations such as Kaliyal, Trivandrum, Thiruvalla, Angamally, Perunthalmanna, Calicut and Mangalore. The management of POABS group in its endeavor to achieve optimum production and to fulfill the statutory requirements related to quarrying activities approached NIRM to suggest scientific and eco-friendly quarrying methods in order to enhance their production with due regard to safe quarrying practices.

Studies were taken up in all the seven quarries. The existing method of quarrying was studied with respect to production and productivity, adherence to safety standards in particular to blast vibration, air overpressure, noise, water and dust. During the field investigations, both bench and toe blasts were monitored. Drilling of holes was done by jack hammer drills employing 32 mm diameter holes. The blasthole depth varied from 1.6 m to 2.4 m. A minimum of 11 blasts were monitored at each quarry. The number of holes per blast varied from 21 to 51. The maximum charge per delay ranged from 3.025 to 5.6 kg with a maximum total charge of 35 kg. Holes were charged with ANFO (0.5 to 0.6 kg) primed with slurry explosive in combination with electric delay detonators and bottom initiation. The vibration and air overpressure levels were monitored at different locations simultaneously using four seismographs. The recorded peak particle velocity did not exceed 10 mm/s at a distance of about 50 m from blast sites.

From the analysis of the data, predictor equation was derived for 50% confidence level and it can be used for estimation of peak particle velocity. The dominant frequency of blast vibrations was greater than 30 Hz. Although peak particle velocity of 15 mm/s could be permitted by the DGMS Standards 1997, it was restricted to 12.5 mm/s for enhanced safety of the surrounding buildings and considering blasting needs of small scale quarry operations. Drilling and blasting patterns for improved fragmentation and measures for control of ground vibrations and air-overpressure were suggested. A typical design is shown in Fig. 9.3.

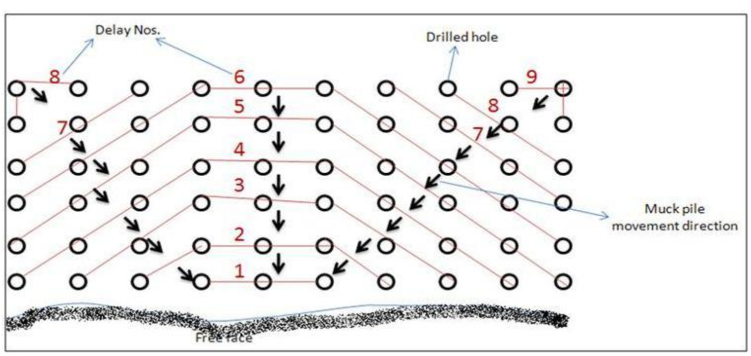


Fig. 9.3 shows the recommended blast pattern

10. MICROSEISMICS AND AUTOMATION

Microseismics and Automation Department has developed expertise in real time strata monitoring of underground excavations for their long term stability assessment. Real time strata monitoring helps to predict the time dependent strata instabilities and provide information on support system performance in powerhouse caverns in hydroelectric projects, oil storage caverns transportation tunnels and mining tunnels.

10.1 Nanoseismic monitoring in the power house of Tapovan-Vishnugad hydroelectric power project, Project No. MS1101, On-going.

(C. Sivakumar and Vikalp Kumar)

Reconnaissance survey to study attenuation characteristics of rock strata was conducted after recording ground vibration signals (Fig. 10.1) from three test blasts. P-wave velocity was calculated and a 30-geophone station nanoseismic sensor network (Fig. 10.2) was designed for the installation of real time monitoring system. Nanoseismic system specifications were worked out and placed order for equipment after inviting the Global tenders. The system procurement is in progress. Meanwhile the preparation works like underground laboratory establishment, data communication facilities etc., for the installation of Nanoseismic monitoring system are in progress.

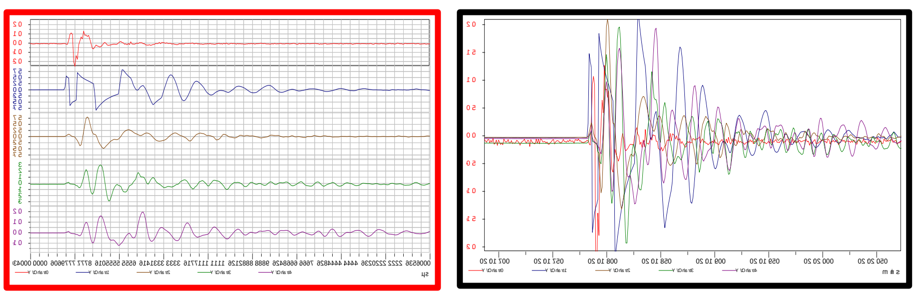


Fig. 10.1 Blast signatures recorded for reconnaissance survey

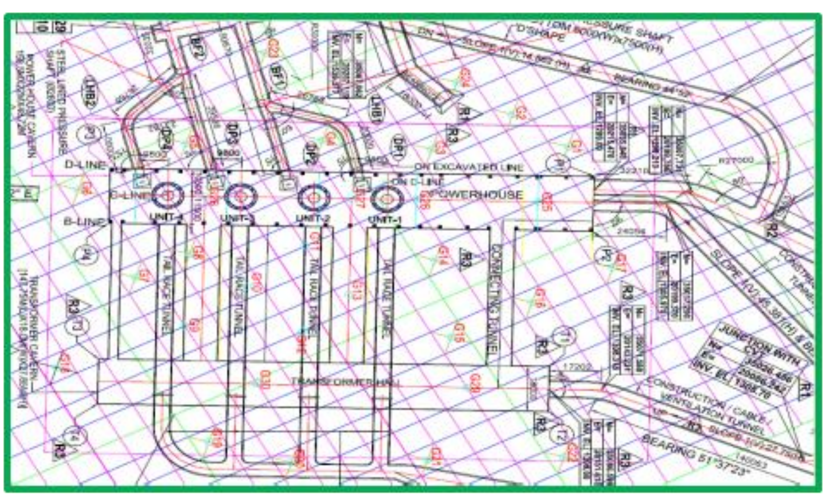


Fig. 10.2 Nanoseismic monitoring system sensors locations marked on powerhouse plan

11. ENVIRONMENTAL ENGINEERING

Environmental engineering department deals with assessment of water, air, noise, soil pollution, air pollution modeling, assessment of atmospheric and meteorological parameters, environmental auditing in mining and allied industries, EIA/EMP preparation, remediation measures for the environmental problems and waste management.

11.1 Impacts of gold mill tailings dumps on agriculture lands and its ecological restoration at Kolar Gold Fields, Project No. IN 1101, Completed

(S. Roy, P. Gupta and T. A. Renaldy)

A study was conducted to know the influence of gold mill tailings dumps on agriculture lands around Kolar Gold Fields as physico-chemical properties of dumps may react with soils nutrients and influence its concentrations. The study also tried to identify native plant species suitable for the reclamation of the dumps.

The low moisture content in mill tailings indicated that drought resistance/native species should be grown on dumps. Increase of mill tailings in soil-tailings mixture enhanced water holding capacity, which can save water for irrigation. Increase in cation exchange capacity revealed addition of cations from mill tailings. The highest electrical conductivity of 1.97 mS/cm among soil-tailings mixture revealed that further mixing will be unsuitable. Lower pH (< 6.5) in south showed poor growth in tomato plants. Yellow leaves, leaves of purple colour and chlorosis with leaf margin scorching revealed deficiency for nitrogen, phosphorus and potassium respectively. Calcium and sulphur deficiency did not occur whereas curling of leaves upward showed magnesium deficiency.

Iron, manganese, zinc and copper decreased with the increase of mill tailings in soil however the values were many times higher than the limit prescribed indicating non-deficiency in tomato. Positive correlation among them showed common source of their occurrence. The micronutrients increased with the increase of clay and decreased with increase of sand percentage indicating coarser size particles reduce the nutrients.

Iron, manganese, and copper in tomato fruits did not exceed the limit prescribed for consumable vegetables whereas zinc was within the norm in north, south, east and up to 30% of mill tailings in west indicating further mixing will cause zinc toxicity. Soil-plant transfer coefficient showed that zinc at 20% onwards in east and in all proportion of west is higher in tomato fruits than soil-tailings mixture (Table 11.1).

Sufficient growth of tomato plant with some blossoms indicated the presence of nitrogen, phosphorous and potassium in mill tailings. Native plant species like Babool, Gulmohar, Neem and Eucalyptus were found to be suitable for the reclamation of the dumps. These plants will not only provide ecological benefits in terms of fuel, organic matter input to dumps, and timber but will also be adequate for the control of wind and water erosion.

Table 11.1 Soil/Plant transfer coefficients for micronutrients

Mix	Iron				Manganese				Zinc				Copper			
(%)	N	S	E	W	N	S	E	W	N	S	E	W	N	S	E	W
0	0.01	0.01	0.01	0.01	0.04	0.02	0.09	0.05	0.47	0.67	0.82	1.19	0.36	0.19	0.32	0.28
10	0.01	0.01	0.01	0.01	0.06	0.02	0.10	0.06	0.53	0.74	0.98	1.42	0.37	0.24	0.37	0.41
20	0.01	0.01	0.01	0.02	0.07	0.03	0.12	0.10	0.63	0.82	1.18	1.70	0.38	0.27	0.51	0.49
30	0.01	0.01	0.02	0.02	0.07	0.04	0.14	0.14	0.84	0.90	1.33	1.81	0.42	0.33	0.66	0.56
40	0.02	0.01	0.02	0.02	0.08	0.05	0.20	0.18	0.92	0.94	1.47	2.52	0.46	0.42	0.69	0.61

Note: Mix = Mill tailings content, N-North; S-South; E-East; W-West

11.2 Scientific study on dust and gas monitoring generated due to blasting operation and water quality monitoring at Mangampet, Kadapa district, A.P., Project No. EE1001 Completed
(T. A. Renaldy, P. Gupta and S. Roy)

The Andhra Pradesh Mineral Development Corporation Limited is operating Barytes Mine by opencast mining method at Mangampet, Kadapa District. A detailed field studies was conducted at the mine for monitoring of dust and gas levels at different locations during blasting period. Water sampling and analysis were also carried out.

The particulate matter concentrations were marginally higher whereas the gaseous pollutants were within the limits when compared with standards of 24 hourly basis. The blasting dust was momentary and dispersed quickly with time and distance. Groundwater source was not observed to be affected by the blasting activity.

11.3 Scientific studies at the quarries of POABS Granite products Pvt. Ltd for suggesting eco-friendly quarrying methods, Chully, Angamally, Kerala, Project No. EE1003 Completed
(P. Gupta, T. A. Renaldy and S. Roy)

In this project, particulate matter, noise and water quality monitoring was conducted in seven different granite quarries (Kaliyal, Trivandrum, Thiruvalla, Angamaly, Perunthalmanna, Calicut, Mangalore) of POABS Granite Products Pvt. Ltd. The observations are as under:

Particulate monitoring: Three respirable dust samplers were installed at different locations and the parameters like SPM (TSP), RPM, SO_2 and NO_x were monitored during working hours (8 hrs) of each quarry including blasting period. In some quarries, SO_2 and NO_x were monitored before and after blasting to know the impacts of different types of explosives. All the parameters were observed within the norm.

Noise assessment: Integrating sound level meter was used to monitor the ambient noise and Logging noise dose meter for the operator noise dose measurements. Different machines indicated different safe zones for ambient noise. Operator noise dose for jackhammer drill operators exceeded the norm in each quarry, which can be controlled by using ear plugs/ear muffs.

Water Quality Assessment: To find out the suitability of water for drinking purpose, samples were collected from different locations of the quarries. The water quality parameters like pH, electrical conductivity, temperature, dissolved oxygen, turbidity, total dissolved solids, nitrate, fluoride, sodium and potassium were analysed. At some locations, pH was slightly acidic and turbidity also exceeded the norms. Other parameters were found within the limits.

12. MATERIAL TESTING LABORATORY

Material Testing Laboratory caters to the needs of mining and other industries for testing of wire ropes, vital components of mine machinery and its accessories using destructive (Torsion, reverse bend and tensile test) and non-destructive testing (NDT). NIRM has state-of-the-art facilities and infrastructure to carry out these tests as per various standards and statutory regulations including DGMS guidelines. This laboratory is manned by qualified and experienced scientific and technical personnel. During 2011-12, this laboratory has provided services to twenty mining and allied industries.

12.1 Testing for Andhra Pradesh Heavy Machinery and Engineering Limited, Vijayawada. Completed.

(M. Victor, A. Rajan Babu, S. Sathyanarayana, Syed Azghar, S. Thobias and Y. Naveen Anand)

Description of component	• Bracket assembly for white metal rope cappel-16 nos. (drawing no 7800-01-207) • 16 bolt ham bone clamp-16 nos. (drawing no 7800-01-126)
Type of test conducted	• Proof load (tensile mode) • Magnetic particle testing • Ultrasonic test
Equipment used for proof load test	Universal horizontal testing machine, 200 MT capacity Mfr: Tokyo Testing Machine Mfg. Co., Japan


Fig. 12.1 Proof load testing of bracket assembly for white metal rope cappel

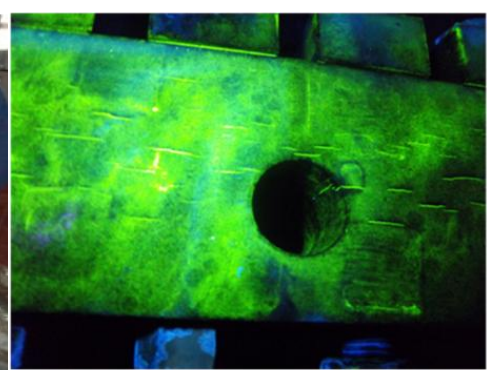



Fig. 12.2 Magnetic particle testing

Proof load and NDT tests were conducted on the bracket assembly with white metal rope cappel at one end (16 Nos.) and 16 bolt ham bone clamp (15 Nos.). No deformation was recorded. They were found to be free from surface, sub surface cracks and internal flaws. Therefore it is recommended for use. The 16th (16 bolt ham bone clamp) was however rejected.

12.2 Testing for Faiveley Transport India Ltd. Harita, Hosur, Tamilnadu, India. Completed.
(M. Victor, A. Rajan Babu, S. Sathyanarayana, Syed Azghar, S. Thobias and Y. Naveen Anand)

Description of component	Advance double acting draft gear with floating plate (type BC 80/45 F assembly)
Type of test conducted	• Compression test (200 T) • Tensile test (100 T) • Proof load test (150 T) • Strain measurements at five specified locations with graphical output.
Equipment used for testing	Universal horizontal testing machine, 200 t capacity, Mfr: Tokyo Testing Machine Mfg. Co., Japan.
Test details	• Draft gear pushed up to a buff load (compressive force) of 200 T • Draft gear pulled up to a drag load (tensile force) of 100 T • Draft gear pulled up to a drag load (tensile force) of 150 T
Strain gauge details	Make: Tokyo Sokki Kenkyujo Co. Ltd. Type: ulfa-3-350-11, Gauge length: 3 mm, Gauge resistance : 350±1.0 ω, Gauge factor : 2.11±1%, Transverse sensitivity : -0.3%
RDSO and customer specification	As per the RDSO spec. Ck009 rev02 clause 4.1.1 & 4.1.2 Ft7271035-e01tts.rev a00 dated 15.09.2011
Acceptance criteria	No fracture should be observed at a load of 150 T. The residual strain should be below 0.2% after release of load

Five strain gauges were used to measure the strain in the draft gear. The locations of the strain gauges were provided by the client.

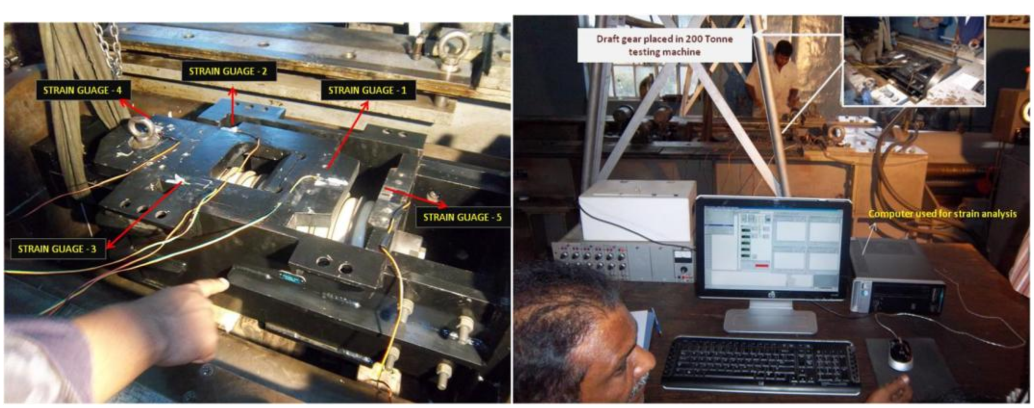


Fig. 12.3 Location of strain gauges on the draft gear for compression testing

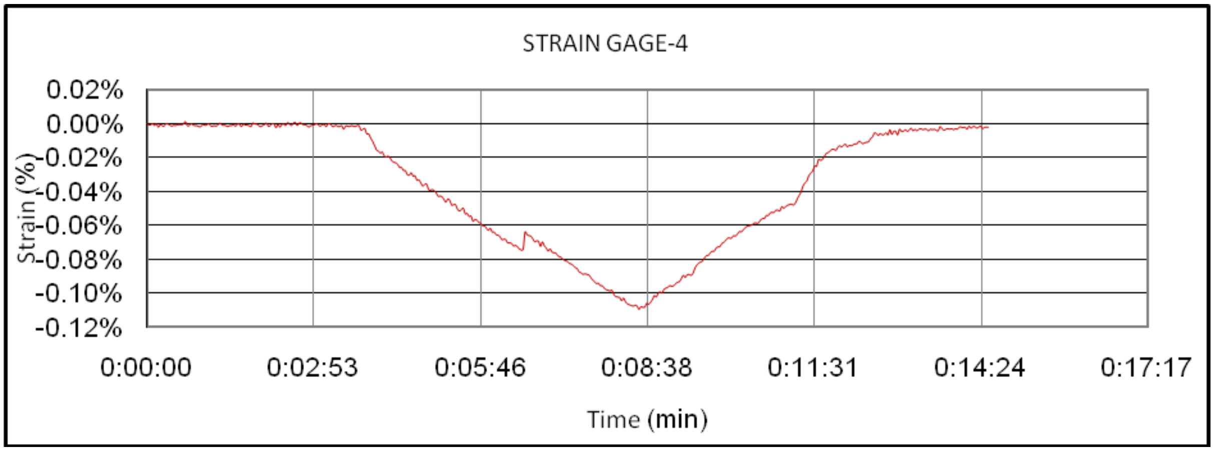


Fig. 12.4 Strain observed in one of the location

Test conducted	Observations
Draft gear pushed up to a buff load (compressive load) of 200 T	No fracture/ damage were observed in the draft gear after application of compressive load of 200 T. The strain observed in all the five locations was found to be within the acceptable limit of 0.2%. The maximum strain observed was 0.11 at strain gauge location-4
Draft gear pulled up to a drag load (tensile force) of 100 T.	There was no fracture observed in the draft gear after application of tensile load of 100 T. The strain observed in all the five locations was found to be within the acceptable limit of 0.2%. The maximum strain observed was 0.07 at strain gauge location-4
Draft gear pulled up to a drag load (tensile force) of 150 T.	There was no fracture observed in the draft gear after application of tensile load of 150 T. The strain observed in all the five locations was found to be within the acceptable limit of 0.2%. The maximum strain observed was 0.08 at strain gauge location - 4
Visual inspection of the draft gear after testing	After completion of all the specified tests, the draft gear was visually inspected with the help of magnifying glass. No fractures/visual damage was observed in any part of the draft gear.

12.3 Testing for National Aluminium Company Limited (NALCO), On-going.

(M. Victor, A. Rajan Babu, S. Sathyanarayana, G. C. Naveen, Syed Azghar, S. Thobias and Y. Naveen Anand)

NALCO is utilising the belt conveyor made of GP rubber compound, (type – offset shoe width – 1137 mm) to transport bauxite ore from opencast mine to refinery plant which is at a distance of about 15 km with a normal speed of 0.5 m/s to 4.67 m/s. The total length of each rope is 30 km. The diameter of the rope is 51 mm having construction of 6 x 25 (12/6 + 6 F/C) with natural fibre core (Galvanized) Right Hand Langs lay. The safe operating load is 368.52 kN with a factor of safety of 4.65. In the total length there were 12 splicing namely blue, white, zebra, red, green, orrange and yellow. The length of each splicing is 51 m and the rope length between splicing is 6 km.

NIRM conducted studies on both Left Hand and Right Hand ropes (Bridon & HaggieRand). The investigation included visual inspection, non-destructive evaluation using wire rope defectograph (Meraster MD120 B) and laboratory destructive evaluation including torsion, reverse bend and tensile test. The O.I.T.A.F (International Organization for Rope Way Transport) regulation was used as the discard criteria.

The visual examination and NDT revealed that the left hand side (Blue splice to white splice) rope was found to contain local faults (LF) like excessive wear, fatigue cracks and isolated broken wires. The right hand side rope was found to be highly deteriorated (within the expected life span of about 8 years) characterized with remarkable defects such as dents, corrosion, pitting, excessive wear and continuous cluster of broken wires. Apart from these defects, a large number of isolated broken wires with a combination of cited defects were also present. The destructive testing also revealed the poor condition of the rope. Moreover, all the 6 splices of HaggieRand rope contained a combination of isolated broken wires, continuous cluster of broken wires with excessive wear both internally and externally. Therefore, as per the standard, discarding criteria of local faults and loss of metallic cross sectional area, the right hand side rope was found to be unsafe for further use and had to be replaced immediately. To minimize the mechanical damage to the wire ropes, adjustable deflection pulleys, non-metallic liners must be incorporated at the earliest. It is suggested to have on line visual monitoring of the wire ropes using Closed Circuit Television covering 360^0 circumferential inspection by running the rope at very low speed.

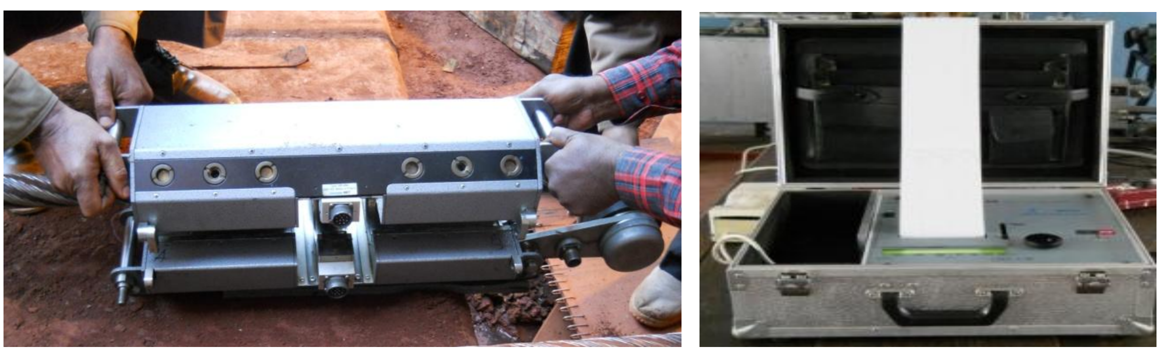


Fig. 12.5 Wire rope tester head unit and recorder (defectograph)

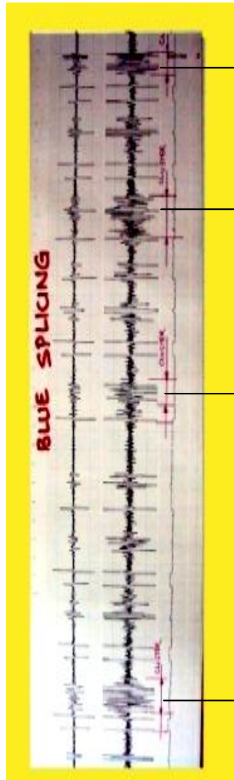
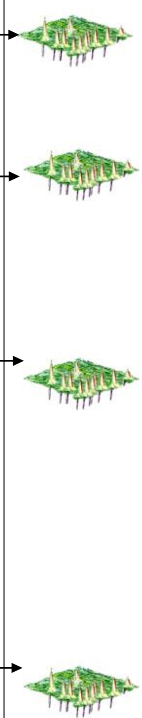
Cable Belt Drive Rope	Scanning Zone Details		Observation
			**Length of splicing scanned – 54 m** **No. Of Cluster broken wires – 42 (at 4 different locations)** a.

Fig. 12.6 The result of a tested rope

12.4 Testing for Khetri and Kolihan Mines, HCL, Rajasthan. <u>On-going</u>

(M. Victor, A. Rajan Babu, G. C. Naveen, S. Thobias and Y. Naveen Anand)

12.4.1 First visit (September, 2011)

Shaft details	**Khetri Copper Mine** • 1600 kW double drum man & material winding hoist • 2870 kW friction hoist for rock winding • Single drum hoist (Cuba) • “0” ML, Single drum hoist **Kolihan Copper Mines** • 400 kW double drum man & material winding hoist • 800 HP rock winding Koepe winder • 100 HP single drum winding hoist • 50 HP single drum winding hoist
Components tested	• Drum shaft • Sheave and sheave wheel shafts • Brake tie rods • Load carrying pins • Suspension gear parts

Material specifications	EN – 24 & 1.5 Manganese Steel

Fig. 12.7 NDT on winder vital components

The results of NDT and observations made on various components as described above do not indicate any significant defects and all the tested components were found to be free from flaws. Hence these components may be put into further use. However, it is recommended to conduct periodic tests to ensure safety. It is also suggested to replace the welded bow and bucket system with a suitable single forged bucket unit.

12.4.2 Second visit (March, 2012)

Ropes tested	**Khetri Copper Mine** • 1600 kW double drum man & material winding hoist rope (51 mm dia RHL east and west) • 2870 kW friction hoist for rock winding rope (25 mm dia RH LAY FLC) • Single drum hoist (Cuba) rope (28 mm dia NR) • “0” ML, Single drum hoist rope (16 mm dia RH LAY FLC) **Kolihan Copper Mines** • 400 kW double drum man & material winding hoist rope (34 mm dia RH LAY FLC) • 800 HP rock winding Kope winder rope (24 mm dia RH LAY FLC) • 100 HP single drum winding hoist rope (19 mm RH LAY FLC) • 50 HP single drum winding hoist rope (16 mm RH LAY FLC)

12.4.3 Wire rope testing

The total length of the rope is 520 m out of which only 266 m was scanned. In the scanned length there were no indications of the sensor signal exceeding lay noise. Thus the scanned rope was found to be free from local faults and loss of metallic area traces.

Fig. 12.8 Testing of rope using Defectograph

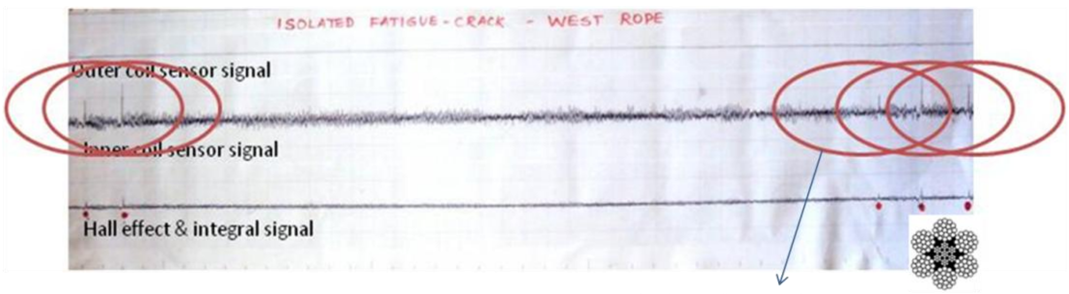


Fig. 12.9 Strip chart of observed fatigue cracks in the tested rope

Khetri Copper Mines	
Particulars	**Observations**
1600 kW double drum man & material winding hoist rope	• The scanned rope of 266 m in east cage was free from LF (local faults) and LMA (loss of metallic area) traces. Whereas in the west rope isolated intact fatigue cracks were observed.
2870 kW friction hoist for rock winding rope	• The scanned rope was visually free from dent, corrosion and pitting. • The scanned rope length of 505 m is free from LF and LMA traces.
Single drum hoist (Cuba) rope	• The scanned rope was visually free from dent, corrosion and pitting. • The scanned rope length of 560 m is free from LF and LMA traces.
"0" ML, Single drum hoist rope	• The scanned rope was visually free from dent, corrosion and pitting. • The scanned rope length of 80 m is free from LF and LMA traces.

Kolihan Copper Mines	
Particulars	**Observations**
400 kW double drum man & material winding hoist rope	• The scanned rope is visually free from dent, corrosion and pitting. • The scanned rope length of 375 m is free from LF and LMA traces.
800 HP rock winding Kope winder rope	• Very slight wear was observed visually in the outer layer wires throughout the length of scanned rope. • The scanned ropes N1, N2 and N3 are found to be free from LF and LMA traces. • Isolated intact broken wires were observed in rope N4.
100 HP single drum winding hoist rope	• The scanned rope is visually free from dent, corrosion and pitting. • The scanned rope length of 79 m is free from LF and LMA traces.
50 HP single drum winding hoist rope	• The scanned rope is visually free from dent, corrosion and pitting. • The scanned rope length of 80 m is free from LF and LMA traces.

12.5 Testing for Rajpura Dariba Mines, HZL, Rajasthan. <u>On-going</u>

(M. Victor, A. Rajan Babu, S. Sathyanarayana, Syed Azghar, S. Thobias and Y. Naveen Anand)

Winder details	• Auxiliary shaft cage winder • Main shaft cage winder • Main shaft skip winder • Crusher shaft
Components tested	• Drum shaft • Drum welding zones • Suspension gear parts • Crusher primary & secondary shaft
Material specifications	EN – 19 & 1.5 Manganese Steel

Fig. 12.10 NDT of winder vital components

The results of NDT and observations made on various components did not indicate any significant defects and flaws. These components may be put into further use. However it is recommended to conduct periodic tests to ensure safety.

12.6 In-situ Non-Destructive testing of vital components of eleven haulers of SCCL, On-going
(M. Victor, A. Rajan Babu, G. C. Naveen, S. Thobias and Y. Naveen Anand)

Hauler type	Man riding system
Components tested in hauler 	• Drum shaft/output shaft • Motor shaft • Ist motion gear shaft • IInd motion gear shaft • Horizontal brake tie rods • Vertical brake hydraulic assembly Load carrying pins • Drum connecting rod • Emergency/thruster brake tie rod and pins
Anchor and man riding car 	• Car attachments (Main chain point load links with D- shackles & Safety chains) • 16 bolts ham bone clamp with welded devise • Turret swivel block

Bogie governer 	Bogie governor (Anchor car) • Wheel shaft • Bogie centre shaft • Bogie arm pins • Ram holding pins
Bogie alternator 	Bogie alternator (Man riding car) • Wheel shaft • Hydraulic ram cylinder pins • Brake pad holding arm pins

The results of NDT and observations made on various components do not indicate any significant defects and all the tested components are found to be free from flaws and there is no problem in putting these components into use.

13. TECHNICAL COORDINATION & PROJECT MANAGEMENT

(G. R. Adhikari, G. S. Govinda Setty and A. Vijaya Kumar)

The primary role of the Technical Coordination and Project Management Department (TCPMD) is to oversee the technical and managerial requirements for the entire life-cycle of R&D and sponsored projects starting from the proposal stage to the implementation stage till the projects are successfully completed. TCPMD acts as an interface between the external stakeholders of projects and the consulting or research teams within NIRM undertaking a particular task to facilitate seamless execution of the identified objectives within the allocated time and budget. The responsibilities of the TCPMD cover a wide spectrum of activities including:

1. Technical Coordination

- Liaisoning between the Institute and the Industry/sponsoring agency
- Inter-departmental coordination within the Institute
- National and international collaboration
- Providing technical inputs to the Director, Peer Review Committee, Governing Body and General Body of the Institute.
- Coordinating important meetings, contracts and memorandum of understanding
- Identification of new areas for research

2. Project Management

- Vetting and submission of project proposals and reports to the clients
- Monitoring of sponsored, S&T and in-house projects through quarterly reviews
- Updating information on R&D activities, achievements, on-going projects and completed projects.
- Maintaining records of project proposals, on-going and completed projects
- Techno-commercial communications related to projects
- Review of feedback from the clients
- Submission of quarterly progress report and financial statements in respect of S&T projects
- Monitoring of tour programmes of Scientists and Scientific staff

3. Publications & Publicity

- Scrutiny and editing of technical papers submitted by Scientists for publication
- Inputs to NIRM website and e-bulletins
- Publication of NIRM Annual Reports and brochures
- Maintaining the records of publications in journals and conferences
- Advertisement of NIRM activities in journals/ Seminar proceedings

4. Library & Documentation

- Maintains the NIRM Library, which has a large collections of books and journals from Indian and foreign publishers in the field of rock mechanics, rock engineering and allied fields.

14. TRAINING PROGRAMMES

During 2011-12, NIRM conducted five training programs in different areas for the benefit of practicing engineers, geologists and geophysicists. Three of them were organized at KGF/Bangalore Unit of NIRM and two at the project sites. The courses comprised classroom lectures, exercises, visits to labs, demonstration of equipment and software.

14.1 Training Programme on Application of Geophysical Investigations to Engineering Projects, IRCON, Banihal, J&K, Code No. HR1101, Completed

(P. C. Jha, V. R. Balasubramanaim, N. Sandeep, Y. V. Sivaram, D. Joseph and B. Butchi Babu)

A training programme on "Application of Geophysical Investigations in Engineering Projects" was conducted for IRCON and Northern Railway officials at Banihal, J&K from July 11 - 16, 2011. Mr. Achal Jain, Chief Engineer, Northern Railway in his inaugural address emphasized the need of such on-site training programmes in geophysical investigations due to the problems faced in tunnelling in Himalayas. Proper and timely subsurface investigations will cut down the design related problems and facilitate smooth implementation of construction projects, he emphasized.

In all, 18 participants, nine each from IRCON and Northern Railway attended this programme, tailor-made for the construction sector. This training course, coordinated by the Engineering Geophysics Department, was divided into two parts. Theoretical aspects and application areas of emerging geophysical techniques were covered in the morning session. Afternoon session was dedicated to video presentation of corresponding field techniques showing the procedure work for data acquisition under standard field conditions. In total, eleven lecture sessions and five interactive video sessions covering seismic, GPR, Electrical and borehole techniques were conducted. Theoretical presentation covered various aspects of investigative studies supported by earlier case studies investigated by NIRM, including the survey work done earlier for T-74 area. The application areas and limitations of each of the geophysical methods were categorically explained during the training and subsequent interactive sessions.

Fig. 14.1 A training session in progress at Banihal, J&K

Entire training programme was heard with rapt attention. The Northern railway officials who had participated in the programme desired to have a long-term cooperation with NIRM for similar investigations and for establishing their bridge and structures Institute proposed at Jammu. Overall, the interactions between the faculty and the participants were very fruitful.

The valedictory programme was chaired by Dr. G R Adhikari, HOD, Technical Coordination Dept. All the participants expressed their appreciation for the training programme, as reflected in an overwhelming positive feedback received from them.

14.2 Training programme on drilling and blasting for the officials of SEW Infrastructure Ltd., Jorethang Project Site, Sikkim, Code No. HR1102, Completed.
(H. S. Venkatesh, A. I. Theresraj, G. Gopinath and R. Balachander)

A three-day onsite training was organised on “Drilling and Blasting for the Official of SEW Infrastructure Ltd.” at Jorethang Project Site, Sikkim. The blasting programme, as part of the SEW orientation programme, commenced on 8 August 2011 and concluded on 10 August 2011.

Twenty nine fresh recruits from different disciplines - Mining, Civil, and Geology - participated in the course. The topics varied from fundamentals of drilling and blasting to design principles for surface and underground excavations. Due stress was given to environmental impacts of blasting and their mitigation measures. In addition, special types of blasting like rip-rap and alternate to blasting were also dealt. In total, 17 lectures were delivered by the faculty comprising Dr. H. S. Venkatesh, Mr. A. I. Theresraj, Mr. G. Gopinath and Mr. R. Balachander. The participants evinced interest in learning the technical aspects of drilling and blasting and an overall impressive feedback was received during the valedictory function. Fig. 14.1 shows group photograph of the Faculty members from NIRM, participants and few officers of SEW taken after the valedictory function.

Fig. 14.2 Group photograph of the participants with faculty members and organisers

14.3 Training programme on Application of Numerical Modeling to Tunnels, Caverns and Slopes, Code: HR1103, Completed
(Sripad R Naik, Roshan Nair, K. Sudhakar)

A six-day training programme on application of numerical modeling in analyzing tunnels caverns and slopes was conducted from 1 to 6 August 2011 at NIRM, Bangalore office. The training was attended by ten participants representing various organization like DGPCL(Bhutan), CMPDIL(Ranchi) and BMRCL(Bangalore). The course was tailor made to focus on both civil engineering and mining industries. The inauguration address by Dr. P.C. Nawani, Director (NIRM) laid emphasis on the importance of numerical modeling on various stages of construction and mining activities.

The programme covered from elementary topics like requirements for numerical modeling, rock mechanics principles, use of Rocklab and CAD software to detailed hands on experience on numerical analysis software like UDEC, 3DEC and FLAC. Numerous problems were solved using these software and discussions were held to effectively analyze the modeling outputs. The participants were encouraged to develop basic numerical models of structures during the exercise sessions. The intricate details of modeling were discussed along with tips for improving the models were also shared during the interaction. Implementation of failure criteria and effectiveness of support system for caverns and slopes were highlighted using modeling tools. Couple of case studies was also discussed to emphasize the interpretation of modeling results.

The participants showed keen interest throughout the programme and desired to extend the schedule for another week. They also proposed to have independent programme for each of the software discussed in order to further enhance their numerical capabilities.

Fig. 14.3 Group photograph

Fig. 14. 4 Interaction with the participants

14.4 Training programme on dimensional stones at NIRM, KGF, Project No. HR1104, Completed

A training programme on dimensional stones was conducted at NIRM, KGF from 23 to 25 November 2011. The programme was coordinated by Mr. A. Rajan Babu Scientist V & HoD, Department of Dimensional Stones Technology. The programmme comprised class room lectures and laboratory demonstrations. This was attended by 18 officers from Assistant Manager to Director levels from different quarries, the Department of Mines & Geology (A.P.), P.R.P Exports (TN), POABS Group (Kerala), Mysore Mineral Ltd., (Karnataka), Pallava Granites, Hamsa granites and Anand Granite (AP) etc. In total, 13 lecturers were delivered by the faculty from various departments of NIRM covering various such as status of granite quarrying in India, exploration of dimensional stone deposits, geophysical aspects of dimensional stone exploration, blasting in dimensional stone quarries, stone quarrying for aggregates, development & planning of granite quarries, introduction to new developments in quarrying technology, case studies, cost analysis, environmental aspects of stone quarrying.

Classroom discussions mainly focused on planning and design of benches for continuous production and topics related to method of mining. Special interest was shown to implement the block spitting techniques. It was pointed out that most of the quarries were experiencing severe damage to the blocks due to want of controlled blasting technique for block spitting as well as overburden removal. Specific field problems addressed by participants were also discussed.

The programme was inaugurated by Dr. V. Venkateswarlu, , Director, Additional Charge, NIRM. In the valedictory function which was held at KGF on 25 November 2011, the participants expressed that they good very good exposure to scientific and innovative techniques of exploitation, which will enhance their productivity at their quarries with optimum cost. At the end, the Director distributed Certificates of Participation.

Fig. 14.5 Mr. A. Rajan Babu delivering lecture on controlled blasting in granite quarrying

14.5 Training programme on Instrumentation for Tunnels, Caverns and Slopes Project No HR1105, Completed.

(Sripad R Naik, Roshan Nair and K. Sudhakar)

A comprehensive training programme on instrumentation systems employed for monitoring of rock mass structures was conducted from 12 to 17 December 2011 at NIRM, Bangalore. The training was aimed to impart both theoretical and practical aspects of various instruments used in the industry. The programme was designed to cover all the major aspects of instrumentation methods like geotechnical, geophysical, seismic and microseismic, vibration monitoring etc. The training was attended by 12 participants representing DGPCL (Bhutan), DHPC (Bhutan) BMRCL (Bangalore), CEA (New Delhi) and AAR VEE Associates (Hyderabad).

The programme included presentations by experienced scientist from NIRM and representatives from leading instrumentation agencies. Apart from the organizing department, the list of distinguished speakers included:

- Dr. V Venkateswarlu, Director (Additional Charge)
- Dr. G R Adhikari, HOD, TCPMD
- Dr. H S Venkatesh, Scientist-F
- Dr. C Srinivasan, Scientist-F
- Mr. C Sivakumar, Scientist-F
- Dr. P. C Jha, Scientist-F
- Mr. Revanna, AIMIL Ltd.
- Mr. Manish Mehta, Encardio Rite Ltd.

The training programme covered various topics varying from principles for instrumentation to instrumentation packages for various types of structures and applications. The instrument demonstration was conducted by M/s. AIMIL Ltd. and M/s. Encardiorite Ltd. Mr. Revanna (AMIL Ltd) discussed and demonstrated High End Total Station along with GPS system. Mr. Manish Mehta (Encardio Rite Ltd) presented the latest system of instruments for monitoring, data collection and transfer followed by online monitoring software. Both the presentations/demonstrations were highly educative and appreciated by the participants. The topics related to Blast monitoring, Seismic, Micro-seismic, Geophysical, Geotechnical instrumentation applicable in tunnels, caverns and slopes were demonstrated and discussed in detail by various speakers. Field demonstration and practice sessions were conducted with regards to total station and its application to tunneling. The participants also visited various laboratories at NIRM, KGF and received hands on experience of various instruments used for rock mass monitoring by various departments. A couple of instrumentation case studies were presented and the analysis of output data was discussed in detail. The programme concluded with an exercise on planning of geotechnical instruments for caverns and slopes.

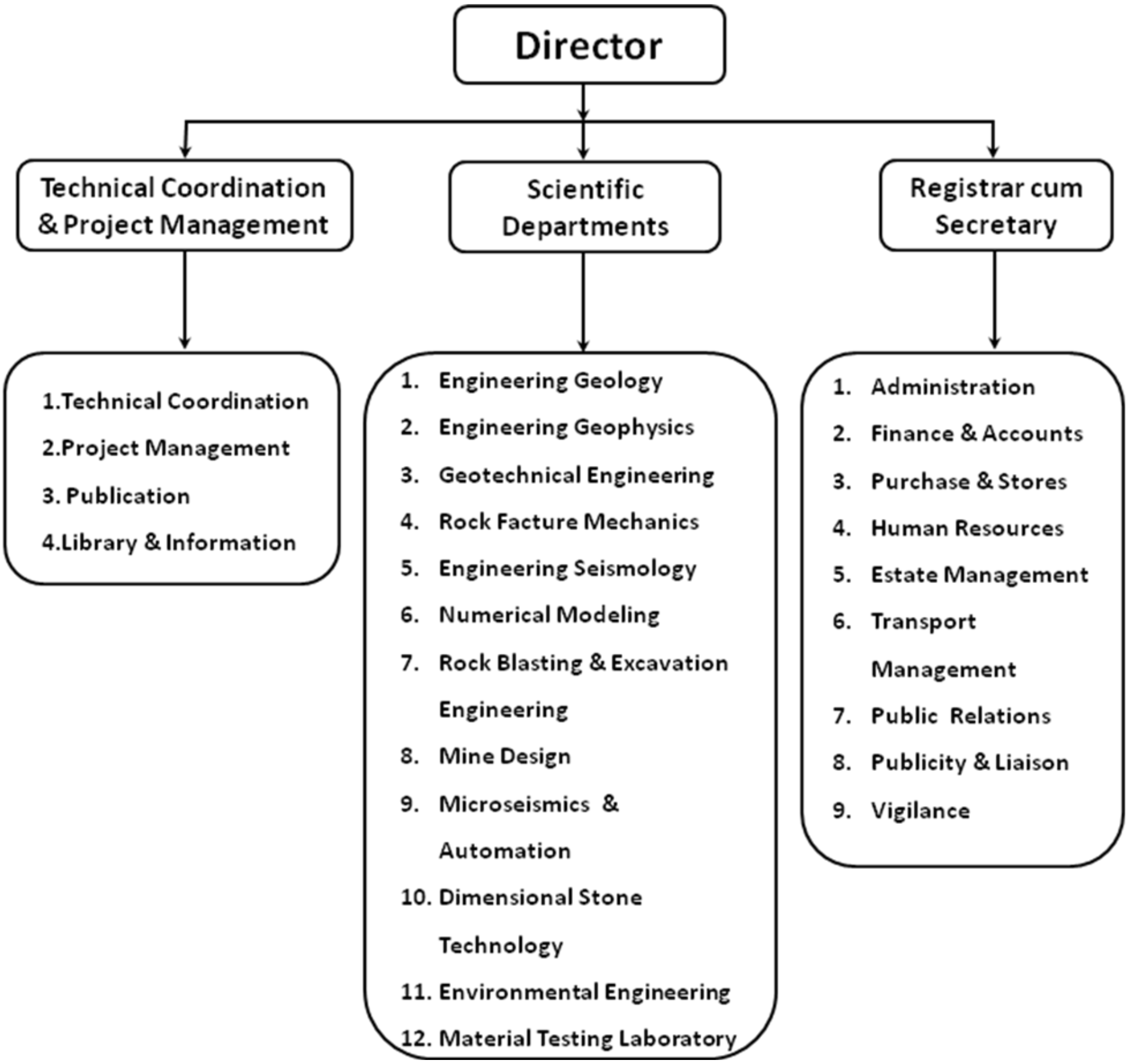
Fig. 14.6 Group Photograph

Fig. 14.7 Demonstration of Instruments

Annexure

Annexure - 1

ORGANISATION CHART



Annexure - 2

MEMBERS OF THE GENERAL BODY

Chairman

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Director General
Directorate General of Mines Safety
Dhanbad – 826 001
Jharkhand

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THDC India Ltd
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Uttarakhand

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Uttar Pradesh

Shri Ravi Shanker
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Annexure - 3

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Champion Reefs
Kolar Gold Fields - 563 117

Annexure - 4

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Champion Reefs
Kolar Gold Fields - 563 117

Annexure - 5

SUPPORTING ORGANISATIONS / CLIENTELE

Central Government Ministries & Departments

Ministry of Mines, Government of India
Ministry of Coal, Government of India
Ministry of Earth Sciences, Government of India
Dept of Science & Technology, Ministry of Science & Technology, Govt. of India

Public Sector Organisations/ State Government

Airport Authority of India, Chennai (AAI)
Andhra Pradesh Mineral Development Corporation Ltd. (APMDC)
Atomic Minerals Directorate (AMD)
Central Mine Planning & Design Institute Limited (CMPDI)
Department of Mines and Geology, AP
Engineers India Limited (EIL)
Himachal Pradesh Power Corporation Ltd. (HPPCL)
Hindustan Copper Ltd. (HCL)
Hutti Gold Mines Limited (HGML)
IRCON International Limited
Kerala State Electricity Board (KSEB)
Malabar Cements
Manganese Ore India Limited (MOIL)
Mysore Minerals Ltd (MML)
National Aluminium Company Limited (NALCO)
NHPC Ltd.
North Eastern Electric Power Corporation Limited (NEEPCO)
NTPC Ltd.
Nuclear Power Corporation of India Ltd (NPCIL)
Sardar Sarovar Narmada Nigam Limited (SSNNL)
Satluj Jal Vidyut Nigam Limited (SJVNL)
Singareni Collieries Company Limited (SCCL)
Tamilnadu Electricity Board (TNEB)
THDC India Limited
Uranium Corporation of India Limited (UCIL)
Western Coalfields Limited

Private Companies

AFCONS Jv
Aiswarya Granites
Andhra Pradesh Heavy Machinery and Engineering Limited
Faiveley Transport India Ltd
Ferro-Alloys Corporation Limited (FACOR)
Gammon India Ltd
GMR Infrastructure Ltd
Hindustan Construction Company Limited (HCC)
Hindustan Zinc Limited (HZL)
Indian Metals and Ferro Alloys Limited
Navayauga Engineering Company
POABS Rock Products Pvt. Ltd
SEW Infrastructure Ltd.
Soma Enterprises Ltd
The India Cements Limited (ICL)

International Organisations

Druk Green Power Corporation Limited (DGPCL), Bhutan
(Formerly Tala Hydrolectric Project, Bhutan)

Annexure – 6

LIST OF PUBLICATIONS

1. Gopinath, G., Vamshidhar, K. and Venkatesh, H. S. (2012) Ground vibration measurements at Sangam Kalan limestone mine, *Souvenir Mines Environment & Minerals Conservation Week*, Hyderabad Region, January, pp. 64-70.
2. Gupta, P. and Roy, S. (2012) Evaluation of spatial and seasonal variations in groundwater quality at Kolar Gold Fields, India, *American Journal of Environmental Engineering, Vol. 2,* No. 2, pp. 19-30.
3. Jain, P., Naithani, A. K. and Singh, T.N. (2011) Application of tunnel boring machine (TBM) for the construction of Maroshi-Ruparel College tunnel, Mumbai, India, *Journal of Engineering Geology*, Vol. 37, No 1-4, pp. 144-152.
4. John, B., Singh, Y., Rao, D.T. and Babu, K. K. (2012) Suspected Archeological evidence of an earthquake near Visakhapatnam. *Indo-US Workshop on Intraplate Seismicity,* Institute of Seismological Research, Gandhinagar, Gujarat, India, 16-18 January.
5. Kumar, M., Roy, S. and Gupta, P. (2011) Assessment of traffic noise at Kolar Gold Fields, India, *Journal of Environmental Science & Engineering* (In press).
6. Lokhande R. D. and Venkateswarlu, V. (2011) Strata control investigations in continuous miner panels" *International Conference INDOROCK-2011*, organized by ISRMTT at IIT Roorkee, October 13-15.
7. Mahesh, V.S., Senthilkumaran K., and Jha, P.C. (2011) 3D digitization of sub surface features using 3D GPR, *ASME-2011 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* August 28-31, Washington, DC
8. Mohapatra, A. K., Mohanty, W. K., Khisley, K and Tiampo, K. F. (2012) Earthquake Forecasting in Bhuj, Western India, *Indo-US Workshop on Intraplate Seismicity,* Institute of Seismological Research, Gandhinagar, Gujarat, India, 16-18 January.
9. Mohapatra, A.K., Mohanty, W.K., Khisley, K and Tiampo, K. F. (2012) Earthquake forecasting in Northeastern India using pattern informatics method, *Seismological Research Letters*, Vol. 83, No. 1, pp. 216.
10. Naik, S. R., Nair, R. and Nawani P.C. (2011) Stability Analysis Of Underground Powerhouse Caverns Using Discontinuum Numerical Modelling, *Journal of Engineering Geology*, Vol. 37, No. 1-4, pp. 268-276.
11. Nair, R. and Sastry, V.R. (2011) Multiseam longwall mining: a parametric study using finite element method, *Journal of Engineering Geology*, Vol. 37, No 1-4, pp. 227-334.
12. Naithani, A. K. and Nawani, P.C. (2011) Engineering geological investigations of Dik Chhu hydroelectric project, Sikkim Himalaya, India. *Journal of Nepal Geological Society*, Vol. 43, pp. 71-80.
13. Naithani, A. K., Rawat, G. S. and Nawani, P. C. (2011) Investigation of landslide events on 12 July 2007 due to cloudburst in Chamoli District, Uttarakhand, India, *International Journal of Earth Sciences and Engineering*, Vol. 4, No. 5, pp. 777-786.

14. Naithani, A.K., Kumar, M., Bhusan, R. and Nawani, P. C. (2012) Engineering geological investigations of rock mass from the excavated north wall face in the Pump House area of Mahatma Gandhi Lift Irrigation Scheme-III, District Mahboobnagar, Andhra Pradesh, *E-journal Earth Science India*, Vol. 5, No. 1, pp. 1-11.
15. Naithani, A.K., Singh, L.G., Jain, P., Singh, D., Bhusan, R. and Nawani, P.C. (2011) Engineering geological evaluation of the underground water conducting system of Malshej Ghat PSS Project, Maharashtra, India, *Journal of Engineering Geology*, Vol. 37, No 1-4, pp. 179-188.
16. Naithani, A.K., Singh, L.G., Singh, Devendra and Nawani, P. C. (2012) Engineering geological and geotechnical evaluation of dam spillway of Bunakha Hydroelectric Project, Bhutan Himalaya, *Proc. Seminar on Geotechnical Challenges in Water Resources Projects*, Organised by CBIP and ISRM (India), Dehradun, pp. 12-18.
17. Nawani P. C. (2011) Engineering geological investigations for underground excavations, *Journal of Engineering Geology*, Vol. 37, No 1-4, pp. 98-119.
18. Nawani, P.C., Naithani A. K. and Naik, S. R. (2011) Stability Analysis of Underground Powerhouse of Malshej Ghat PSS Project, Maharashtra, India, *Journal of Engineering Geology*, Vol. 37, No 1-4, pp. 303-311.
19. Rajan Babu, A., Adhikari, G.R. and Pitchumani, P. K. (2011) Excavations by controlled blasting for the construction of an underground LPG storage cavern at Vizag, *Journal of Engineering Geology*, Vol. 37, No 1-4, pp. 381-410.
20. Rao, G.M. N., Udayakumar, S. and Jennifer, P. D. (2011) Predicting rock mass properties for nuclear waste repositories from laboratory strength data, *Journal of Engineering Geology*, Vol. 37, No 1-4, pp. 218-224.
21. Roy, S., Gupta, P. and Renaldy, T. A. (2012) Impacts of gold mill tailings dumps on agriculture lands and its ecological restoration at Kolar Gold Fields, India**,** *Resources and Environment,* Vol. 2, No. 1, pp. 67-79.
22. Roy. S. (2012) Prediction of particulate matter concentrations using artificial neural network, *Resources and Environment,* Vol. 2, No. 2, pp. 30-36.
23. S. Sengupta, D. S. Subrahmanyam, R. K. Sinha, D. Joseph (2011) Investigation into the causes of severe roof problems in some Indian coal mines and formulation of guidelines to reduce ground control problems, *International Journal of Mining and Mineral Engineering*, Vol. 3, No. 4 pp. 290-302.
24. Sandeep N., Jha P. C., Sivaram Y.V., Balsubramaniam V. R. and Babu, B. B. (2011) Integrated geophysical investigations for site characterisation along a hydro tunnel under low overburden conditions, *Journal of Engineering Geology*, Vol. 37, No. 1-4, pp. 153-160.
25. Sengupta, S., Sinha, R. K., Subrahmanyam, D. S., Shyam G. (2011) Assessment of impact of nearby excavations on the deformability and stress conditions around a proposed powerhouse by field and numerical modeling, *Proc. 45th U. S. Rock Mechanics/ Geomechanics Symposium*, June 26-29, San Francisco, California.
26. Vallinayagam, G. and Singh, L. G. (2011) Radioactive heat producing acid volcanic – plutonic rocks of Dhiran area, Malani igneous suite Northwest Peninsular India. *E-journal Earth Science India*, Vol. 4, No. 2, pp. 68-79.

Annexure-7

NEWS LETTER

1. Best Paper Award for a paper entitled “Control measures for ground vibration induced by blasting at coal mines and assessment of damage to surface structures”, authored by G.R. Adhikari, N.K. Jain, S. Roy, A.I. Theresraj, R. Balachander, H.S. Venkatesh and R.N. Gupta, published in Journal of Rock Mechanics and Tunnelling Technology, Vol. 12, No. 1, 2006, pp. 4-19, for the year 2006 under the category “Rock Blasting and Rock Dynamics” was declared in 2011 by ISRMTT.
2. Dr. H. S. Venkatesh coordinated in finalsing the documentary video on Controlled Blasting at BMRCL entitled “NIRM: A Partner in Development”
3. Dr. H. S. Venkatesh delivered lectures on “Controlled blasting techniques for infrastructure applications” at the Workshop on Drilling and blasting for surface and underground excavations, 11 -12 August, 2011, CBIP, New Delhi.
4. Dr. H. S. Venkatesh delivered lectures on “Blasting Technology” and “Techno Commercial Advantages of ANFO”, at Seminar-cum-Workshop on Use of ANFO, 22 – 24 January, 2012, Deepak Fertilisers, Hyderabad.
5. Dr. S. Roy and Mr Piyush Gupta participated in the workshop on “On-site visualization and dust monitoring on Bangalore Metro Project” on 24 January 2012 at Bangalore.
6. Dr. S. Roy guided students of Dr. T. Thimmaiah Institute of Technology, KGF, Karnataka for their project entitled “Impact of cement industries on air environment”.
7. Dr. S. Roy guided a student of National Institute of Technology, Calicut, Kerala in his project entitled “Assessment of traffic noise at Kolar Gold Fields, Karnataka”.
8. Dr. Roshan Nair delivered a lecture on “Monitoring and warning technologies for landslide & demonstration” at Administrative Training Institute at Mysore on 29 July 2011.
9. Dr. Roshan Nair attended the seminar on “Geosynthetics India’11 and an introductory course on Geosynthetics”, organized by Indian Chapter of International Geosynthetics Society & CBIP at Chennai from 22-24 September 2011.
10. Mr. K. Sudhakar attended the seminar “Embedded System” orgainsed by EDN Asia at Bangalore on 21 April 2011.
11. Mr. A. Rajan Babu, Mr. S. Sathyanarayana, Mr. M. Victor, Mr. S. S. Meena. Mr. G. C. Naveen and Mr. Syed Asgar participated in STONA-2012 at Bangalore during 1- 4 February, 2012.
12. Mr A. Rajan Babu attended the CED-6 Committee meeting of the Bureau of Indian Standards at CDOS, Jaipur on 11 January 2012. The grading methodology developed by NIRM was circulated and discussed.
13. Mr R. D. Lokhande attended two weeks training programme on “Science Administration and Research Management for Middle and Senior Level Scientists” at ASCI, Hyderabad, during 5-16 September 2011.

14. Mr Amrith T. Renaldy attended one week training programme on “Instrumentation for Tunnels, Caverns and Slopes” at NIRM, Bangalore during 12-17, December 2011. He also attended the training programme on “Numerical Modelling Techniques” organized for THDC executives at NIRM, Bangalore during March-April 2011.

15. Mr. R. D. Lokhande guided three final year Mining Engineering students of TTIT on the topic “Yield Pillar Method of Partial Extraction in Coal Mines.”
16. Dr. A. K. Naithani attended “Bureau of Indian Standard 1st Panel Meeting of Geological Investigation and Subsurface Exploration Sectional Committee, WRD-05” at BIS Office, New Delhi on 5 September 2011.
17. Dr. A.K. Naithani attended the seminar on “Geotechnical Challenges in Water Resources Projects”, organised by CBIP and ISRM at Dehradun, Uttarakhand during 19-20 January 2012.
18. Dr. A. K. Naithani was nominated as a member of the “Task Force of Experts on Landslide Management” constituted by the National Disaster Management Authority, Govt. of India, New Delhi.
19. Dr. A. K. Naithani was nominated as a panel member for reviewing and draft preparation of “IS 4464:1985 – Code of Practice for Presentation of Drilling Information and Core Description in Foundation Investigation” and “IS 5313:1980 – Guide for Core Drilling Observations” constituted by the Bureau of Indian Standards, Govt. of India, New Delhi.
20. Dr. A. K. Naithani was nominated as a Member of the Doctoral Committee, VIT University, Vellore, Tamil Nadu.
21. Dr. C. Srinivasan attended a training programme on “Right to Information Act, 2005-Analysis of the Law of Information and challenges of CIC during 14-16, September, 2011, organized by Param Institute of Statutory Rules, Bangalore.
22. Dr. C Srinivasan delivered a talk on analysis of strong motion accelerograh data of Wangkha dam and application of microseismic technique in Hydroelectric projects to the executives of Druk Green Power Corporation, Bhutan on 13th November, 2011.
23. Dr. C. Srinivasan delivered Keynote address “Mining hazards in the mines of Kolar Gold Field” at National Seminar on Engineers Preparedness for Disasters Mitigation on Sept, 15, 2011 at Dayanandasagar College of Engineering, Bangalore.
24. Mr V. R. Balasubramaniam, Mr Sandeep Nelliat attended the “Training programme on Geotechnical Investigations for Hydroelectric Projects” at CSMRS, New Delhi on Feb 27-29, 2012.
25. Mr. Y. V. Sivaram, and Mr. D. Joseph attended a seminar on “Virtual Instrumentation” organized by National Instruments at Bangalore during 12-13 October, 2011.
26. Mr. Rajan Babu attended the Granite Development Council meeting under the chairmanship of the Secretary, MOM at Bangalore on 2nd February, 2012 and presented the services of DDST, NIRM to the members.
27. Mr. Y. V. Sivaram attended Educators Day- the annual technical forum for students, academicians and research scholars at Bangalore on October 2011.

Annexure - 8

Director (Additional Charge)
Dr. V. Venkateswarlu

Departments

Engineering Geology

Dr. A. K. Naithani
Mr. D. T. Rao
Dr. Biju John
Dr. Rabi Bhusan
Dr. L. Gopeshwor Singh
Mr. Devendra Singh Rawat
Mr. Yogendra Singh
Mr. Prasnna Jain
Mrs. K.S. Divyalakshmi
Mr. Manoj Kumar
Mr. G. H. Kotnise
Mr. K. Kanna Babu
Dr. A. K. Mohapatra

Engineering Geophysics

Dr. P. C. Jha
Mr. V. R. Balasubramaniam
Mr. Sandeep Nelliat
Mr. D. Joseph
Mr. Butchi Babu
Mr. Y. V. Sivaram

Geotechnical Engineering

Dr. S. Sengupta
Dr. D. S. Subrahmanyam
Mr. R. K. Sinha
Mr. G. Shyam
Mr. Moses Immanuel

Rock Fracture Mechanics

Dr. G. M. Nagaraja Rao
Mr. S. Udayakumar
Mr. G. D. Raju
Mrs. Praveena D. Jennifer
Mr. Abdul Majeed

Engineering Seismology

Dr. C. Srinivasan
Mr. Y. Ahnoch Willy
Mr. R. M. Carter

Microseismics and Automation

Mr. C. Sivakumar
Mr. Vikalp Kumar

Mine Design

Dr. V. Venkateswarlu
Mr. C. Nagaraj
Mr. Sagaya Benady
Mr. S. Kumar Reddy
Mr. Ritesh D. Lokhande
Mr. N. Selvaraj
Mr. Ch. Ramesh

Rock Blasting & Excavation Engg.

Dr. H. S. Venkatesh
Mr. A. I. Theresraj
Mr. G. Gopinath
Mr. K. Vamshidhar
Mr. R. Balachander

Numerical Modelling

Mr. Sripad
Dr. Roshan Nair
Mr. K. Sudhakar

Dimensional Stone Technology

Mr. A. Rajan Babu
Mr. Sultan Singh Meena
Mr. G. C. Naveen
Mr. S. Thobias

Material Testing

Mr. S. Sathyanarayana
Mr. M. Victor
Mr. M. S. Nagaraj
Mr. G. Mohandoss
Mr. Syed Asgar
Mr. Y. Naveen Anandan
Mr. S. Raja

Environmental Engineering

Dr. Surendra Roy
Mr. T. Amrith Renaldy
Mr. Piyush Gupta
Mr. M. Lakshmipathy

Technical Coordination & Project Management

Dr. G. R. Adhikari
Mr. G.S. Govinda Setty
Mr. A. Vijaya Kumar
Mr. N. Sounderrajan

Administration

Mr. A. N. Nagarajan
Mr. Pankaj Kumar
Mr. S. Ravi
Mr. J. V. Sastry
Mrs. S. Lourdu Mary
Mr. N. Jothiappa
Mrs. C. V. Lalitha
Mr. J. Raja
Mr. K. Manogaran
Mr. M. Venkatesh
Mr. S. Sekar
Mr. T. Anjaniappa
Mr. P. Venkata Reddy
Mr. Antony Cruz
Mr. K. Manjunath
Mr. Charles Sounder Raj

Resignation

Mr. S. K. Mohanty
Mr. Ravi Dimri

Retirement

Mr. Y. L. Visweswaraiah
Mr. A. Yesupadam

Expired

Mr. A. Narayanaswamy
Mr. P. S. Varma