वार्षिक प्रतिवेदन २००८–०९
Annual Report 2008–09

राष्ट्रीय शिला यांत्रिकी संस्थान
NATIONAL INSTITUTE OF ROCK MECHANICS

(Ministry of Mines, Government of India)

An ISO 9001:2008 Certified Research Institute

Quality Objectives

NIRM works to -

1. Excel as an R&D organisation by providing high quality, need based, value added services in the emerging areas of rock mechanics and rock engineering for surface and underground excavations.

2. Develop innovative technologies and retain them through intellectual property rights.

3. Disseminate the knowledge and expertise through publication of papers in national and international journals and seminars.

4. Facilitate skill enhancement through training and workshops.

5. Conduct training courses and workshops for professionals, and provide research facilities for higher education in the areas of rock mechanics and rock engineering.

Quality Policy

NIRM is dedicated to –

1. Carry out advanced research in the areas of Rock Mechanics and Rock Engineering to remain a centre of excellence.

2. Provide quality services to the total satisfaction of customers with strict adherence to contractual specifications.

3. Enhance knowledge and skill of the employees through self development on continuous basis.

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ANNUAL REPORT
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(An ISO 9001: 2008 Certified Research Institute)

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National Institute of Rock Mechanics

(Ministry of Mines, Govt. of India)

Champion Reefs

Kolar Gold Fields - 563 117

Karnataka, India

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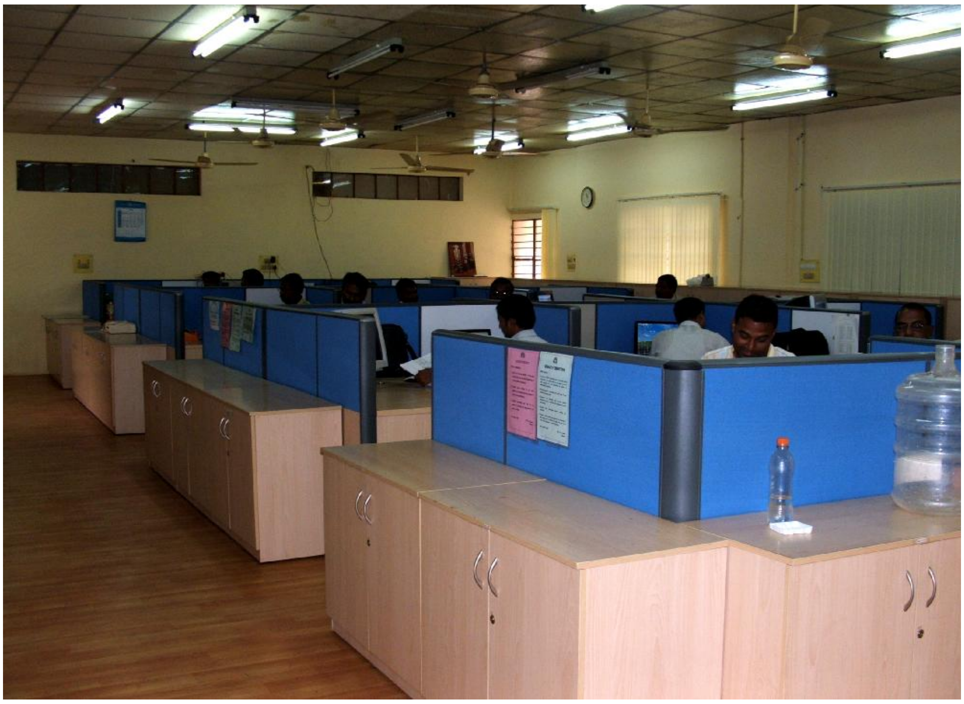
Front cover: Excavation of tunnels by TBM and D&B method at Joshimath

Back cover: Activities of different departments of NIRM

NIRM main building at Kolar Gold Fields



NIRM office at Bangalore

Contents

Director's Report

The National Institute of Rock Mechanics (NIRM) is a premier centre for research in applied and basic rock mechanics. NIRM is committed to provide enabling technology to mining, civil and construction industries, both in India and abroad, to achieve improved production, productivity and quality, with enhanced safety and economy.

NIRM integrates theory and practice to provide specialised services of rock mechanics/rock engineering for coal and non-coal mines, hydroelectric & tunnelling projects, underground storage cavern projects and other construction projects. With the rich experience of highly qualified scientific personnel and state-of-the-art equipment, the Institute offers its services through laboratory and field investigations.

The Institute has eleven scientific departments for carrying out research and sponsored projects and one department for technical coordination and project management. Three of the scientific departments are operating from Bangalore unit while all other departments are located at its headquarter at Kolar Gold Fields. Most of the major projects are interdisciplinary in nature and are well coordinated to accomplish the identified objectives within the stipulated time and budget.

I am very happy that a large number of organisations dealing with rock excavations (surface and underground) and also for DPR stage investigations in hydroelectric projects have approached NIRM for its services. With a team of well qualified, experienced and dedicated scientists, NIRM has been able to complete the assignments to the satisfaction of our clients. The work has been increasing and to cater to the needs of our esteemed clients, NIRM has added 25 Scientists to its existing strength during 2008-09.

It is my great pleasure to place before you the 21^{st} Annual Report of NIRM for the year 2008-09. During this year, NIRM was involved in 50 projects, out of which 26 were successfully completed and 24 projects were in progress. It would not have been possible without continued support of our funding organisations, both governmental and private. The institute has published 31 technical papers in various journals and proceedings of seminars. News bulletins were published regularly at NIRM web site. NIRM scientists shared their knowledge and experience with academic institutions and others by way of several invited lectures/talks and theses/dissertations for graduate and post-graduate engineering students.

NIRM is trying its best to generate sufficient funds through S&T and sponsored projects to meet the expenditure. The total cash flow from projects during 2008-09 was Rs. 3,13,94,958/-

I am grateful for the support extended by the Ministry of Mines, Government of India, the General Body, the Governing Body and the Peer Review Committee. I express my sincere thanks to Scientists and staff who are working very hard for the growth and success of NIRM.

'Jai Hind'

18 August 2009

(Dr. P. C. Nawani)
Director

1. ENGINEERING GEOLOGICAL INVESTIGATIONS

Engineering Geology Department comprises three groups, namely Engineering Geology, Seismotectonics and Remote Sensing. The objective of this department is to carry out engineering geological investigations at different stages, viz. feasibility report, detailed project report, construction and post-construction stages. These investigations are pre-requisite for economic and safe design of projects in various sectors like power (hydro, thermal or nuclear), communication (metros, rails, tunnels, roads and bridges), mining and disaster management. This department has one on-going project at construction stage.

1.1 Construction stage Geological / geotechnical investigations at Tapovan-Vishnugad hydroelectric project (520 MW), Uttarakhand, Project No. GC0701, On-going

(S.K. Mohanty, Ravi Dimri and P. C. Nawani)

Tapovan Vishnugad Hydroelectric Project, a run-of-the river scheme, envisages construction of a barrage on the Dhauliganga river near Tapovan, a 11.60 km long and 5.64 m diameter circular Head Race Tunnel, and an underground Power House near Helang for 520 MW (4 X 130 MW) of power generation under the spur between Animath Nala and Alaknanda river. The major components of the project are shown in Fig. 1.1.

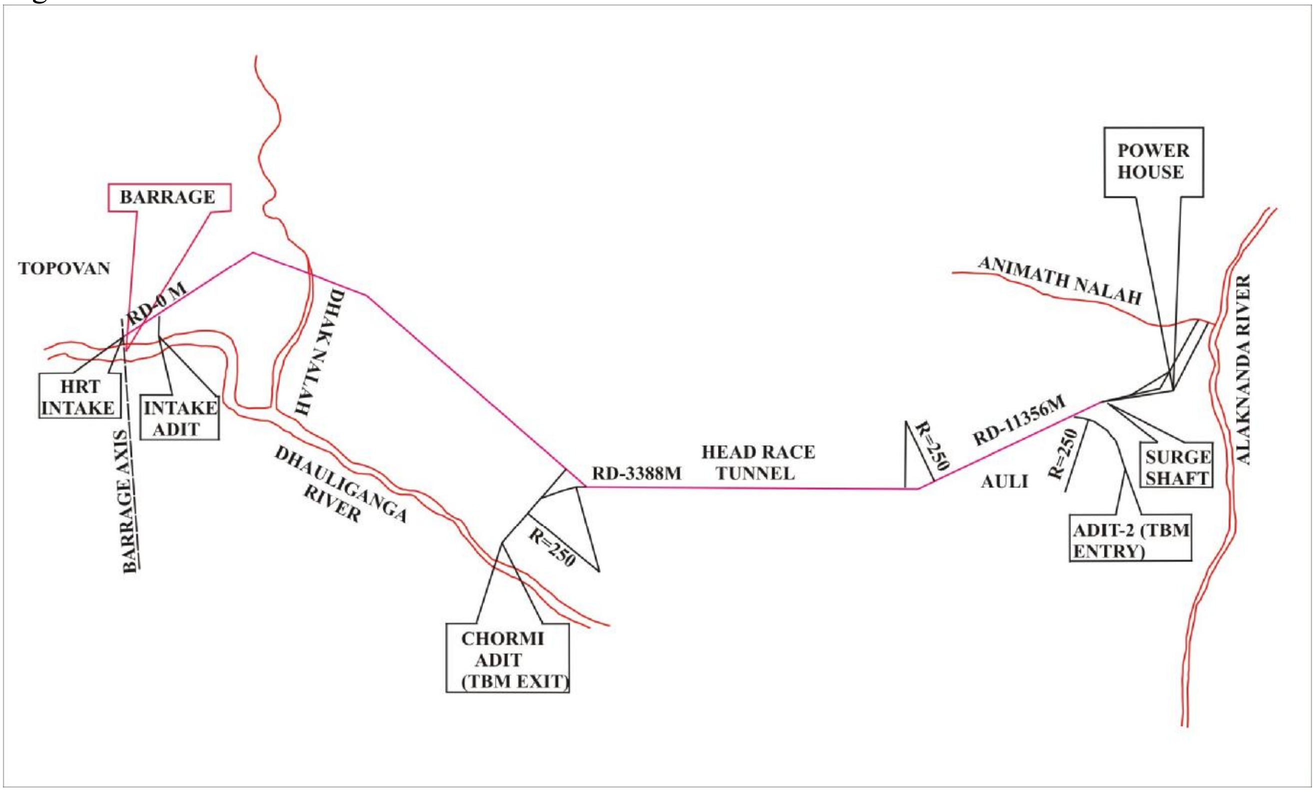


Fig. 1.1 Layout of Tapovan Vishnugad Hydroelectric Project, Uttarakhand

This project area falls in the Higher Himalayas where metamorphosed rocks of greenschist to amphibolites facies of Proterozoic age are exposed. Granites of various ages are emplaced in the metamorphosed rocks. The project area is located within the tectonic block bounded by Main Central Thrust in the south and Vaikrita Thrust in the north.

Construction stage geological / geotechnical mapping, which was carried out by NIRM in the year 2007-08, continued in 2008-09 also. The following is the major scope of work:

- 3D Geological mapping of the underground excavations
- Estimation of rock mass quality based on Q-values
- Suggestions for suitable support measures

Geological / geotechnical mapping was carried out in the construction adits (Intake and TBM) and HRT (Intake) after every drill & blast-mucking-scaling cycle and/or road header cutting-mucking-scaling cycle. Rock matrix description (petrographic name and weathering grade), rock discontinuity orientation (dip amount and strike) and description (type, spacing, persistence, aperture, roughness and alteration) were recorded. A typical face log of HRT on 1:100 and a 3D geological log of HRT on 1:200 scales are depicted in Figs. 1.2 and 1.3.

Investigations were carried out for HRT, D-shaped TBM adit (470.54 m long), Charmi adit (668.00 m long) and Intake adit (239.35 m long), each of 6.75 X 6.75 m size for rock mass characterization / classification and permanent rock support recommendations on day to day basis. The rocks are mainly composed of medium to high grade metamorphics of Central Himalayan Crystallines. The intake adit, TBM adit and HRT (U/S & D/S) are being excavated with drill & blast / road header method. The rock mass conditions fall under extremely poor to fair (Q=0.012-10), poor to fair (Q=1-10), extremely poor to poor (Q=0.01-4) and poor to good (Q=1-40) categories respectively. Table 1.1 gives details of rock class in terms of length and percentage of excavation in different locations.

Table 1.1 Rock mass classification at various sites of the project

Site Location	Total Excavated Length, m	Rock Class 2 Q: 10-40		Rock Class 3 Q: 4-10		Rock Class 4 Q: 1–4		Rock Class 5 Q: 0.1-1		Rock Class 6 Q: 0.01–0.1	
		L (m)	%	L (m)	%	L (m)	%	L (m)	%	L (m)	%
Intake Adit	239.35			135.00	56.40	071.20	29.75	016.50	06.89	016.65	06.96
TBM's Adit	130.00			064.00	49.23	066.00	50.77				
HRT U/S	127.50					099.84	78.30	006.00	04.71	021.66	16.99
HRT D/S	453.00	081.35	17.96	281.00	62.03	090.65	20.01				

Note: L= Length

The TBM adit between Ch. 130.00 and 371.08 m was excavated by a double shielded tunnel-boring machine. The rock mass was observed from the muck either on the conveyor belt or in the dumping yard, through the holes for pea gravel, grouting and erector in the precast segments, in front of the cutter head and through the telescopic shield. The rock mass in TBM adit are predominantly quartz mica gneiss with mica schist and quartzite bands, and quartzite (Joshimath Formation), which are highly to slightly weathered and / or disintegrated (Weathering grade: W3 to W1). The rock mass is characterized by prominent two or more joint sets and few random joints with silty or sandy-clay coatings and small clay fraction (non-softening), and non-softening minerals, sandy particles, and clay-free disintegrated rocks, etc. along them. The rock mass is completely dry in general and wet at some places. Judging from the total thrust force of the cylinders, which lies mostly below 5000 KN, the rock mass condition appears to be Poor to Fair.

Based on the estimated Q-values, permanent rock support (a combination of rock bolts, steel fiber reinforced shotcrete and steel ribs) was recommended for HRT.

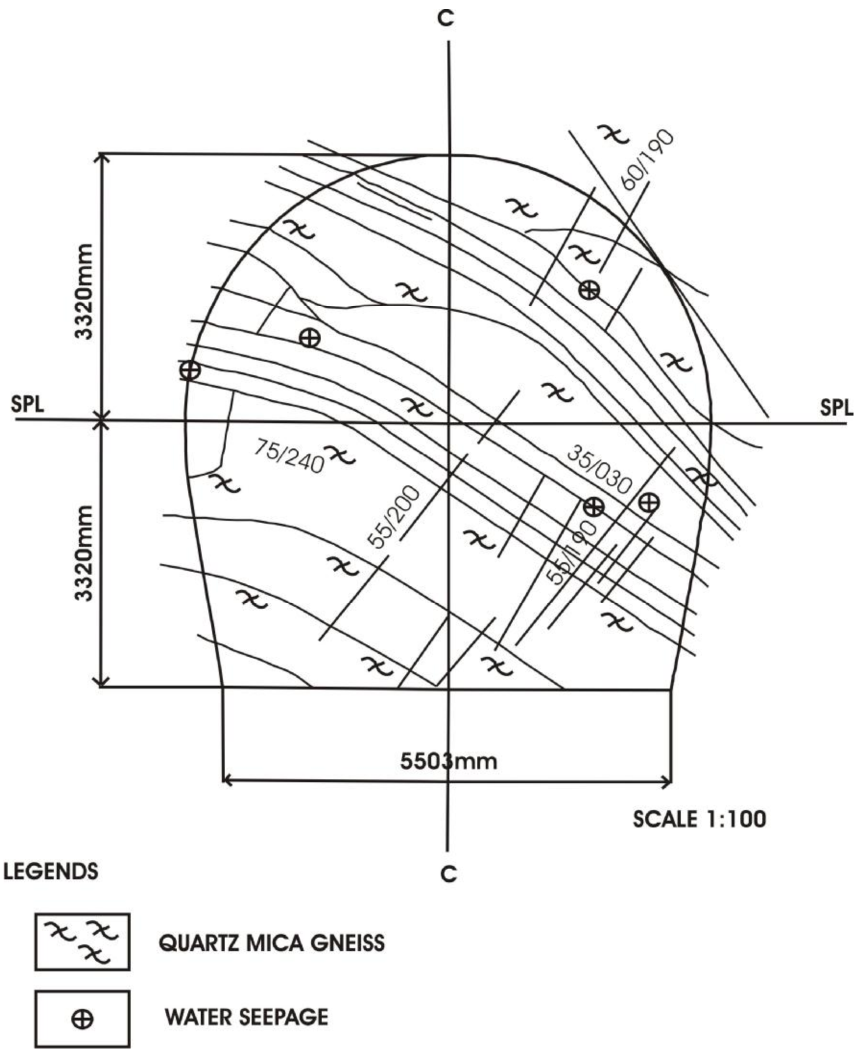


Fig. 1.2 Face log of HRT at Tapovan Vishnuugad project

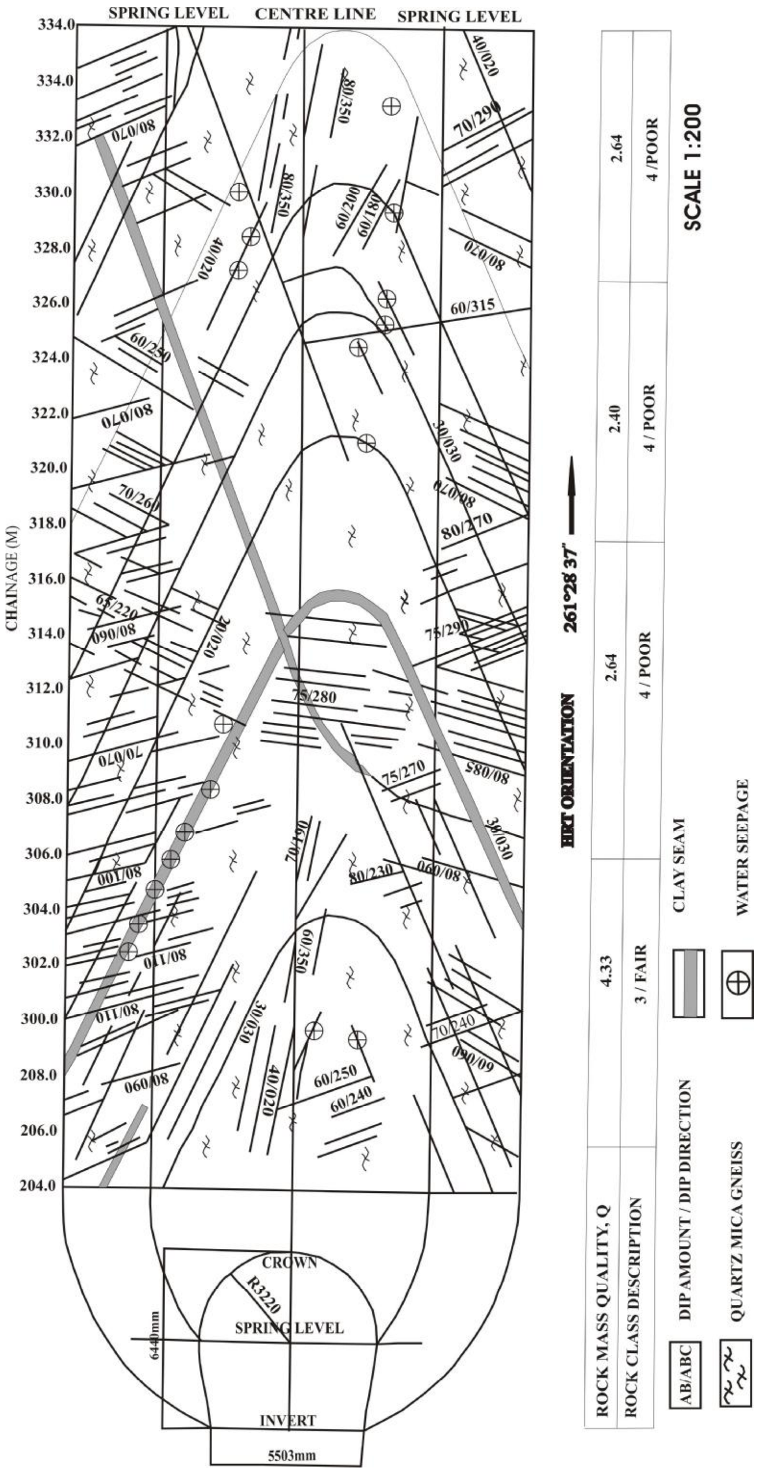


Fig. 1.3 3D geological log of head race tunnel at Tapovan Vishnugad project

2. ENGINEERING GEOPHYSICAL INVESTIGATIONS

Geophysical investigations are essential to unravel subsurface geological conditions at the project sites. With state-of-the-art facilities in surface and borehole geophysics, the Institute has the capability to carry out mapping of the subsurface features using refraction, reflection, sounding, profiling, imaging and cross-hole tomography methods using seismic, electrical and GPR survey techniques. The Institute has a high resolution and deeper penetrating GPR, which can map subsurface details from 5 m to 70 m in ideal conditions, signal enhancement digital seismographs and multi-channel resistivity meter to carry out engineering geophysical investigations including cross-hole tomography for various civil, mining and infrastructure projects during pre-construction, construction and post-construction or trouble-shooting stages. During 2008-09, this department completed four sponsored research projects and another one is in progress.

2.1 Mapping of subsurface strata conditions at Upper and Lower Demwe HEP, Arunachal Pradesh, Project No. EG0705, Completed

(P. C. Jha, V. R. Balasubramaniam, N. Sandeep and Y.V. Sivaram)

In order to utilise the hydro power potential of the Lohit River Basin in east Arunachal Pradesh, two hydroelectric projects, the Upper Demwe (1800 MW) and the Lower Demwe (1200 MW) are proposed to be taken-up by Energy Infratech Private Limited (EIPL). As part of DPR studies, EIPL requested NIRM for seismic refraction survey for estimating the thickness of the overburden and the depth to bedrock along important surface and subsurface structures. Accordingly seismic refraction survey was carried out for a length of 1265 m at the proposed Upper Demwe site and 1685 m at the proposed Lower Demwe site during April-May 2008. The objectives of the survey were to map:

- the subsurface geological conditions up to 40/ 80m
- the geological characterisation of overburden and bed rock
- the bedrock profile
- any other anomalous geological feature

Geologically, rocks at Upper Demwe project site comprise the para-metamorphic complex represented by mica-hornblende gneiss, biotite schist, amphibolites, and schistose quartzite. The litho unit in the left bank was hard, compact and massive rocks with fewer fractures and shears whereas the right bank rocks were highly fractured and sheared. A major fault zone was suspected to cross the river downstream of the dam axis with an upstream continuity, which might affect the powerhouse and the TRT on the right bank. The Lower Demwe site is located about 22 km downstream of the tiding suture zone and is marked by moderate hill slopes and wider benches. The right bank slope is covered by rock debris of para-metamorphic origin and a few weathered exposures of hornblende gneiss, micaceous quartzite, garnetiferrous schist and crystalline rocks. The overburden thickness is about 70 m on the lower benches closer to the river.

It was inferred from the geophysical survey that the overburden thickness along the dam axis at the Upper Demwe HEP site varied between 15-45 m. Along the right bank road in the TRT area overburden thickness is exceptionally high (above 70 m). A suspected fault zone dipping upstream was mapped crossing the river about 500 m downstream of the dam axis. The representative seismic section (Fig. 2.1) shows the displacement in hard rock level of the order of 15 m.

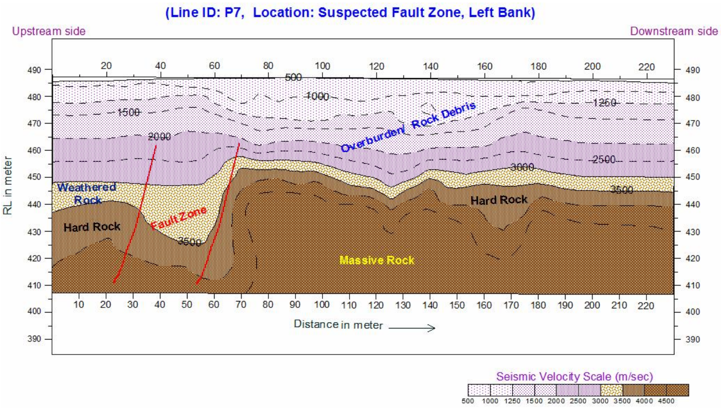


Fig. 2.1 Seismic section on left bank showing a suspected fault

In order to confirm the disposition of this fault plane, few more lines need to be surveyed. At present, confirmatory drilling is in progress at site to determine the extent of this fault.

The inferred thickness of overburden along the dam axis at the Lower Demwe HEP varies from 20-40 m whereas it is about 40-60 m in the powerhouse site. Two paleochannels, one along the dam axis and one downstream of the dam axis, were mapped at the Lower Demwe site. One such paleochannel mapped in the downstream of the dam axis is shown in Fig. 2.2.

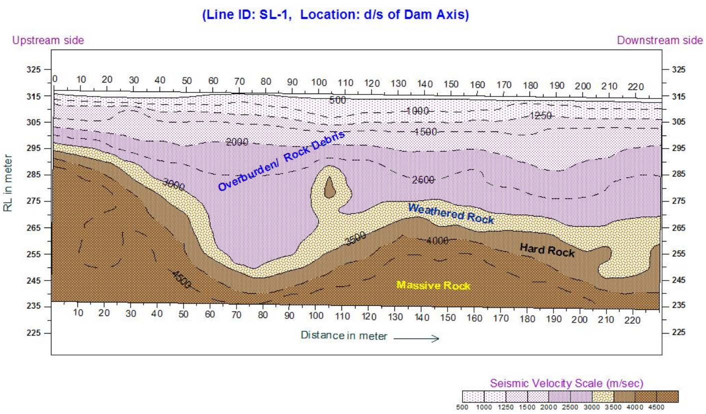


Fig. 2.2 Seismic section showing the presence of a likely paleo-channel on the dam axis at Lower Demwe site

It was recommended that further detailed geophysical studies should be carried out at the Upper Demwe project site to study the suspected fault zone and also for mapping the bedrock profile underlying the massive overburden. Detailed investigations were also suggested for the mapping a suspected fault zone and paleochannel in the powerhouse area and the dam axis of the Lower Demwe project site.

2.2 Seismic refraction survey for Sleemanabad Carrier Canal Project near Katni in Madhya Pradesh, Project No. EG0801, Completed

(P. C. Jha, V. R. Balasubramaniam, N. Sandeep and Y. V. Sivaram)

In order to augment the irrigation facility in the state of Madhya Pradesh using the Narmada water, a 25 km long carrier canal is proposed in the Narmada Basin area, south of Katni town near Sleemanabad. This canal originates from right bank of the river basin and is called Sleemanabad Right Bank Carrier Canal. Out of the 25 km of the proposed canal stretch, first 12 km stretch (104-116 km) will be a tunnel, which is proposed to be driven by Tunnel Boring Machine (TBM). In order to provide input for design of TBM, seismic velocity grading of the rock types in the tunnelling medium is required. Accordingly, the seismic refraction survey was taken up on request from M/s Patel-SEW Joint Venture for detailed subsurface mapping in terms of seismic velocity up to a depth of 40 m, for deciphering the overburden thickness and its nature, rock types in terms of seismic velocity, and the presence of anomalous geological features, if any.

Geologically, the area forms part of the Vindhyan Basin and the rock types are predominantly marble and fractured sandstone with quartzitic veins. Drilling data indicated the presence of claystone and patches of weathered sandstone as part of the overburden.

Seismic sections indicate that almost 35% of the tunnel alignment is passing through hard rock, 50% through weathered rock and the remaining 15% through overburden material. On correlation with the borehole data provided by the client, the seismic sections were found to be in unison. Fig. 2.3 shows a typical seismic section along the proposed tunnel alignment between 106.40-106.650 km.

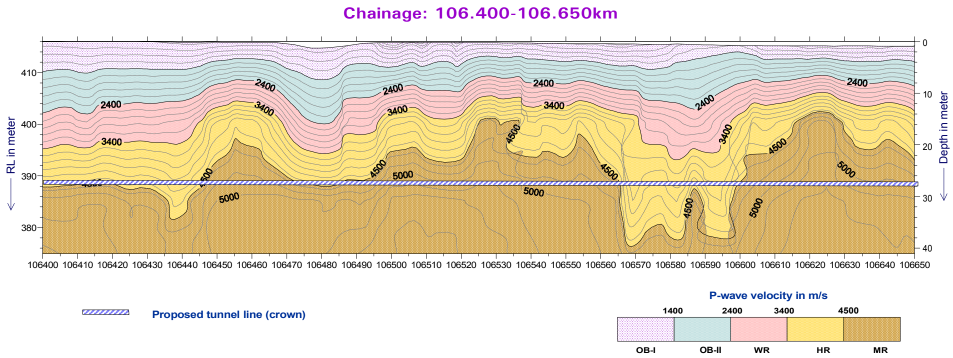


Fig. 2.3 Typical seismic section showing the tunnelling medium around the proposed excavation

Apart from classifying the subsurface strata in terms of overburden, weathered, jointed and hard rock categories, seismic velocity contours at 200 m/s velocity intervals were drawn to facilitate the explicit design of TBM.

2.3 Subsurface investigations using GPR and electrical resistivity imaging for assessing the stability of the Haldia-Barauni oil pipeline of IOCL in the Raniganj area, Project No. EG0802, Completed
(P. C. Jha, V. R. Balasubramaniam, N. Sandeep and Y.V. Sivaram)

The occurrence of fire in one of the coal pits close to the HMRB oil pipeline prompted the IOCL management to study its impact on the pipeline stability as a precautionary measure. Though the fire was quickly put out by the authorities, subsequent analysis of the thermal imagery map of the area as obtained from NRSA showed the pipeline in a high thermal zone which was posing a direct threat to the stability of the pipeline running just 1.5m deep and 20-50m distant from the fire zone.

Therefore, the IOCL requested NIRM to visit the site to assess the requirement of the possible geophysical studies to find out the presence of cavity pocket or likely zone of subsidence or any other threatening features close to the oil pipeline that might impact its stability. Following the site visit and considering the objectives of the problem, NIRM proposed twin methods for survey, i.e., a reconnaissance survey using resistivity imaging and a high resolution mapping of the suspected area using Ground Penetrating Radar (GPR) on either side of the oil pipeline within the vulnerable stretch of 3km length in the active fire zone. The survey work was planned with the following objectives:

- Reconnaissance survey by electrical resistivity method to delineate the likely stretches that might have void or weak zones
- Mapping the extent of void by GPR scanning.
- Suggest suitable remedial measures and
- Identify likely locations required, if any, for periodic monitoring of the subsurface conditions by cross-hole GPR tomography.

Accordingly, GPR profiling and resistivity imaging were carried out on either side of the pipeline at a distance of 5 m from central alignment between 245.500-248.500 km. The survey results indicate the presence of at least two shallow cavity pockets (within a depth of 3 m), which might be extending below the pipeline. Water table at many places in the area was found very shallow (less than 5 m deep). Hence spread of mine pit fire might not have incinerated up to the pipeline as no traces of firey zones were found in any portion of the surveyed sections. A typical electrical resistivity image showing a low resistive patch and the conjugate GPR section showing the extent of cavity pocket is shown in Fig.2.4.

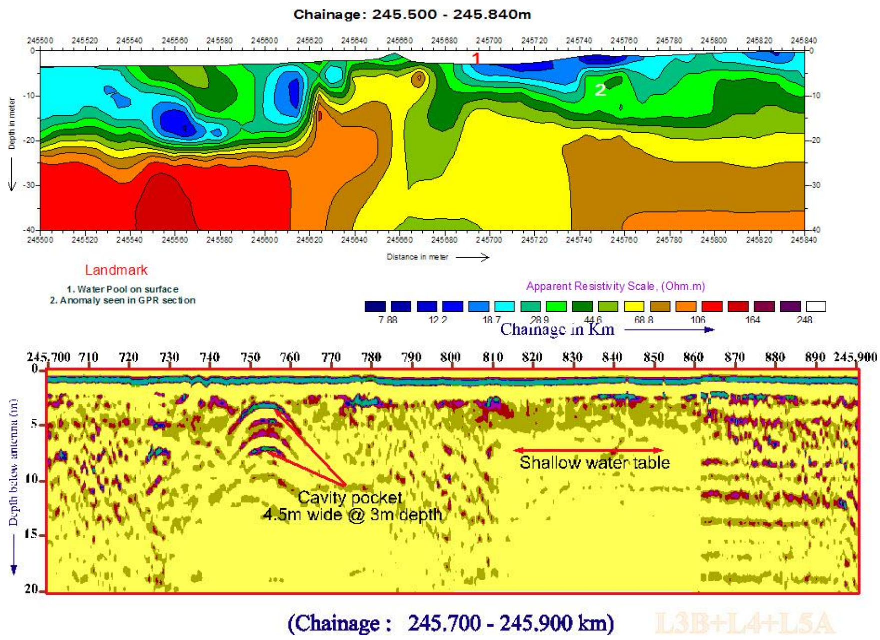


Fig. 2.4 Typical electrical and GPR section showing presence of cavity pocket at shallow depth

After detailed data processing and a comprehensive analysis following conclusions were drawn and recommendations were made:

a) Though there were shallow cavity pockets at two locations, the extent of cavity was not enough to threaten the stability of the pipeline. Therefore, it was suggested that pipeline operation could go on as usual.

b) Two cavity pockets mapped within 5m depth at 245.75 km and 247.91 m locations might be threatening in future if situation deteriorates further. Even cracks were appearing on the surface (Fig. 2.5) at the first location but the cavity at second spot was still in the hibernation as no visual signature could be seen on the surface.

Fig. 2.5 Surface crack seen above cavity pocket

Since the extent of these cavities along the survey line was only 4-5 m in width, it was suggested that these should be packed immediately to ward off any future threat to stability of the pipeline.

c) In order to formulate a comprehensive plan of evaluating the safety of the pipeline along the entire 42 km stretch passing through the Raniganj coalfields, it was recommended that further studies be commissioned for finding out the potential hazardous stretches. Similar survey should be carried out in those stretches on either side of the pipeline.

d) Since the deterioration in subsurface conditions is a dynamic phenomenon, it was recommended that survey in identified stretches should be carried out at periodic intervals (at least one in a year). It was also suggested that temperature probes should be installed 40-50 m away from the pipeline at vulnerable locations in the sensitive stretches to get an advanced warning on the approaching coal fire.

2.4 GPR survey for tracing archaeological remains along the subsurface section of the Bangalore Metro-Rail Alignment, Project No. EG0803, Completed
(P. C. Jha, V. R. Balasubramaniam, N. Sandeep and Y.V. Sivaram)

A portion of the Phase-I of the Bangalore Metro Rail alignment is planned underground in the busy K R market area of Bangalore city. This subsurface stretch, measuring 1500m, is passing below the Vani Vilas hospital and has two historical monuments Tippu's Fort and Tippu's Palace on either sides at the beginning and end. It was suspected by the ASI that these two monuments are interconnected by a tunnel and this stretch of Bangalore metro rail alignment is cutting across the heritage tunnel. Further presence of some artefacts was suspected in this portion. In order to confirm the presence of this inter-connecting heritage tunnel and hidden artefacts within the proposed excavation regime (planned at a depth of 10-15m) of the metro rail alignment, it was suggested by the ASI to conduct subsurface scanning along the alignment using GPR. Therefore, BMRCL requested NIRM for GPR survey along the proposed stretch. The scope of the work was to investigate 20 m wide area up to a depth of 20 m. The objectives of GPR survey was to:

1. Scan the section of alignment between 8900-9600 m up to a depth of 20 m.
2. Detect and identify buried structures, if any.
3. Look out for any underground interconnecting tunnel or path-way between the Tippu's palace and the fort cutting across the proposed metro alignment.

Hence, it was planned to carry out survey along two lines 10m apart on either side of the central alignment axis. Considering the objectives, it was decided to carry out high resolution GPR survey to detect any anomalous target of the size of ±1.5 m within a depth of 20 m.

Most of the stretch along the survey area has the hospital building on surface and the only available locations for survey were grass lawns or interconnecting roads between different hospital blocks. Towards the end, the alignment was running along the footpath of KR Road and then crossing the road obliquely. Hence, GPR survey was carried out in five segments along the available stretches in the grass lawn or interconnecting roads.

Data analysis and interpretations did not show indications of any buried subsurface feature along the surveyed alignment. Going by the trend of reflections (Fig. 2.6) from the subsurface along the profiled segments, presence of any objects or sites of archaeological importance was ruled out in the scanned stretches within the depth extent of survey.

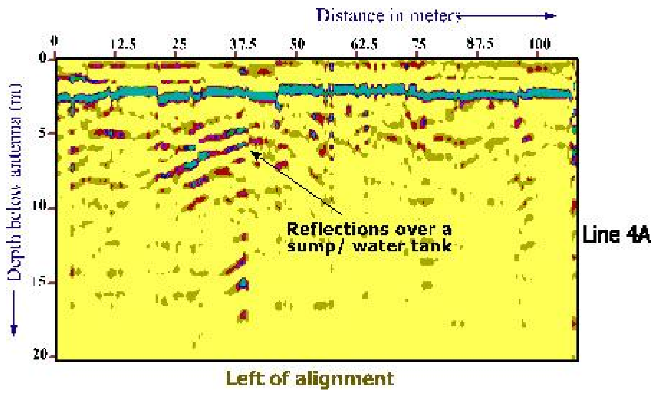


Fig. 2.6 Typical GPR section along one segment

2.5 Resistivity Imaging at the Strategic Petroleum Reserve site of Padur near Mangalore, Karnataka, Project No. EG0804, On-going

(P. C. Jha, V. R. Balasubramaniam, N. Sandeep and Y.V. Sivaram)

The Indian Strategic Petroleum Reserve Limited has identified many locations for crude oil and gas storage in the underground caverns in the vicinity of major ports. One such location is in the Padur village close to Udupi near Mangalore. RITES, Gurgaon is carrying out geotechnical investigations at this site. As part of their investigations, it was required to carry out resistivity imaging to map the subsurface up to a maximum depth of 40 m along various lines. The scope of the investigation was to map:

1. the character of the hard rock within the depth of investigation
2. the prominent geological anomalies, present, if any, and
3. the presence of groundwater table

Geologically, the area has many exposures of hard gneissose granite rock. Faults and shear zones were expected in the sub-surface in the study area. Accordingly, resistivity imaging was carried out along seven lines measuring 1785 m in March 2009.

3. GEOTECHNICAL ENGINEERING INVESTIGATIONS

Geotechnical investigations are an essential and integral part of all civil and mining engineering projects. In-situ stress, rock mass deformability and shear parameters are required for analysis and design of underground excavations and dams. During 2008-09, the Geotechnical Engineering Department completed five sponsored projects for hydropower sector and one in-house research project was in progress.

3.1 Determination of in-situ stress parameters by Hydrofracturing method at the proposed underground LPG cavern at Mangalore, Karnataka, Project No. GE0704

Completed

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

HPCL's Mangalore LPG Import facilities (MLIF), located on the West Coast of India at Mangalore, presently handles approximately 1.5 million metric tonnes of LPG per annum. The facility commissioned in 1996 comprises of LPG Jetty facility at New Mangalore Port Trust (NMPT), a 9 km long and 0.305 m diameter underground pipeline for receiving LPG Imports. With a view to leverage its existing facilities at MLIF and receive LPG in very large size gas carriers (VLGCs), HPCL proposes to set up an LPG underground storage in a mined rock cavern with a capacity of 120 000 m^3. The rock at and around Mangalore belongs to Peninsular Group and generally consists of migmatite rocks and pockets of Basal conglomerate. The exposed rock in the project area is hard and compact, coarse grained reddish brown laterite cover of about 60 m. The joints as revealed in the cores are both shallow and steeply dipping.

The design of the storage gallery is mainly decided by the following two parameters among other geotechnical parameters.

- The axis of the Cavern Main Gallery must be parallel to sub-parallel to the direction of maximum compression
- A high horizontal stress is having bearing on dimensions of the main galleries and design of the support

In order to determine the in-situ stress tensors around the cavern, in-situ stress measurements were carried out by hydrofrac method inside the borehole at four different depths between 131.47 m and 146.57 m. The results show that a medium K value in the order of 1.41 to 1.69 is normal at such condition (no topography effect) and depth. The orientation of maximum horizontal principal stress **(σ_H)** as revealed by hydrofrac stress measurement is N 140^o (Fig.3.1). The stress regime as evaluated by program Gensim is as follows:

Vertical stress (σ_V with a rock cover of 139m mid point between 131.47m and 146.57m and density of rock 2.70 gm/cc)	3.67 MPa
Maximum horizontal principal stress (σ_H)	6.22 ± 1.0003 MPa
Minimum horizontal principal stress (σ_h)	4.15 ± 0.6669 MPa
Orientation of the maximum horizontal principal stress (σ_H)	N 140^0
K(σ_H/σ_V)	1.69
K= (σ_H+σ_h)/2/σ_V	1.41

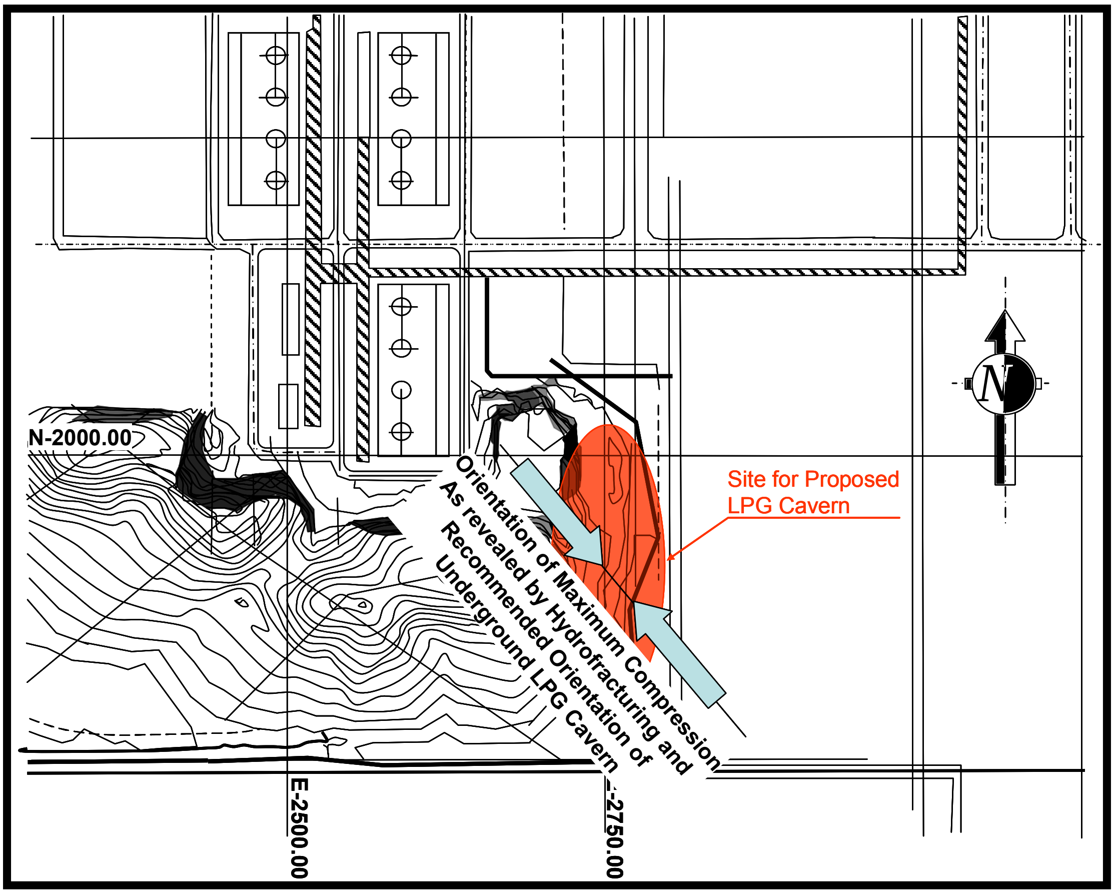


Fig. 3.1 Orientation of maximum horizontal principal stress at Mangalore LPG cavern

3.2 Determination of in-situ stress by hydrofracturing method and in-situ deformability parameters by Goodmanjack at the proposed underground powerhouse and transformer hall of Sawra Kuddu H.E. project, Himachal Pradesh (Project No. GE0702), Completed

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

The Sawra Kuddu Hydroelectric project on Pabbar river at Rohru Tehsil in District Shimla, Himachal Pradesh, envisages utilization of water through average gross head 213.50 m for generation of 110 MW of power in a underground powerhouse. The project envisages construction of a barrage of 15.50 m height with 11 gated spillways of 8 m each, 11.3 km long, 5 m dia, D-shaped HRT to surge shaft of 14 m dia and pressure shaft 312 m long trifurcating in 2 m dia each to feed three 36.67 MW turbines seated in underground powerhouse cavity, on the left bank of Pabbar river near Snail village.

The main rock types in the project area are bedded quartzites, gneissose quartzite, garnetiferous quartz mica schist, porphyro blastic augen gneisses with vein quartz and carbonaceous phyllites belonging to Jaunsar and Jutogh group of rocks. The rock around powerhouse and transformer cavern area (where the stress measurement and deformability measurements were carried out) comprises of porophyroblastic augen gneisses with vein quartz. These are coarse grained in texture and massive in nature and schistose foliations were also noticed, at places. The general trend of gneisses varies from N 30^0 E – S 30^0 W to N 70^0 E – S 70^0 W with 30^0 to 57^0 in NW direction. Local folding has been observed in the area.

The rock is hard, fresh and jointed in nature. The joints are tight but open at places. At some locations these are filled with gauzy material. In general the joints are rough, irregular, smooth and planar.

As the in-situ stress and deformability parameters are of utmost importance for fixing the orientation of the large caverns for maximum stability and for the design of support system, in-situ investigations were conducted for:

- Determination of in-situ stress tensors by Hydrofrac Method inside two NX size boreholes drilled at the proposed powerhouse and transformer caverns

- Determination of in-situ deformability parameters of rock mass by Goodman Jack Method inside two NX size boreholes drilled at the proposed powerhouse and transformer caverns

The following results were obtained from the investigations:

In-situ stress by Hydrofrac method

Power House

Vertical Stress (σ_v with a rock cover of 150 m) (Mid point between 81 m and 219 m and density of rock 2.70 gm/cc)	3.685MPa
Maximum Horizontal Principal Stress (σ_H)	8.855 +/-0.0332MPa
Minimum Horizontal Principal Stress (σ_h)	2.53 +/-0.0095MPa
0rientation of the maximum horizontal principal stress (σ_H)	N 140^o
K (σ_H/σ_v)	2.40
K = (σ_H +σ_h)/2 / σ_v	2.74

Transformer Cavern

Vertical Stress (σ_v with a rock cover of 122.25 m) (Mid point between 106.75m and 137.75m) and density of rock 2.70gm/cc)	3.234MPa
Maximum Horizontal Principal Stress (σ_H)	6.14 +/-0.3026MPa
Minimum Horizontal Principal Stress (σ_h)	3.07 +/-0.1513MPa
0rientation of the maximum horizontal principal stress (σ_H)	N 130^o
K (σ_H/σ_v)	1.89
K = (σ_H +σ_h)/2 / σ_v	1.42

In-situ deformability of rock mass by Goodman Jack Method

Power House			
Depths (m)	Modulus Values		Rock mass quality on the basis of E_d (Chappel 1994)
	E_d (GPa)	E_e (GPa)	
219	18.02	33.4	Good
175	11.96	21.24	Good
81	4.34	6.18	Fair

Transformer Hall			
Depths (m)	Modulus Values		Rock mass quality on the basis of E_d (Chappel 1994)
	Ed (GPa)	E_e (GPa)	
137.75	17.12	32.06	Good
130.75	15.78	24.02	Good
106.75	11.29	18.46	Good
95.75	6.74	9.95	Good
72.75	4.77	6.31	Fair

- A relatively higher K value in the range of 1.89 to 2.40 indicates some tectonic influence around the site in the absence of topography influence. The vertical stress is assumed to be due to overburden.
- The stress configuration $\boldsymbol{\sigma_H} > \boldsymbol{\sigma_v} > \boldsymbol{\sigma_h}$ corresponds to strike slip faulting
- The orientations of maximum horizontal principal stress inside two boreholes are within 10^o to each other. Thus maximum horizontal principal stress **(σ_H)** orientation can be taken as **N 130^o to N140^o** (Fig 3.2) with high confidence limit within the stress regime where powerhouse and transformer cavern are proposed.
- The average rock condition as revealed by deformability measurement can be characterized as 'GOOD' (5 MPa –25 MPa).

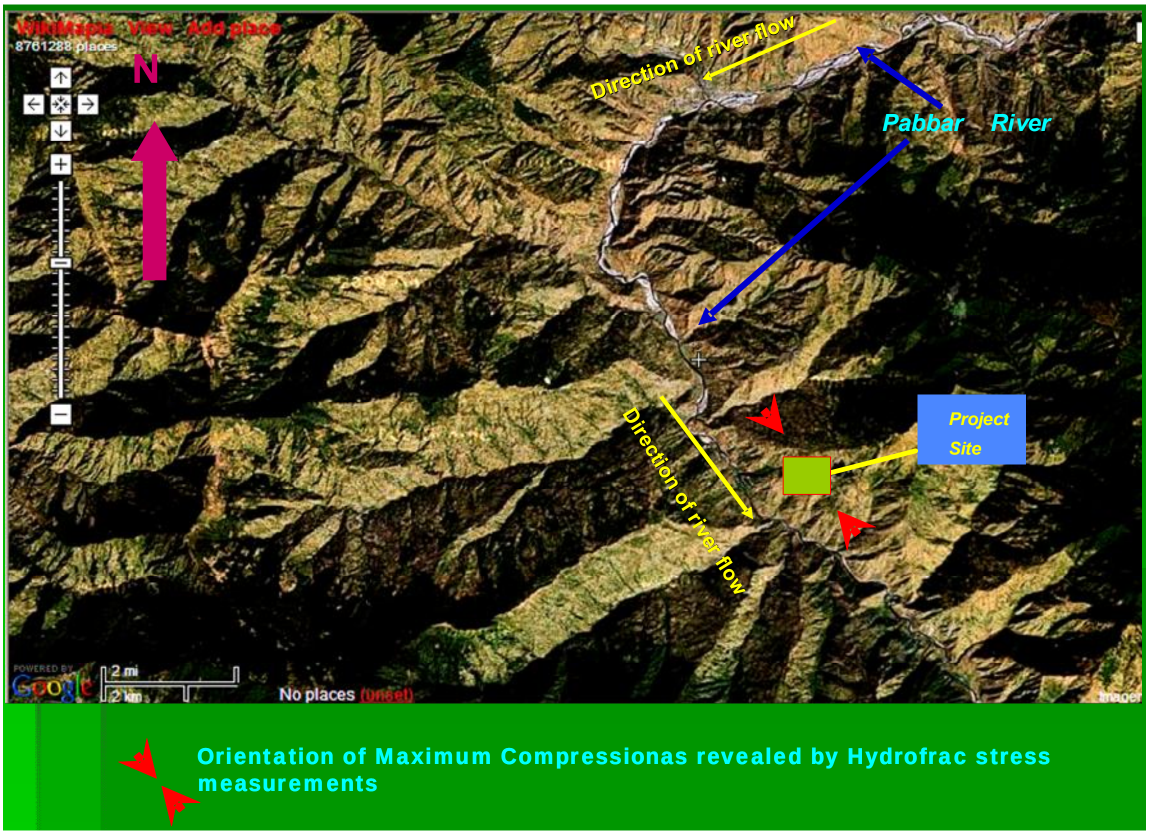


Fig 3.2 Location of Sawra-Kuddu H.E. Project site and orientation of maximum compression as revealed by Hydrofracturing

3.3 Determination of in-situ deformability parameters of rockmass and shear zone exposed at different locations of Surge chamber site at Subansiri lower H.E. project, Arunachal Pradesh, (Project No. GE-0803), Completed

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

Subansiri Lower Hydroelectric Project of NHPC (National Hydro Power Corporation Ltd.) is located on river Subansiri at Kolaptukar/Gerukamukh, Dhemaji District of Assam. The project envisages construction of a 210 m high concrete gravity dam, eight 9.5 m dia and 630 m to 1145m (7150 m) horse shoe shaped head race tunnel, 26m x 21m x 62 m size of eight surge shafts, 192 m to 215 m long eight pressure shafts with a surface power house for generating 8 x 250 Mw (2000 MW) of hydro power.

The Siwaliks sequence near the river Subansiri is complicated by a series of thrusts. The lowermost sequence exposed in the southern foothills is comprised of pebbly sandstones and bands of conglomerates that may be up to 10 m thick. Towards north, the sequence is overlain by sandstone intercalated with bluish clay. The present investigation is restricted in the medium grained sandstone and shear zone with gouges.

For the design of surge chamber, in-situ deformability characteristic of foundation rock mass is required which is critical in the stability and support design of underground structures. The deformability parameters were determined by Plate loading method.

Determination of in-situ deformability parameters near the proposed surge chamber area by plate loading method in sandstone and shear zone (Figs. 3.3 and 3.4)

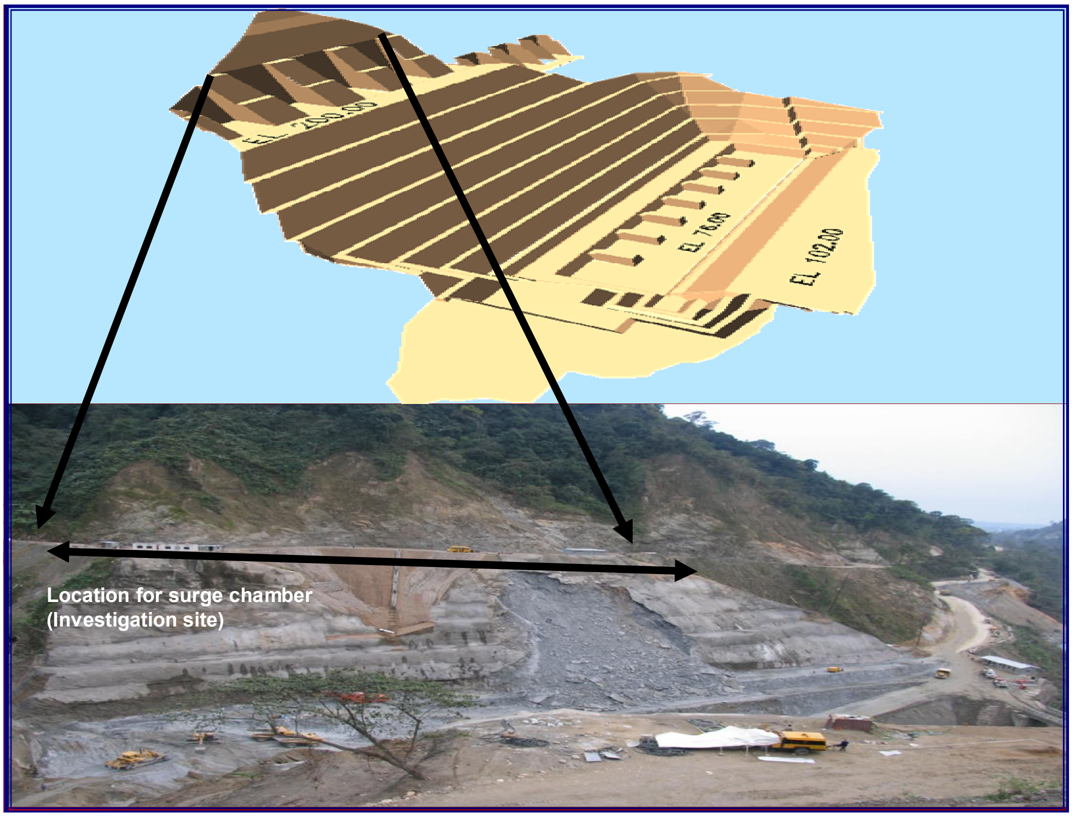


Fig. 3.3 Location Subansiri Lower Hydroelectric Project site

Fig. 3.4 Plateload experimental set-up at Subansiri Lower H.E. Project site

The results show that the average modulus values in sandstone at the surge chamber site ranges from 1.10 GPa to 3.33 GPa (poor category of rock) and in the shear zone it varies between 0.14 to 0.16 GPa (very poor category of rock).

3.4 Determination of in-situ stress by hydrofracturing method and in-situ deformability parameters by Goodmanjack method at the proposed desilting chamber of Vishnugad-Pipalkoti H.E. project, Uttarakhand, (Project No. GE0801 & GE0802), On-going
(S. Sengupta, D. S. Subrahmanyam, D. Joseph and R. K. Sinha)

Vishnugad Pipalkoti Hydroelectric Project of THDC (Tehri Hydro Development Corporation Ltd.) envisages construction of a concrete gravity dam of 65 m height across Alaknanda river, four desilting chambers and an underground powerhouse to generate 444 MW (4x111 MW) of power.

The project area comprises rocks belonging to Garhwal Group and Central Himalayan Crystalline. The MCT (Main Central Thrust) which is present at Helang, has brought the Central Crystallines over the Garhwal Group and is not very well marked as in many other areas of the Himalaya. The rocks occurring at the desilting chamber site are quartzites with biotite schist interbedded and interbanded grey slates and dolomites/limestone.

The design of the desilting gallery is mainly dictated by the orientation of maximum horizontal principal stress for orienting the long axis parallel to it for maximum stability. The complete principal stress tensor was determined by hydrofrac method.

The investigations were carried out to determine in-situ stress parameters inside two boreholes drilled at the proposed desilting chamber area to determine the stress tensor around the desilting chamber. The stress regime as evaluated by program Gensim is as follows:

Up Stream

Vertical Stress (σ_v with a rock cover of 275 m & density of rock 2.70 gm/cc)	7.28 MPa
Maximum Horizontal Principal Stress (σ_H)	11.25 +/-0.4815MPa
Minimum Horizontal Principal Stress (σ_h)	4.50 +/-0.1926MPa
Orientation of the maximum horizontal principal stress (σ_H)	N 20^o E
K (σ_H/σ_v)	1.55

Down Stream

Vertical Stress σ_v with a rock cover of 305 m and density of rock 2.70gm/cc)	8.07 MPa
Maximum Horizontal Principal Stress (σ_H)	12.975 +/-0.1665MPa
Minimum Horizontal Principal Stress (σ_h)	5.19 +/-0.0666MPa
0rientation of the maximum horizontal principal stress (σ_H)	N 30^o E
K (σ_H/σ_v)	1.61

- A medium to slightly high K value in the range of 1.55 to 1.61 indicates slight tectonic influence at the measurement site.

- The orientation of maximum horizontal principal stress (σ_H) as revealed by hydrofrac test ranges between N 20° to N 30°

Based on the investigations it was suggested that the long axis of the sedimentation chambers be oriented along N 20° to N 30° for maximum stability (Fig 3.5)

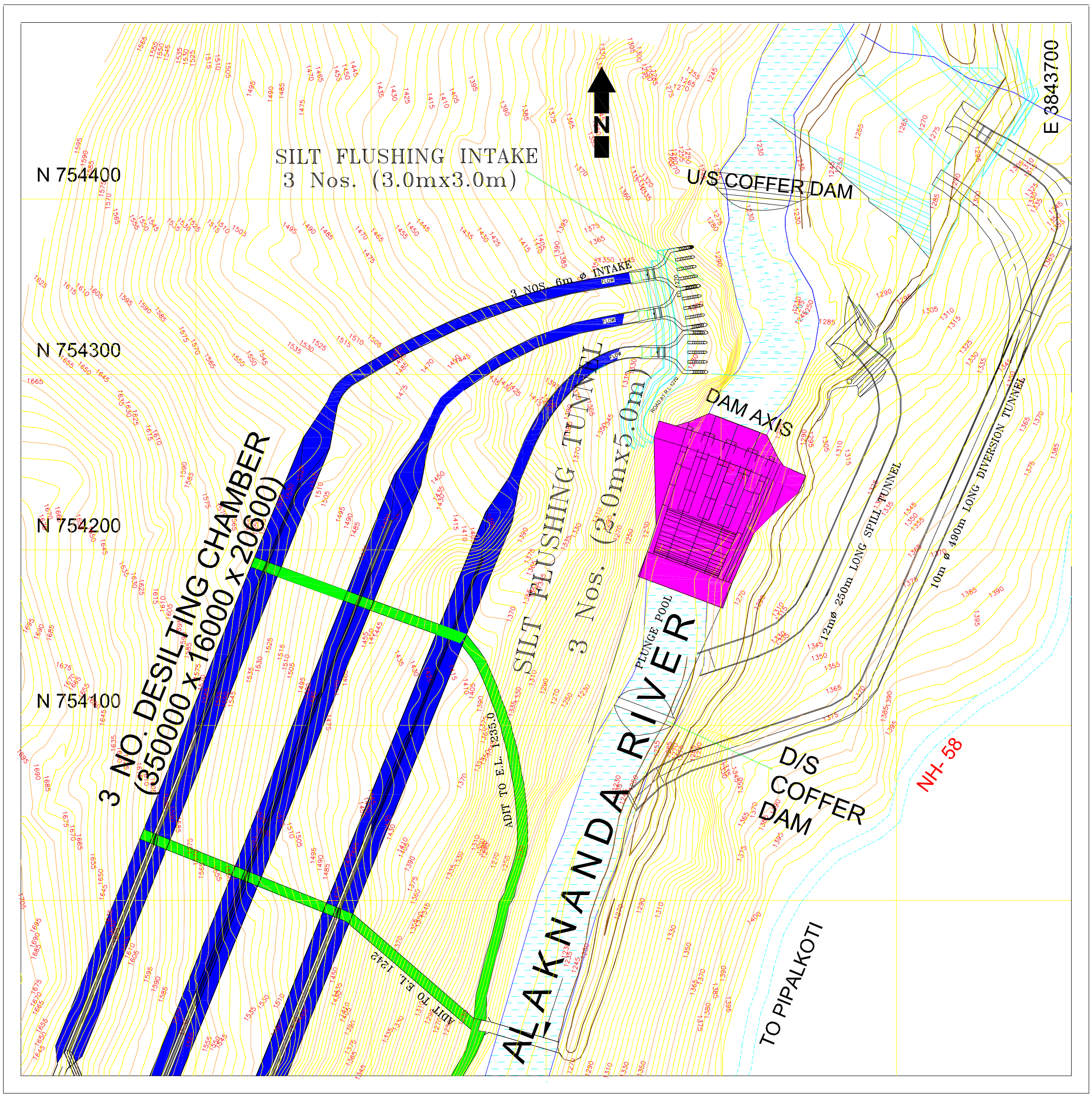


Fig. 3.5 Location of Vishnugad - Pipalkoti H.E. Project site and orientation of maximum compression as revealed by Hydrofracturing

3.5 Determination of in-situ stress by hydrofracturing method and in-situ deformability parameters by Goodmanjack method at the proposed powerhouse chamber of Mangdechhu H.E. project, Bhutan, (Project No. GE0707), On-going
(S. Sengupta, D. S. Subrahmanyam, D. Joseph and R. K. Sinha)

Mangdechhu Hydroelectric Project (4×180 MW) of NHPC (National Hydro Power Corporation Ltd.) is located on river Mangdechhu in Trongsa District of Central Bhutan. This project envisages construction of a 57m high concrete gravity dam, a 13.5 km long head race tunnel, a 12m dia, 150m deep surge shaft, two no 3.5m diameter, 1832m long pressure shafts and an underground power house near Khama village. The tail water shall be discharged back to river Mangdechhu through a 1.5-km long tailrace tunnel & channel system (Fig 3.6).

The project area lies in the Higher Himalayas and consists of rocks belonging to Thimphu gneissic complex and meta-sediments of Chukha formation. The exploratory drift to powerhouse has revealed the presence of quarzites with mica schist bands and occasional pegmatite and mafic intrusions.

For the optimum design of the powerhouse, in-situ stress and deformability parameters are required. The scope of investigations was: 1) determination of in-situ stress parameters inside two boreholes at the proposed powerhouse area to determine the complete principal stress tensor, and 2) determination of in-situ deformability parameters by Goodman jack method inside two boreholes at the proposed powerhouse area. The results of the investigations are given below.

In-situ stress by Hydrofrac method

Power House

Principal stresses	
Vertical Stress (σ_v) in MPa (Calculated with an overburden of 180 m and density of rock = 2.7 gm/cc	4.76 MPa
Maximum Horizontal Principal Stress (σ_H) in MPa	8.38 ± 0.6496 MPa
Minimum Horizontal Principal Stress (σ_h) in MPa	5.59 ± 0.4331 MPa
Maximum Horizontal Principal Stress direction	N 70^0
$K = (\sigma_H + \sigma_h)/2 / \sigma_v$	1.47
$K = (\sigma_H)/ \sigma_v$	1.76

In-situ deformability of rock mass by Goodman Jack Method

Site	E_d (GPa)	E_e (GPa)	E_e/E_d
Vertical Borehole	11.65 – 20.90	36.42- 47.45	2.03- 4.07
Inclined Borehole	13.27 – 16.95	36.29- 48.59	2.54- 3.26

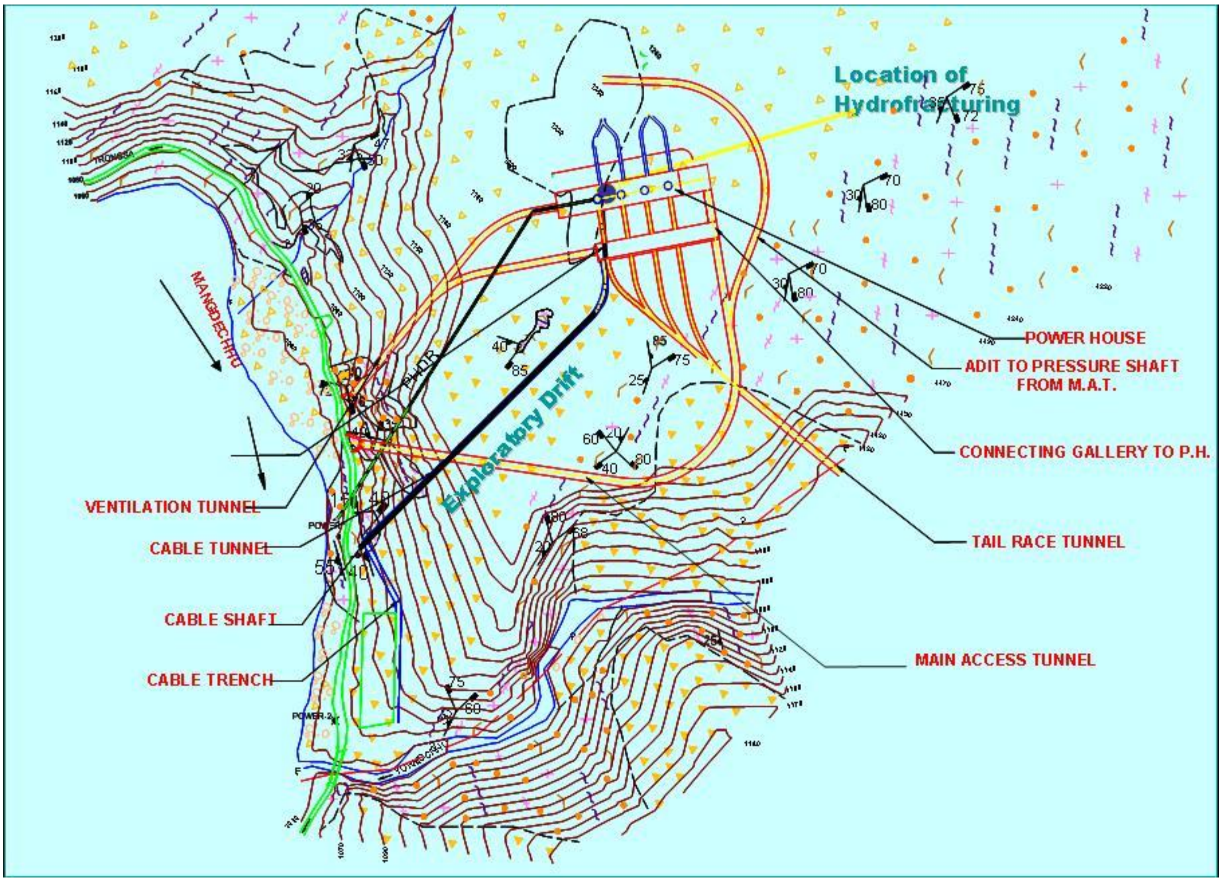


Fig. 3.6 Location of Mangdechhu Hydroelectric Project site

The stress measurement reveals a high K value in the order of 1.76 with a rock cover of 180m, which may indicate a tectonic influence at the measurement site. The vertical stress is assumed to be overburden. The orientation of maximum horizontal principal stress (σ_H) as revealed by hydrofrac test is N 70^o. Hence, the powerhouse must be oriented along N 70^o for maximum stability. The average rock condition can be characterized as GOOD (5 – 25 GPa) on the basis of deformability parameters revealed by Goodman jack test.

3.6 Influence of stress ratio of two principal horizontal stresses on the preferred direction of hydrofrac under poly-axial stress condition for different anisotropic rocks. (In- house Project No. IN0801), On-going

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

The basic assumption in the classical application of hydraulic fracturing is that, when a vertical thick walled cylinder (corresponds to vertical hole drilled parallel to vertical stress σ_V) is externally loaded by tectonic stresses (two principal horizontal stresses σ_H and σ_h) and internally pressurized by fluid pressure, a hydrofracture will be created when resultant tangential stress developed by fluid pressure overcomes the tensile strength of the wall rock which is least along the direction of principal maximum horizontal stress. This principle holds well when rock is homogeneous without much anisotropisms. But in anisotropic rock the orientation of the hydrofracture will be governed by both anisotropic character of the rock and the stress condition. The main objectives of the project are as follows.

- To investigate the limitations and conditions applicable for the implementation of classical hydraulic fracturing theory in anisotropic rocks
- To determine the horizontal stress ratio at what direction of hydraulic fracture is stress controlled rather than controlled by anisotropisms of the rocks
- To understand the behaviour of the trace of the fracture plane at the borehole wall and beyond the influence zone of the borehole.

Generally the following types of anisotropisms are observed in the rocks.

- Foliations in the case of rocks like phyllite, schist and gneiss
- Bedding planes in case of rocks of sedimentary origin
- Presence of micro cracks/cementing materials and other weaker bonding materials

As it is quiet possible that the tensile strength along these anisotropisms will be less than along the principal maximum horizontal stress, the orientation of the hydrofrac may be controlled by one of the above-mentioned anisotropisms. But as the ratio between two horizontal stresses increases with corresponding increase in principal maximum horizontal stress (σ_H), the orientation of hydrofrac may get controlled by stress rather than anisotropisms, and thus validate the classical hydrofrac theory.

4. ROCK FRACTURE MECHANICS AND MATERIALS TESTING

This laboratory is equipped with state-of-the-art facilities to carry out basic research on rock fracture mechanics and to determine properties of intact and jointed rocks. It also has facilities to determine properties of dimensional stones as per ASTM and European standards. It is engaged in studying thermo-mechanical behaviour of rocks, application of acoustic emission and ultrasonic imaging techniques. The material testing laboratory is carrying out testing of wire rope samples and non-destructive testing of mining machinery parts as per the requirement of mines safety. During 2008-09, the Rock Fracture Mechanics Department completed three projects.

4.1 Laboratory rock mechanics investigations- LPG underground storage cavern, Mangalore, Karnataka, Project No. RF0801, Completed

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

RITES, New Delhi is undertaking geotechnical investigations for LPG underground storage cavern at Mangalore for HPCL. Properties of intact rock and rock joints are required for design and modeling of the underground storage cavern. Rock core samples from three vertical and two inclined bore holes were investigated for various properties. The rock properties for bore holes are presented in Table 4.1.

Table 4.1 Physico-mechanical properties of rock samples for different boreholes

Bore hole	Density, kg/m^3	Porosity, %	P-wave velocity, km/sec	Uniaxial compressive strength, MPa	Young's modulus, GPa	Poisson's ratio	Tensile strength, MPa
VBH-1	2643-2837	0.12-0.33	5.54-5.77	78-178	62-82	0.13-0.24	10.90-15.94
VBH-2	2725-3120	0.54-2.00	5.63-6.10	41-98	67-90	(-) 0.04-0.22	7.43
VBH-3	2632-2723	0.15-0.23	5.89-6.05	14-119	44-81	0.07-0.19	10.16-13.44
IBH-1	2656-2675	0.03-0.21	5.72-6.94	89-255	79-123	0.14-0.25	11.23-22.48
IBH-2	2664-2675	3.50-3.63	4.31-5.36	30-50	16-24	(-) 0.04-0.03	-

Compared to the properties of samples of other bore holes, the samples of borehole IBH2 have higher porosity and lower values of other properties. During uniaxial compression test, negative Poisson's ratio was observed for the samples of bore holes VBH-2 and IBH-2. During triaxial compression test, deformations were measured using strain gauges. It was observed that Young's modulus varied from 54 to 110 MPa and Poisson's ratio from 0.25 to 0.40. The cohesion of biotite granitic gneiss varies from 33 to 56 MPa, the difference is attributed to the presence of banding oriented at an angle to core axis in one of the samples. Under uniaxial compression, most of the samples showed axial splitting i.e. tensile failure while a few of them failed along a combination of tensile and shear failure planes or on a complete shear plane. All the samples under triaxial compression failed along the shear plane. Normal stiffness of the joint increases after the first loading cycle; for four cycles it varied from 86 to 498 MPa/mm. Peak shear strength and residual shear strength increases with the increase of normal stress. For typical normal stress of 0.66, 1.21, 2.24 and 3.26, shear stiffness varies from 0.54, 0.65, 0.62 and 0.53. Shear stiffness initially increases with the increase of normal stress and decreases afterwards, possibly due to shearing of the asperities.

Poisson's ratio is the ratio of lateral strain to axial strain. When a rock material is compressed, it contracts in the axial direction and expands in the lateral direction. Similarly, a metal under tensile load elongates in the axial direction and contracts in the lateral direction. By convention the Poisson's ratio is treated as positive and varies from 0 to 0.5 in almost all the materials. However, some materials contract in the transverse direction under uniaxial compression or expand laterally when stretched. These materials are said to have negative Poisson's ratios. They are usually called as auxetic materials, e.g. polymer foams. In the laboratory a few rock types showed negative Poisson's ratio similar to synthetic materials for a small stress range under uniaxial compression testing (Fig. 4.1).

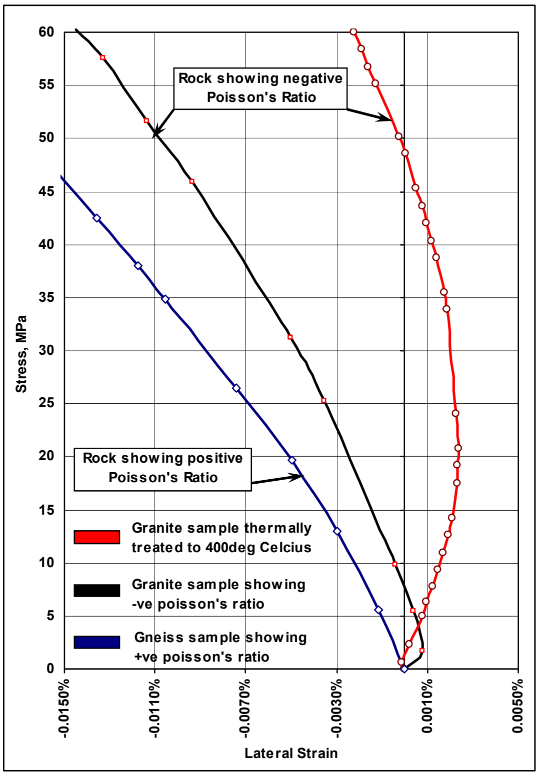


Fig. 4.1 Lateral strain versus stress showing negative Poisson's ratio

4.2 Laboratory rock mechanics investigations for crude oil underground storage cavern, Mangalore, Karnataka, Project No. RF08 02, Completed

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

RITES, New Delhi is carrying out geotechnical investigation for crude oil underground storage cavern at Paddur near Mangalore for ISPRL (Indian Strategic Petroleum Reservoirs Limited). Rock properties are required for the design and modeling of the underground storage cavern. Rock samples have been identified as into gneissic biotite granite, felsic granite and granite. The intact rock properties were determined for the drill cores obtained from four bore holes and the overall range in properties is presented in Table 4.2.

Table 4.2 Physico-mechanical properties of rock samples for different boreholes

Bore hole	Density, kg/m^3	Porosity, %	P-wave velocity, m/sec.	Uniaxial compressive strength, MPa	Young's modulus, GPa	Poisson's ratio	Tensile strength, MPa
CH-7	2628-3006	0.03-0.81	4976-6608	21-132	54-112	0.12-0.22	5-32
CH-8	2636-2693	0.21-0.30	4402-5528	174-224	60-75	0.22-0.25	10-14
CH-9	2638-3068	0.24-0.61	4854-6541	150-212	57-74	0.20-0.25	9-16
CH-10	2676-2877	0.48-2.82	4769-5064	33-172	22-74	0.05-0.47	6-15

Significant variation in the compressive strength, Young's modulus, Poisson's ratio and tensile strength was observed for the samples of bore hole CH-7 and CH-10. The cohesion for felsic granite varied from 29 to 35 MPa, whereas it varied from 23 to 29 MPa for gneissic biotite granite. Friction angle varied from 53 to 56^O for felsic granite and 34 to 40^O for gneissic biotite granite. During uniaxial compression test, most of the samples of bore holes CH-7 & 8 failed under shear due to the presence of fracture and tight joints. However, tensile/conical failures were observed in few of the samples. Most of the samples of borehole CH9 & CH10 showed axial splitting and a few of the samples showed a combination of tensile and shear failure. During triaxial testing, all the samples showed shear failure plane and a few of them showed multiple shear failure planes.

4.3 Laboratory geotechnical investigation of basalt, In-House Project No. RF0601, Completed
(G. M. Nagaraja Rao, S. Udayakumar and Praveena Das Jennifer)

Two types of basalts (non-vesicular, vesicular) were investigated at the laboratory for both intact rock and rock joints properties. Non-vesicular basalt is free from vesicules and vesicular basalt contains vesicules. Table 4.3 gives the average properties of two types of basalts.

Table 4.3 Properties of basalts.

Type of basalt	Uniaxial compressive strength, MPa	Young's modulus, GPa	Poisson's ratio	Tensile strength, MPa	Cohesion, MPa
Non-vesicular basalt	120	43	0.21	11.23	13.15
Vesicular basalt	60	24	0.22	7.93	19.61

The uniaxial compressive strength as well as Young's modulus of non-vesicular basalt was higher when compared to vesicular basalt. Presence of vesicules and pores are responsible for the lower strength and modulus for vesicular basalts. However, not much variation in Poisson's ratio was observed between the two types of basalts. Non-vesicular basalt shows slightly higher tensile strength than the vesicular basalt, probably the presence of vesicules acts as obstacles for the growth of crack as the result for vesicular basalts shows higher shear strength. From the post failure studies of triaxial compression test, it was observed that brittle to ductile transition in vesicular basalts takes place above a confining pressure of about 20 MPa but a higher confining pressure of more than 60 MPa is required in non-vesicular basalt.

Joint roughness coefficient varied from smooth to medium rough. Vesicular basalts showed a slightly higher basic and residual friction angle due to the presence of vesicules. Substantial variation in joint wall compressive strength was observed between the non-vesicular and vesicular basalts, lower value for vesicular basalt indicates they are more weathered/altered compared to non-vesicular ones. Vesicular basalts showed lower normal stiffness compared to NV basalts. Depending on the joint roughness coefficient, loading cycle and stress range normal stiffness varies from 117 to 2183 MPa/mm. Shear stiffness increases with the increase of normal stress. Rock samples having low joint roughness coefficient showed higher stiffness compared to the samples having higher joint roughness coefficient. Vesicular basalts showed low stiffness compared to non-vesicular basalt. Depending on the joint roughness coefficient and normal stress, shear stiffness of the joint varies from 1.23 to 10.85 MPa/mm.

For measuring the deformation under triaxial compressive stress conditions, strain gauges are used but there are practical problems in measuring the strain of porous rocks. With a small increase in the confining pressure, the strain gauges undergo local deformation due to pores. The output from the gauge reaches saturation and thereby the gauges become non-functional. Fig. 4.2 shows a close view of the local deformation of the gauges, where small cavities were observed on the surface of the gauge. The figure show the strain gauge before and after the application of confining pressure inside the triaxial cell.

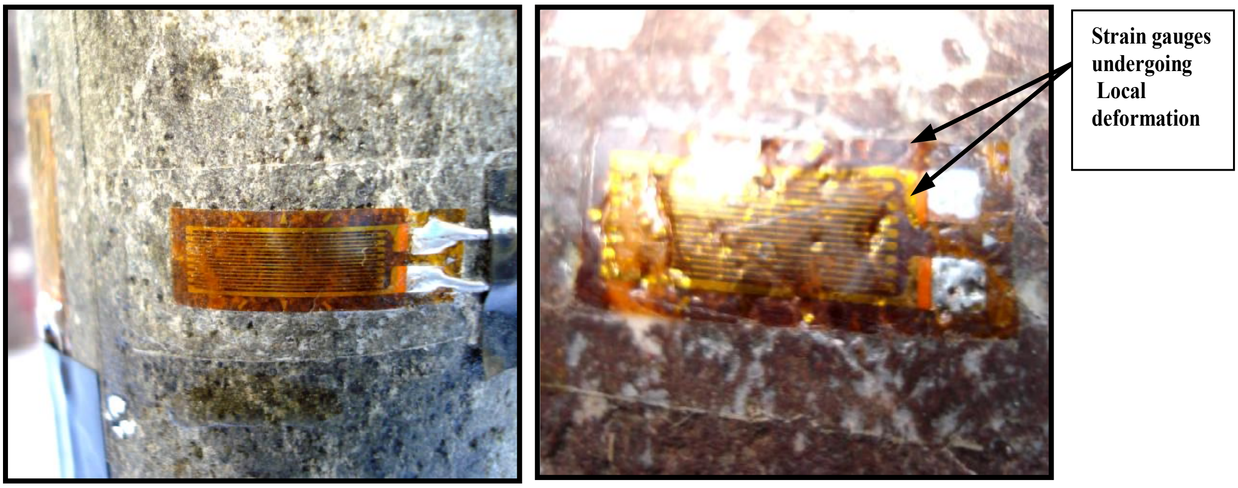


Fig. 4.2 Measurement of strain under triaxial conditions

In order to overcome this problem, pores on the surface of the sample were closed by applying commercially available putty (trade name: Sheenlac) to the samples where the strain gauges are to be bonded. The putty was allowed to dry for about 24 hours at room temperature. By doing this, putty closes all the pores and the surface of samples becomes more or less uniform. After closing the pores with putty, samples were prepared as per the established procedure and strain gauges were bonded to the surface, and strain was measured without the failure of the gauges.

4.4 Testing of dimension stones

(G. M. Nagaraja Rao, S. Udayakumar and Praveena Das Jennifer)

Marble and Granite Samples were received for testing from Zoom Mineral Development (P) Ltd, GMT Metrology (P) Ltd, Jeevan Granites, Alliance Minerals Pvt. Ltd, and R.K. Marbles Pvt. Ltd. The properties were determined at NIRM as per the ASTM Specification (Table 4.4).

Table 4.4 Properties of granite and marble samples received from different companies

Sample Tested	Bulk density, kg/m^3	Water absorption, %	Compressive strength, MPa	Flexural strength, MPa	Modulus of rupture, MPa	Abrasion resistance of stone
Black Granite, Hassan	3072	0.003	349	-	-	124
Black Granite, Tamil Nadu	3087	-	270	28.50	-	-
Granitic Gneiss (Rose wood and Ghibili), Tamil Nadu	2600-2613	0.23-0.31	164-189	8.42-8.60	10.36-11.87	88-115
Brown Quartzite, Tamil Nadu	-	-	-	18	-	53
Marble (Green glacier and polar)	2705-2708	0.09-0.13	49-60	8-10	10-12	11-13
Marble (flawless white)	2720	0.11	69	10	11	11

4.5 Materials testing

(S. Satyanarayana, M. Victor and G. M. Nagaraja Rao)

Two types of tests were carried out on wire ropes to assess the suitability for their continuation for man riding winders. These tests include tensile tests on rope, and tensile, torsion and reverse bend tests on individual wires.

Wire ropes were tested for almost all the mining industries across India. A total of 85 wire ropes received from 11 organizations were tested. Proof load tests were conducted on suspension gear components of Balaghat Mines of Manganese Ore India Limited. Ultrasonic flaw detection and magnetic particle tests were carried out for various organisations including Hutti Gold Mines Limited, Ferro Alloys Corporation Limited, Singareni Collieries Company Limited, Hindustan Zinc Limited, Manganese Ore India Limited and Uranium Corporation of India Ltd.

5. ENGINEERING SEISMOLOGY

Monitoring of seismic activity is essential for assessing stability of underground and open cast excavations. During 2008-09, the Engineering Seismology Department has monitored rockburst from the mines of Kolar Gold Fields using broad band seismic station and strong motion accelerograph.

5.1 Establishment of Broad Band Seismic Station at KGF, Project No. SI0601, On-going

(C. Srinivasan, Y.A. Willy and C. Sivakumar)

The Broad Band Station, installed at the Central Seismic Station (KGF Observatory) by the Ministry of Earth Sciences under the World Bank assisted project, is working satisfactorily. The data retrieved from the system is sent to IMD, National Seismological Data Center, New Delhi after preliminary analysis. VSAT has been installed at the KGF Observatory for transmitting data from KGF Broad Band Station to central place at NGRI, Hyderabad. Solar panel has been connected at KGF Observatory to power the VSAT. The connectivity has been checked and seismic data from KGF Observatory are being downloaded at NGRI, Hyderabad. The possibility of downloading seismic data from other stations in the Peninsular seismic network was explored. The earthquake recorded at the KGF Observatory from Pakistan is shown in Fig. 5.1.

The Strong Motion Accelerograph installed at NIRM is working satisfactory. Fig. 5.2 shows the earthquake recorded by the Strong Motion Accelerograph from Vellore in Tamil Nadu. During the year, 191 rockbursts were recorded. The strong motion data has been used for computing source parameters of rockbursts, such as source radius, seismic moment, stress drop and corner frequency. These parameters are useful to characterize rockburst. The source parameters computed from the available data for a South African mine have been compared with those of KGF rock bursts (Table 5.1). The local magnitudes computed from KGF strong motion data were found to be higher than those of South African events, probably due to variations in the magnitude.

Table 5.1 Source parameters of rockbursts

Source parameters	KGF mine	South African Mine
Local Magnitude	1.7	0.8
Seismic Moment (Dyne-cm)	2.94×10^{22}	4.84×10^{17}
Stress Drop (MPa)	1.01	0.53
Source Radius (m)	130	38.3
Corner Frequency (Hz)	9.45	39.78

Hence appropriate corrections were incorporated for the site considering it as soft and modified the relation as mentioned below.

The local magnitude based on accelerograms at short distances to the fault shows distance dependence in that it reduces gradually up to 20 km followed by an increase as distance varies from 20 to 100 km. Therefore, the use of the Richter's original correction factor $\log A_0(R)$ is, in general, not suitable to describe the attenuation of strong-motion amplitudes in the near field, particularly within 20 km. To eliminate this distance dependence, a modification in the

Richter's attenuation function for smaller distances was taken. Other authors suggested similar modifications in $\log A_0(R)$ for small distance *(R)*, but their failure to include the local geological effects in the analysis resulted in a biased estimate of seismic attenuation. However, these modifications were found to be insignificant at very short distances within about 5 km. Finally it was shown that the peak values of the response of Wood-Anderson seismographs (WAS) may occur at different wave periods depending upon the source-to-station distance, magnitude, and the geological condition at a site. Therefore, using the frequency-dependent attenuation function and the knowledge of the frequency where most of the energy is concentrated in the strong-motion as filtered by the Wood-Anderson seismographs, it was defined an improved attenuation function $Att(\Delta_0)$ in place of the Richter's function, where Δ_0 is the hypocentral distance.

This new attenuation function represents much faster decay of strong ground motion than the Richter's function for distances up to 35 km. However, the local magnitude based on near fault strong-motion data may still differ significantly from the commonly reported magnitudes based on the actual Wood-Anderson seismographs at long distances. The reported magnitudes are underestimated significantly due to more prominent inelastic attenuation of high frequencies with distance. To normalize these differences, it was proposed an empirical correction factor $D\left(\overline{M}_L^{SM}\right)$. An empirical correction factor has also been suggested for the amplification of strong-ground motion on the soil sites. Thus, the methodology used to compute the local magnitude using the strong-motion acceleration records in the present study can be summarized as follows:

- Compute M using improved attenuation function $Att(\Delta_o)$ given as below

$$M = \log A_{synthetic} - Att(\Delta_o) \quad (1)$$

- Correct M for local geological site condition to get $\left(\overline{M}_L^{SM}\right)$ as

$$\left(\overline{M}_L^{SM}\right) = M - b_2(M)(2-s) \quad (2)$$

  where s=0 for soft ground and 2 for firm ground and the coefficient $b_2(M)$ is given for M = 3.5 to 7.5. The value of $b_2(M)$ for M = 3.5 has to be used for lower values of magnitude also.

- The strong-motion local magnitude, M_L^{SM}, is finally defined as

$$M_L^{SM} = \overline{M}_L^{SM} - D(\overline{M}_L^{SM}) \quad (3)$$

The empirical correction factor $D(\overline{M}_L^{SM})$ is given in for $\overline{M}_L^{SM}$ = 4.6 to 7.3. The value for $\overline{M}_L^{SM}$ = 4.6 only can be used for lower values of $\overline{M}_L^{SM}$.

Using the above corrected equations, the magnitude computed for the major rockburst which occurred on 02-11-2005 at 18:14:56 hrs is 2.8, whereas the magnitude computed earlier for the same rockburst was 4.2 without applying the site correction.

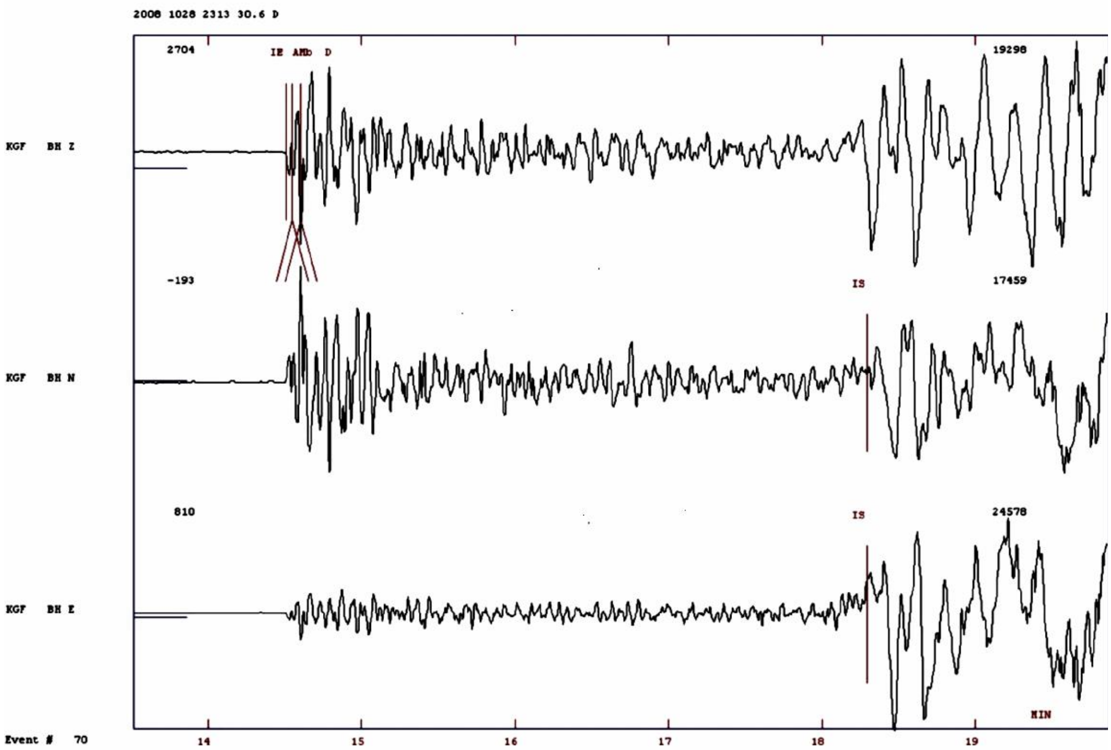


Fig. 5.1 Earthquake on 28-10-2008 at 23:13:30 (UTC) M_b = 6.4, Location: Ziarat, Southern Pakistan

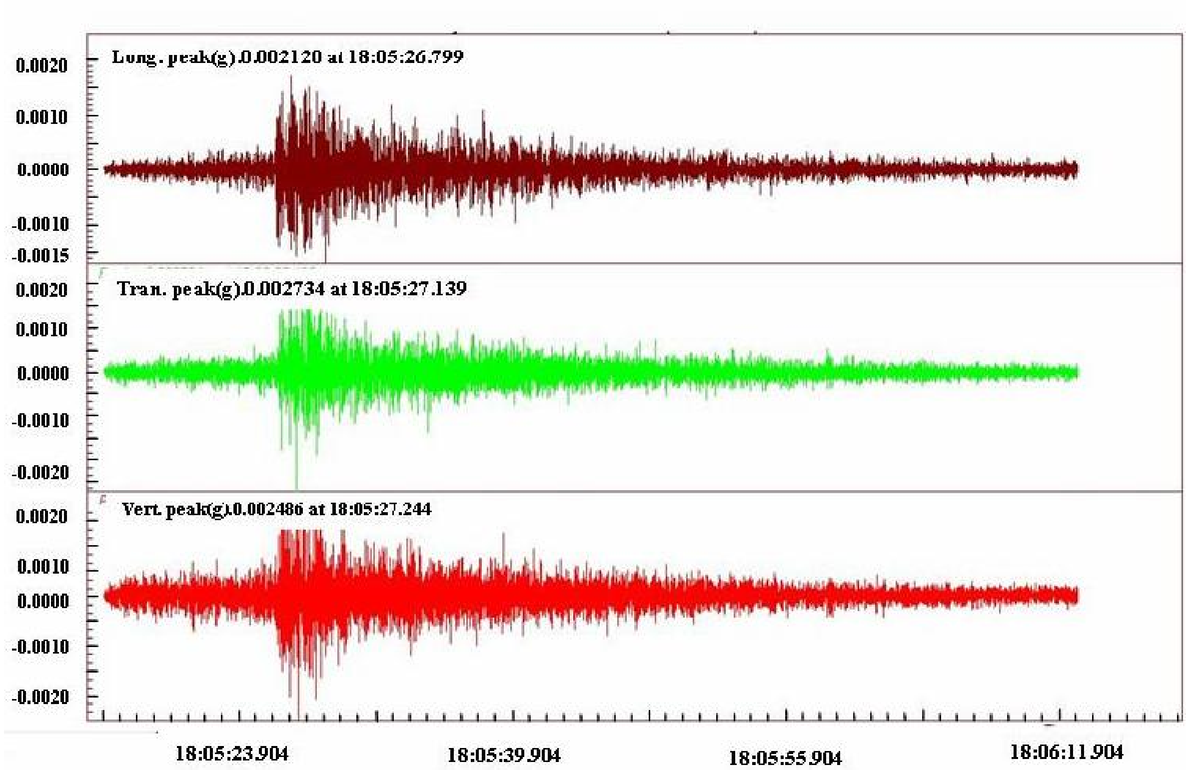


Fig. 5.2 Typical record of earthquake (Vellore) on 07.06.2008 at 18.00 hrs (UTC), Magnitude 3.8 as recorded by the Strong Motion Accelerograph

6. NUMERICAL MODELING, INSTRUMENTATION AND MONITORING

Numerical modelling is one of the tools for design of excavations in rock. Stress analysis and support design for surface and underground excavations are carried out using software based on discrete and continuum element methods. During 2008-09, the Numerical Modelling Department undertook projects involving numerical analysis, instrumentation and monitoring work.

6.1 Instrumentation, monitoring and data analysis of underground powerhouse complex, desilting chambers of Tala Project, Bhutan, Project No. NM0801, Completed

(Sripad, K. Sudhakar, G. D. Raju, P. S. Varma and P. C. Nawani)

Tala Hydroelectric Project in Bhutan is a 1020 MW run-of-the-river scheme. NIRM has been carrying out instrumentation for this project since the year 2000. The project started generation of power in 2006 and recently, it was handed over to Druk Green Power Corporation Ltd (DGPCL). NIRM is continuing the analysis of the instrument data at powerhouse complex and desilting chambers to study the overall stability of the caverns. The instruments were installed at different stages of excavations, and monitored during excavation, post excavation and operational periods. The actual instrumentation section installed at machine hall cavern and desilting chamber is shown in Fig. 6.1.

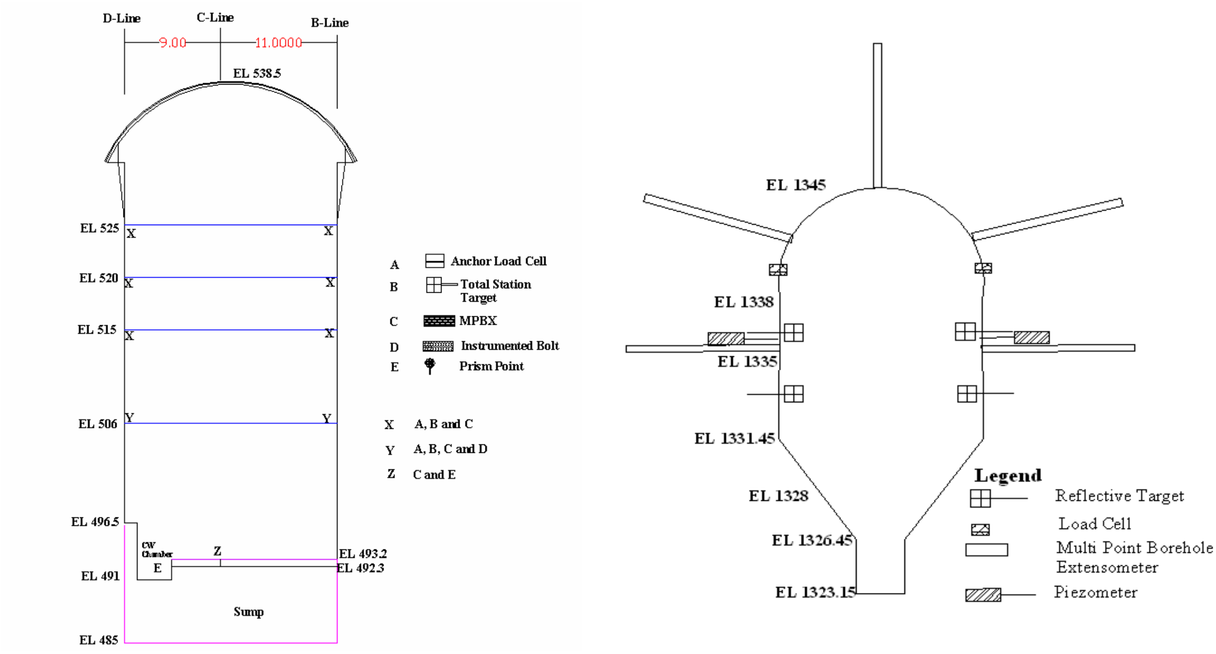


Fig. 6.1 Section of machine hall cavern and desilting chambers showing locations of the instruments

The stability of the machine hall cavern was assessed based on the convergence observations of the side walls, the load on the rock bolts and the stress distribution along the length of the instrumented bolts and the floor heave observations.

During the operation stage, it was observed that the load on most of the rock bolts shows a stabilizing trend. At EL 525, the load cells on both upstream and downstream rock bolts show minor changes, mostly decreasing trend. At EL 520, load cells during the initial stages of operation RD 150 u/s showed some indication of upward trend which during the last one year showed a stabilising trend at most of the locations. At EL 515, the load cell at 110 d/s showed an increase of 11.64 tonnes during the operational stage and continues its upward trend. Other load cells at same elevation on both the walls show a stabilising trend. At EL 506, upward trend of load is observed at RD 150 u/s and RD 110 d/s during the operational stage.

Analysis of instrumented bolt data also indicates that there are no appreciable changes in the stress levels on the rock bolts. The convergence of the sidewalls during the operational period varies from 7-19mm. The convergence rate during last one year is in the range of 0.01 to 0.02 mm/day. The total convergence observed at EL 525 is 366 mm at RD 65 and 335 mm at RD 110. Convergence measured at some more locations during the operational period also shows similar trend with same convergence rates. The convergence observations at EL 525 at Machine Hall Cavern are shown in Fig. 6.2.

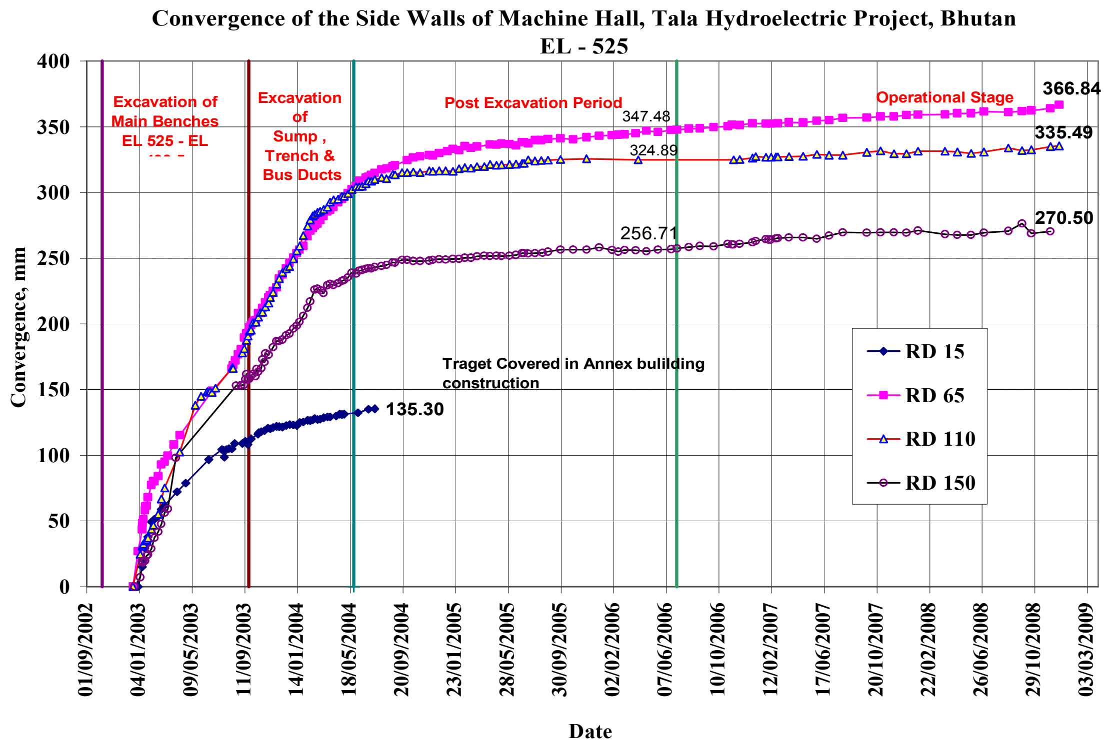


Fig. 6.2 Convergence of side walls of Machine Hall Cavern at EL 525

Although, the failure of rock bolts is continuing in the machine hall cavern, the stability of the cavern is not affected as it is also evident from the physical observations of the repaired crack for a period of more than two years. The behaviour of the cavern is tending towards stability and behaviour is as expected during the period of excavation and post excavation period and is currently under the process of stabilization and undergoing time dependent deformations. NIRM is conducting additional studies (microseismic monitoring of the nearby areas of Machine hall cavern and Back Analysis using 3D Numerical Modelling) to ascertain the stress conditions as the Powerhouse is situated within the Main Central Thrust.

Instrument observations at Transformer Hall, Bus Ducts and other locations also indicated a stabilizing trend.

At desilting chambers, cables of load cells and piezometers were brought to a remote location for monitoring during the operation stages. The pore water pressures in the surrounding rock mass shows the trend as expected (Fig. 6.3).

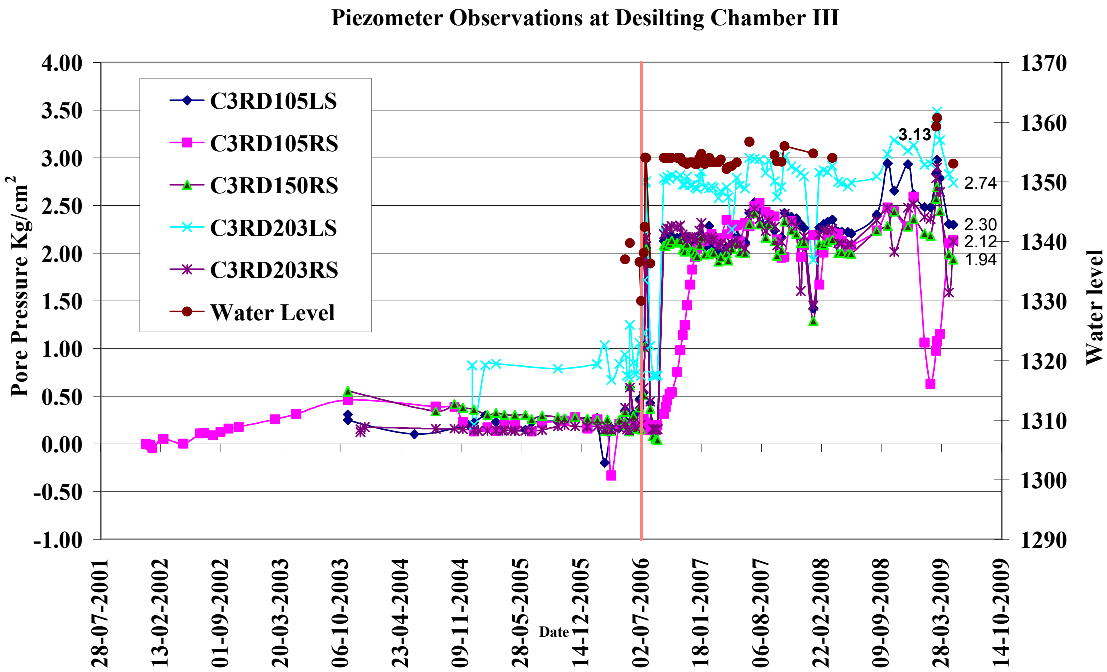


Fig. 6.3 Pore pressure observations at Desilting Chamber III of Tala HEP, Bhutan

Table 6.1 Locations and status of instrumentation at Tala Project

Type of instrument	Machine Hall		Bus ducts/ PS MF		Transfor mer Hall		Desilting Chambers		Surge shaft		HRT		TRT		PS Bottom EL499		PS-BFV Chamber		Total Installed	Working Currently
	I	W	I	W	I	W	I	W	I	W	I	W	I	W	I	W	I	W		
VW Anchor Load Cell	42	23	8	3	28	9	12	1	--	-	11	0			-	-	-	-	101	36
VW Rib Load cell	12	4	12	11	12	4	19	15	3	1	68	0	6	0	-	-	-	-	134	35
VW Piezometers	32	30	10	10	15	8	19	11	-		11	0			-	-	10	10	97	69
MPBX (Magnetic)	21	1	3	0	13	0	45	0	9	0	23	0			7	0	-	-	121	1
MPBX (Mechanical)	46	3	-	-	9	0	-	-	-	-	2	0	-	-	-	-	-	-	57	3
Instrument Bolts	8	8	-	-	7	4	-	-	-	-	-	-	-	-	2	1	-	-	17	13
Strain Gauges	2	2	-	-	2	0	-	-	-	-	2	0	-	-	-	-	-	-	6	2
Strain meter (Mechanical)	-		-	-	-	-	-	-		-	15	0	-	-	-	-	-	-	15	0
Strain meter (Electronic)	-		-	-	-	-	-	-	-	-	6	0	-	-	-	-	-	-	6	0
Total Station Target Sec.	23	7	6	0	14	0	61	0	-		67	0	3	0	4	0	-	-	179	7
Prism Points	13	0	-	-	3	0	-		-		2	0	-	-	6	0	-	-	24	0
Total	190	78	39	24	103	25	156	27	12	1	207	0	9	0	19	1	10	10	754	166

Note: I: Installed and W: working, VW: Vibrating wire, MPBX: Magnetic Ring Multipoint Bore Extensometer

The instruments installed at all the underground locations at Tala Project are summarised in Table 6.1. It also gives the instruments which are in operation currently.

6.2 Analysis of instrumentation data of dam at Tala Hydroelectric Project, Bhutan, Project No. NM0802, Completed
(Sripad, K. Sudhakar, G. D. Raju and P. C. Nawani)

The Druk Green Power Corporation Ltd, Bhutan, regularly monitored the health of the dam through instrumentation. The data was collected through the Data Acquisition System, stored and supplied to NIRM for analysis. Pore pressure variations were recorded with piezometers (Fig. 6.4) and crack width with joint meters (Fig. 6.5). During the monitoring period, all instruments showed normal behavior except one joint meter between block 5 & 6, which showed some seasonal variations.

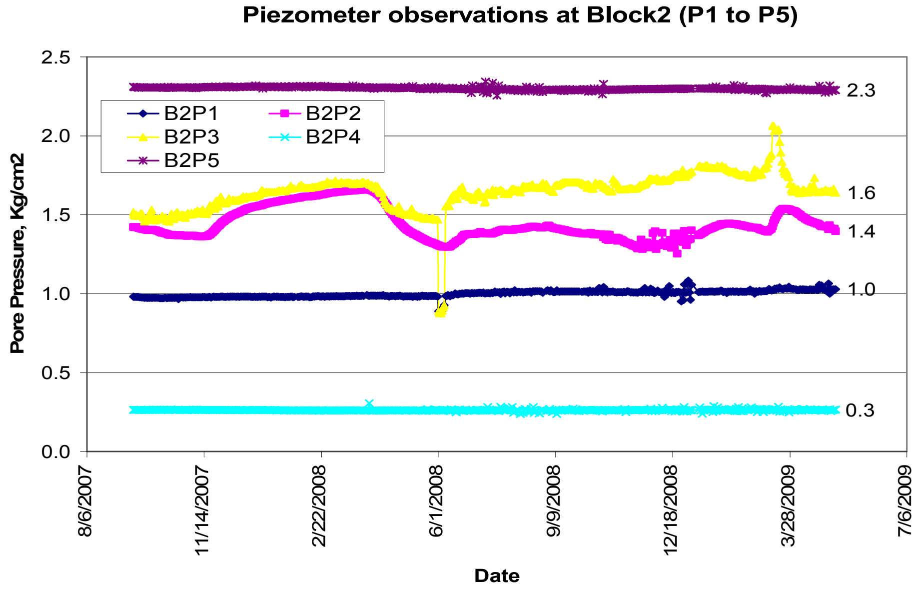


Fig. 6.4 Pore pressure observations at Block No.2 of Wangkha Dam at THEP

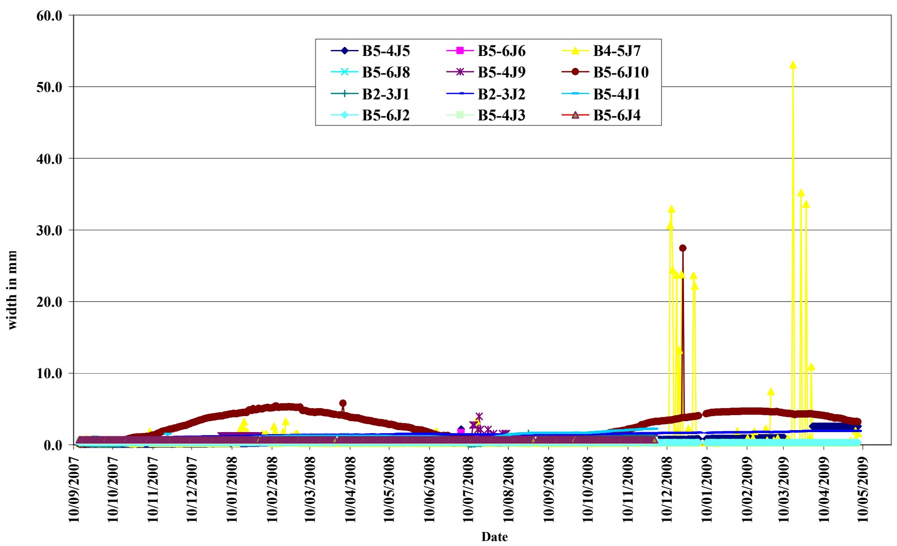


Fig. 6.5 Joint meter observations at Block No.2 and 5 of Wangkha Dam at THEP

6.3 Analysis of instrumentation data of machine hall and desilting complex of NJHEP, SJVNL, Shimla, Project No. NM0708, Completed

(Sripad, G.D. Raju, K. Sudhakar, P. S. Varma and P.C. Nawani)

Jhakri Hydroelectric Project (1500MW) of SJVNL is regularly monitoring instruments in the underground powerhouse complex as well as in the desilting complex. NIRM was associated in analyzing the instrumentation data generated from these complexes to ascertain the stability of the caverns during operational stage.

The extensometer and piezometer data from the powerhouse complex and desilting chambers are analyzed for identifying the displacement pattern and location of the cracks and the pore water pressure in the surrounding rock mass. The piezometer observations in Chamber 2 are shown in Fig. 6.6 and the extensometer observations in Machine Hall at RD 60 is shown in Fig. 6.7.

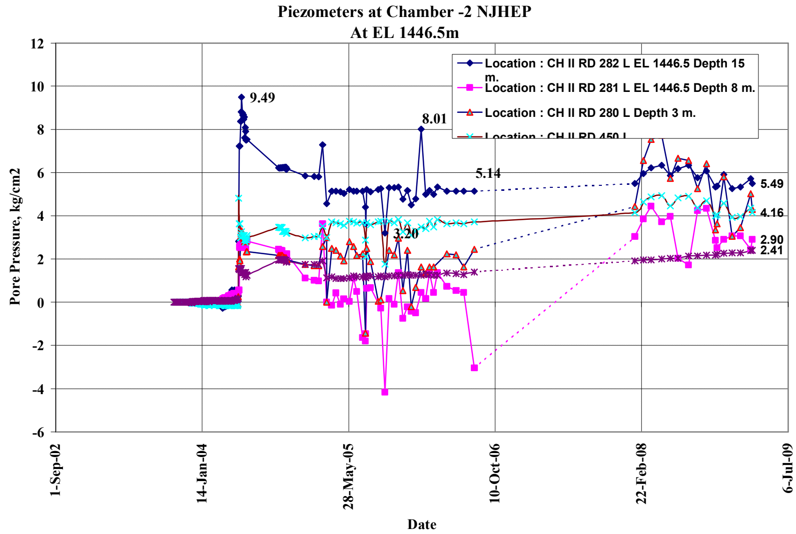


Fig. 6.6 Piezometer observations at Desilting chamber 2 of NJHPS (SJVNL)

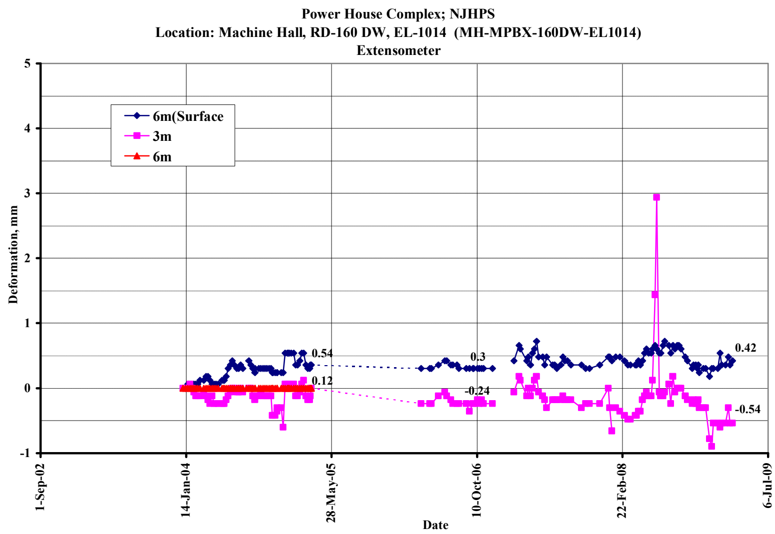


Fig. 6.7 Observations of MPBX at Machine Hall (RD160, EL1014) of NJPHS (SJVNL)

The analysis of the instruments data indicates that there is no excessive buildup of water pressure at any of the locations. During the operational period, the displacement of the walls of the caverns is insignificant indicating the overall stability of the caverns.

6.4 Support design for tunnel at Nettempadu lift irrigation scheme, Stage–II, A.P. (NM0701), Completed

(Sripad, G. D. Raju, K. Sudhakar and P. S. Varma)

Delta Construction Systems is executing Nettampadu Lift Irrigation Scheme – II for Govt of Andhra Pradesh. The underground components of this scheme are: 1) pump house of 49.6 m x 18.6 m and 70 m deep, 2) surge pool of 49.6 m x 25.6 m and 65 m deep, 3) 5.6 m dia horse shoe tunnel 2400 m long, and 4) three inclined shafts @45deg 100 m long.

The method of excavation in all the above are by conventional drill and blast method. The main objectives of this study were

- Stress analysis of the pump house and surge pool for estimating the support requirement
- Support design and methodology of excavation for the tunnel portion

This project has a horse shoe type tunnel, 5.6 diameter and 2400 m long. This has three faces, two from the intermediate adit and one face from the zero point. There was no problem with the adit faces with the existing support system and methodology. At zero point face, after advancing 10 m from the portal, the problem of rock spitting/rock ejection resulted in instability of the face. This has affected the safety and the progress of the face. It was reported by the project authorities that the face used to eject with great sounds soon after the blasting of the face, not allowing even for mucking or any other activities.

Based on the analysis of the results of the numerical models and field trials, the following recommendations are made:

- Rock bolts of 3 m length 25 mm dia at 1.0 m spacing may be installed throughout pump house and surge pool.
- After strengthening of the rock ledge, the analysis shows controlled deformations on the pump house side. Hence, anchoring for the crane beam columns in the centre pillar (rock ledge) may be anchored beyond the rock bolt horizon and into the hard rock portion.
- The slopes at various sections of the approach channel have been analysed taking the designed cut slopes. These are showing stable condition. However, keeping in view the damage to the rock mass during formation of these slopes, it is recommended that 100 mm thick shotcrete with spot bolting may be applied as per the site conditions.

6.5 Three dimensional numerical modeling of underground caverns of Loharinag Pala and Tapovan Vishnughad HEPs of NTPC, Noida, Project No. NM0704, On-going

(Sripad, G. D. Raju, K. Sudhakar, P. S. Varma and P.C. Nawani)

NTPC Ltd. is executing Loharinag Pala Hydroelectric Project (600 MW) and Tapovan Vishnugad Project (520 MW) in the Uttarakhand Himalaya across river Bhagirathi and Alakananda respectively. A brief account of three-dimensional numerical modelling of the major underground caverns for these projects is presented.

6.5.1 Three dimensional discontinuum modelling of Loharinag Pala desilting chambers

The three desilting chambers separated by a rock pillar of 35m each at depth varying from 180-430m are being excavated in gneiss and jointed biotite gneiss rock. The desilting chambers were modeled using 3DEC a three dimensional discontinuum code. The stress analysis showed that after installation of the supports there is a reduction of 4-9% in the total displacements. The maximum compressive stresses were also reduced and were in the range of 27-87 MPa. The factors of safety of the pillars, hopper, silt flushing tunnel and the pillar between the chambers also improved with the installation of the support system. The displacement pattern at RD 25 m after installation of the supports is shown in Fig. 6.8.

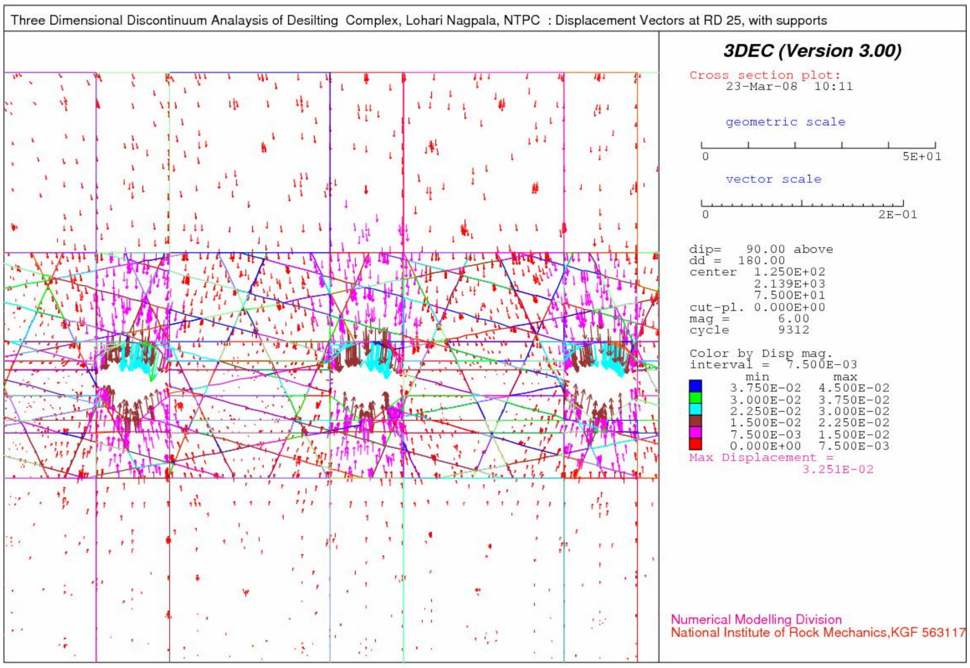


Fig. 6.8 Displacement pattern at RD 25 m with installation of supports

6.5.2 Three dimensional discontinuum modelling of Tapovan Vishnugad powerhouse complex

A three dimensional numerical modelling analysis of the powerhouse complex was carried out using a discontinuum 3D code, 3DEC. The actual joint sets, weak zone and shear zone were incorporated in the model. The model of the powerhouse complex is shown in Fig. 6.9.

In the walls of the cavern, the displacements of higher magnitudes were expected in the vicinity of the shear zone from RD 60 to RD 100 m. The measured displacements are in the range of 225-325 mm. The effect of shear zone is more prominent on the upstream side than on the downstream wall. As the zone between RD 65 and RD 95 m is highly deformed, it was recommended to take adequate precaution in terms of timely support both on the upstream and downstream wall. The Bus Duct-1 also falls under this zone and the effect may be felt during its excavation.

The effect of the shear zone on the displacement pattern of the machine hall cavern is shown in Fig. 6.10. Further studies are in progress.

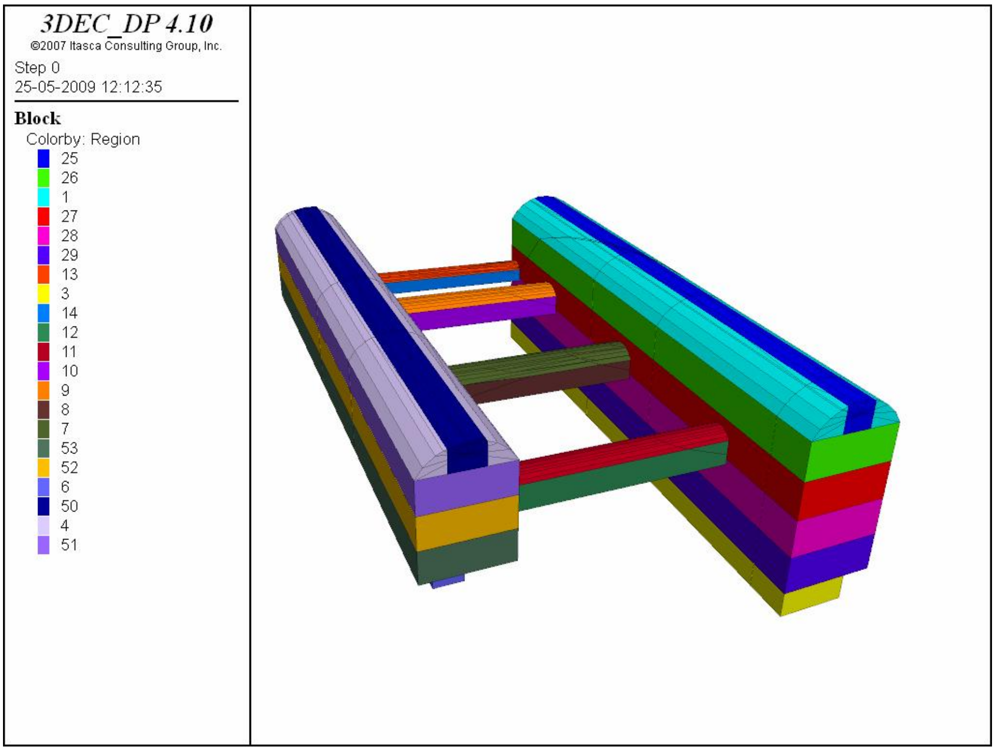


Fig. 6.9 Three dimensional model of powerhouse complex of Tapovan Vishnugad project

Fig. 6.10 Effect of shear zone on the displacement pattern of powerhouse

6.6 Three dimensional stability analysis (Discontinuum) of the right bank cut slopes of Koteshwar Hydroelectric project, THDC, Rishikesh, Project No. NM0706, On-going
(Sripad, G. D. Raju, K. Sudhakar, P. S. Varma and P.C. Nawani)

Koteshwar Hydroelectric Project (400 MW) of THDC is under construction on the river Bhagirathi in Uttarakhand. It will facilitate the functioning of Tehri Power Complex as a major peaking station in Northern grid.

The main objective of this study is to assess the stability of the right bank cut slopes using discontinuum methods using 3DEC from EL 532 to EL 780m (from Ch 80 u/s to 660m d/s). The initial 2D models with UDEC suggested that the model should include the left bank and the dam and associated structures. The actual geological sections prepared by GSI were provided by THDC.

Various sections were analysed by two-dimensional numerical models using UDEC. A transverse section covering the cut slopes at various sections from EL 530 to EL 780 were chosen for modeling the caverns using UDEC. For this purpose a model was constructed with the actual geometry of the slopes. The actual slope profile was taken as the outer boundary of the model and the model was subjected to gravity loading under existing in-situ stress conditions. The support system installed was also included in the model.

Considering the extent of yield zone and need to effectively counter the high shear stresses, installation of the cable bolts was necessary. The length and spacing of the cable bolts were determined by model runs to reach the optimum dimensions. The results indicate that 70 tonnes (Pre-tensioned to 70 tonnes with 120 tonnes ultimate capacity) capacity cable bolts of 25 m length, placed at 8 m interval at few locations, can provide adequate support and can ensure long term stability.

The locations of cable bolts (Table 6.2) were determined based on the horizontal displacement contours and tensile stresses and safety contours of less than 2.0. However, it is suggested that the actual length of the cable bolts may be decided at the time of installation by the site engineer based on the actual geology encountered during the drilling so as to ensure proper anchorage in the competent rock.

Table 6.2 Locations of proposed cable bolts at various sections

Location	Left Bank EL	Right Bank EL
Dam Axis	575m – 640 at 8m spacing	575m – 640 at 8m spacing and 2 rows between 640m and 675
30 d/s	575m – 625 at 8m spacing	575m – 625 at 8m spacing 2 rows between 650m and 665m
50 d/s	589 – 653m at 8m spacing	591 -637m at 8m spacing 2 rows between 667 – 677m
90 d/s	570 – 592m at 8m spacing	564 -585m at 8m spacing
120 d/s	598 – 635m at 8m spacing	585 – 679m at 8m spacing
150 d/s	Cable bolts not required	EL 611m and EL 613m
30 u/s	EL 572 and EL 579m	EL 604 -618 m

6.7 Deformation monitoring of underground powerhouse cavern of Sardar Sarovar Project, Gujarat (NM0707), Completed

(Sripad, G. D. Raju, K. Sudhakar, P. S. Varma and P.C. Nawani)

The underground powerhouse complex of Sardar Sarovar Project consists of powerhouse of 23 m wide, 57 m high and 210 m long. There are six pressure shafts of 9 m diameter for intake of water from the reservoir to the powerhouse and six draft tubes of 16 m wide double D-shaped for drawing out water to collection pool. On the downstream side, there are three D-shaped bus galleries of 12 m wide and 7.5 m high connected to bus shafts. There are few interconnecting tunnels and access tunnels, which are close to the powerhouse.

NIRM monitored and analysed the displacement patterns in the powerhouse cavern using the existing MRMPBX (Magnetic Ring Multi Point Borehole Extensometer) and Total Station targets. The following are the observations.

- Maximum displacement observed at 7 to 10 m depth from machine hall sidewall as measured by bus duct gallery was negligible.
- The displacements at 7 to 9 m depth in the vicinity of bus galleries show a stable trend.
- The wall movements measured from bus galleries under investigation showed a stable trend.
- The wall movements measured at EL0 & EL17.5 on both downstream and upstream side shows a stabilizing trend.
- The displacements measured on the columns and beams are within 3-4 mm and show a stabilizing trend.

7. ROCK BLASTING & EXCAVATION ENGINEERING

Optimisation of blast design parameters for mining and hydroelectric projects along with monitoring and control of ground vibration, air overpressure and fly rock are needed to solve challenging problems during surface and underground excavations. During 2008-09, Rock Blasting and Excavation Department completed seven industry-sponsored projects and another eight are in progress.

7.1 Ground vibration and air overpressure study due to quarry blasting at Survey no. 80/Y, Shivagiri Associates, Pandavapura, Mysore, Project No. RB0803, Completed

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

M/s Shivgiri Associates operate a granite stone quarry near Vaddarahalli village, Mandya district, Karnataka. From the quarry, the stone is excavated by drilling and blasting with the production is about 500 tonnes per day. A scientific study was conducted by NIRM in August 2008 to assess the ground vibration and air overpressure levels due to routine blasting operations at their quarry.

During the field investigations, eight blasts were monitored using six seismographs which were mounted at distances varying from 20 m to 1040 m. The vibration level was as low as 0.3 mm/s and the air overpressure was less than 133 dB at the nearest village, Vaddarahalli, at a distance of about 1200 m from the quarry.

The field data was analysed and site-specific predictor equations were derived for estimation of ground vibration and air overpressure. Considering the structures at the Vaddarahalli village and the apprehensions by the local people, a permissible level of 5 mm/s was recommended as per DGMS standards.

7.2 Ground vibration and air overpressure study conducted during test blasts at an alternate site for Bangalore Metro Rail Corporation Ltd. (BMRCL), Project No. RB0804, Completed

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

For BMRCL, blast monitoring was carried out at an alternate site to estimate the probable ground vibration and air overpressure levels that may be experienced at various distances during the actual blasting operations in the proposed station areas.

Three blasts were monitored using ten seismographs placed at different distances ranging from 5 m to 60 m. Based on the data analysis, permissible ground vibration limit of 10 mm/s was arrived. The results indicated that vibration levels could be restricted to 10 mm/s during the actual blasting operations beyond a radius of 20 m from the blasting site (Fig. 7.1).

Though the measured air overpressure levels were higher than the permissible levels, it is possible to control air overpressure by adopting appropriate techniques during the actual blasting operations. Considering all these aspects, controlled blasting methodology was suggested and the same was submitted to BMRCL for tender document.

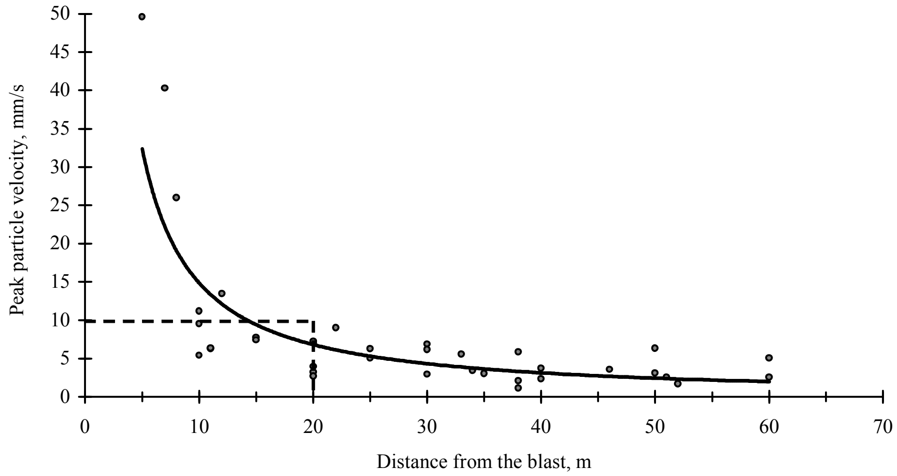


Fig. 7.1 Peak particle velocity versus distance at an alternate site suggested for BMRCL

7.3. Vibration study to assess the impact of Utti opencast blast of HGML on reinforced concrete aqueduct, NRBC, KBJNL, Narayanpur, Karnataka, Project No. RB0801, Completed

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

A reinforced concrete (RC) aqueduct was proposed to be constructed as part of 9A distributary of Narayanpur Right Bank Canal in Karnataka. It passes through a private land adjacent to the boundary of Utti open cast mine of Hutti Gold Mines Limited (HGML) which is planning to go for underground operations in future using deep hole blast method. Apprehending that these mining blasts may cause damage to the aqueduct, HGML authorities requested KBJNL to get a vibration study conducted by NIRM.

Two field visits were made to the project site and six blasts were monitored to assess ground vibration and air overpressure. Two seismographs were installed towards the proposed aqueduct at different distances, with one seismograph always near the proposed aqueduct.

The ground vibration and air overpressure data was analysed and regressed to derive site-specific predictor equations. The distance between the mine and the aqueduct was about 900 m and the maximum peak particle velocity recorded near this proposed aqueduct was 1.32 mm/s. The recorded frequencies of these events were greater than 20 Hz.

Considering the safety of the proposed RC aqueduct, a safe vibration limit of 5.0 mm/s was suggested and the maximum charge per delay to 600 kg, which is the current practice at the open cast mine. It was also suggested that the maximum charge per delay should be further reduced as blasting operations advance towards the aqueduct.

7.4. Study on ground vibration and air overpressure produced from quarry blasting beyond 500 m and assess its impact on Yeleru dam, Yeleswaram area, East Godavari, Andhra Pradesh, Project No. RB0802, Completed

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

The Department of Mines and Geology had granted certain leases for quarrying for road metals in Yeleswaram village, East Godavari district, Andhra Pradesh. After the construction of the Yeleru Reservoir, the Irrigation department was apprehensive about the adverse impacts of blasting on the reservoir structure and raised objections with regard to blasting in these quarries. Though a study was conducted by CWPRS, Pune, to resolve the issue, the quarry leases were cancelled. The affected quarry lease holders represented that banning of quarrying will result in depriving of livelihood to local labourers.

Considering the above, a four member state level committee was constituted by Government of Andhra Pradesh to study the issues with regard to quarrying activities vis-à-vis safety of Yeleswaram dam. As member of this committee, Dr. H. S. Venkatesh, Scientist, NIRM, along with other members visited the site. The committee recommended that the suggestions of CWPRS may be adhered to and that the quarrying at Yeleswaram could be resumed beyond 500 m from the reservoir structures. In addition, this committee opined that a study on ground vibration and air overpressure shall be conducted by NIRM for quarry blasts at Yeleswaram beyond 500 m from the dam to further supplement with more field data.

Field investigations were carried out by NIRM in July 2008 (Fig. 7.2). The investigations showed that the recorded peak particle velocity beyond 200 m was attenuating to levels below 0.5 mm/s. Considering the critical structures of Yeleru reservoir as objects of historic importance and sensitive structures, the most conservative permissible vibration level of 2 mm/s as per DGMS standard was recommended. The quarrying operations in Yeleswaram shall be restricted to beyond 500 m from the earthen dams / reservoir structures etc. The normal blasting practice followed during the field investigation shall be continued. Keeping the apprehensions and the practical aspects in view, it was recommended to restrict the charge per hole and maximum charge per delay to 0.65 kg.

Fig. 7.2 Monitoring of ground vibration and air overpressure at Yeleru dam, A.P.

7.5. Design of controlled blasting pattern for rock excavation and monitoring of ground vibration for an additional 42 MW MLHEP, Shillong, Meghalaya, Project No. RB0703, Completed
(H. S. Venkatesh, R. Balachander and A. I. Theresraj)

Myntdu Leshka Hydro Electric Project Stage I (2 x 42 MW) belonging to the Meghalaya State Electricity Board (MeSEB) is under construction at Jaintia Hills, Meghalaya. The construction work like concreting, erection of turbine parts etc. were under progress. MeSEB planned to construct an additional third unit at about 12 m from the second unit whose erection is nearing completion. The nearest critical structures happen to be the hardening concrete and other concrete structures (Fig. 7.3). MeSEB requested NIRM to suggest controlled blast design for rock excavation in order to take care of the progressing units from any damage due to blasting.

Fig. 7.3 Blasting at the proposed turbine unit 3 close to the existing turbine units 1 & 2

Field investigation was carried out in October 2008. Five controlled blasts were carried out and vibration was monitored. The blast areas were thoroughly muffled to control the flyrock within the blast area. Fourteen sets of vibration readings were used for site specific predictor equation.

The frequency of ground vibration in and around the excavation site was greater than 8 Hz. The maximum charge per delay for different distances was computed keeping the permissible level of ground vibration as 40 mm/s. It was recommended that no blasting shall be undertaken at less than 30 m within 72 hours after casting and that the vibration limit was restricted to 40 mm/s, irrespective of the aging of the concrete.

Suitable blast designs were suggested for different initiation systems like Twindets (Down the hole delay of 400 ms and Trunk Line Delay of 25 ms) or electric delay detonators (Short delay/long delay periods).

7.6. Blast impact studies on the existing hydropower plant structures due to blast vibration produced from the proposed excavation of pumped storage plant at Tehri HPP, Project No. RB0807, Completed
(H. S. Venkatesh, A. I. Theresraj and R. Balachander)

Tehri Hydro Power Development Corporation (THDC) is operating a 1000 MW (4 x 250 MW) hydro power plant (HPP). As the existing HPP structures and equipment are located close to the proposed pumped storage plant, 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 pumped storage plant. The installations associated in these caverns of HPP happen to be the most critical structures.

Blasts were organized at the working faces of link adits 8 and 9 and vibrations were monitored at various distances from these full-scale production blasts. Fifteen sets of readings were used for regression analysis and a predictor equation was derived at 95% confidence level, which was used to calculate the safe maximum charge per delay for known distances.

Considering the civil structures in the HPP caverns as critical structures, a permissible limit of 10 mm/s was recommended based on DGMS standard. The safe maximum charge per delay for different distances was estimated. The recommended maximum charge per delay was 23 kg at a distance of 50 m and above. It was also recommended that regular monitoring of vibration should be carried out while blasting at about 100 m from the existing HPP structures. It was concluded that blasting shall not be carried out at less than 30 m from the structures and hence, other means of excavation should be thought of at these locations.

7.7. Ground vibration and air overpressure study due to quarry blasting by S.T.G. Stone Crushers, Pandavapura, Mandya, Project No. RB0810, Completed
(R. Balachander, G. Gopinath, H. S. Venkatesh and A. I. Theresraj)

STG Stone Crushers operates a granite stone quarry at Chinkorli Hobli, Pandavapura taluk, Mandya district, Karnataka. The Krishna Raja Sagar Dam is about 8 km from the quarry. The company wanted to assess the effect of quarry blasting on the dam and the nearby surface structures. A scientific study was conducted in December 2008 to monitor ground vibration and air overpressure levels from blasting.

In total, seven blasts were monitored using six seismographs at different distances. The field data was analysed and site-specific predictor equations were derived for estimation of ground vibration and air overpressure. Considering the dam and the surrounding villages, a safe permissible level of 5 mm/s was recommended as per DGMS standards. As the vibration was negligible beyond 1.0 km, it is concluded that the KRS dam is safe with respect to quarry blasting.

7.8. Technical advice for controlled blasting at Gokak Small Hydel Project (4.5MW), Forbes Gokak Limited, Belgaum, Project No. RB0607, On-going
(H. S. Venkatesh, A. I. Theresraj, R. Balachander and G. R. Adhikari)

Gokak Mills Division of Forbes Gokak Limited is constructing a small hydroelectric project (4.5MW) at Gokak, Karnataka. The construction activity involves blasting parallel to the existing canal/buried penstock, blasting near existing powerhouse, opening in the weir structure etc. A preliminary visit to the project site was made and pre-tender blast design specifications were submitted. Subsequently, a procedure for controlled blast design for excavation of powerhouse adjacent to the existing powerhouse was submitted and field-tested. Based on our designs most of the excavations were completed except for the opening in the weir.

7.9 Ground vibration monitoring at Sangam Kalan Limestone Mine, ICL, Tandur Mandal, A.P., RB0701, On-going
(R. Balachander, H. S. Venkatesh and A. I. Theresraj)

Sangam Kalan limestone mines belonging to India Cements Limited is located in the Tandur Mandal of Ranga Reddy district of Andhra Pradesh. The mine management wanted to assess the ground vibration levels due to their quarry blasting for dry and wet seasons for a period of two years. The first field visit was made during November 2008 to monitor ground vibration and air overpressure due to blasting and the details as required by the project authorities were submitted.

7.10 Providing technical guidance for site grading at MRPL, Phase III Part A, Mangalore, Project No. RB0805, On-going
(G. Gopinath, R. Balachander, A. I. Theresraj and H. S. Venkatesh)

Engineering Projects (India) Ltd (EPIL) was awarded site grading work of Phase III Part-A of MRPL, which involved excavation of about 90,000 cubic meters of hard rock by blasting. Considering the proximity and criticality of the structures, only controlled blasting was permitted under the technical guidance of NIRM. Procedures for controlled blasting and safety aspects were prepared and submitted and presented at the site for the benefit of the concerned officials from MRPL, EIL, EPIL and contractors.

Controlled blasts were carried out near storage tanks in massive rock, embedded boulders and free boulders (Fig. 7.4). Field studies were taken up for two weeks and ground vibrations were also monitored using two seismographs.

Fig. 7.4 Blasting near storage tanks

7.11 Optimisation of blast design for Jilling Langalota Iron & Manganese mines, Keonjhar, Orissa, Project No. RB0806, On-going
(H. S. Venkatesh, A. I. Theresraj, R. Balachander, K. Vamshidhar and G. Gopinath)

Essel Mining & Industries Limited is operating non-captive iron ore mines at Joda/Babri sector in Keonjhar district of Orissa. Jilling Langalota Iron & Manganese mines belonging to this company have a production capacity of 5 million tonnes of iron ore per annum. The hole diameter followed in this mine is 102 mm and the bench height is 9 m. The mine management was planning to switch over to 165 mm hole diameter, while retaining the same degree of fragmentation. At the request the Essel Mining, a field study was conducted to evolve guidelines on blast design and fragmentation with respect to the use of 165 mm diameter holes. Field investigation on existing practice using 102 mm diameter holes was conducted during October 2008. Blast records for six months at different benches were collected and summarised in Table 7.1.

Table 7.1 Summary of main blast design parameters

Parameters (Average values)	RL 491m	RL 500m	RL 509m	RL 518m	RL 527m	All benches
Burden (m)	2.61	2.62	2.67	2.68	2.71	2.65
Spacing (m)	3.11	3.11	3.17	3.18	3.21	3.15
Bench height, m	7.06	6.85	7.85	8.29	7.02	7.4
Burden to hole diameter ratio	30.52	25.72	26.14	31.14	26.56	25.98
Burden to bench height ratio	2.69	2.60	2.98	3.13	2.61	2.78
Specific charge, kg/m^3 (Powder factor, t/kg)	0.86 (4.07)	0.87 (4.02)	0.84 (4.17)	0.82 (4.27)	0.80 (4.38)	0.83 (4.19)

The recorded ground vibration and air overpressure were used for regression analysis and a site specific equation was derived. The blasts were videographed and were analysed (Fig. 7.5). An interim report was prepared and submitted. Second field visit was made to evaluate the performance of blast with 165 mm diameter holes. Analysis of the data is in progress.

Fig. 7.5 Videography during and after blasting

7.12 Study on ground vibration and air overpressure due to blasting near Kasholi adit, Package 1, Rampur HEP, Jhakri, HP, Project No. RB0808, On-going

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

Satluj Jal Vidyut Nigam Limited (SJVNL) is constructing Rampur Hydro Electric Project (68.67 X 6 MW) in Rampur district of Himachal Pradesh. In this connection, a 10.50 m diameter Head Race Tunnel (HRT) having a length of 15.08 km is under construction. To facilitate its excavation, HRT is approached by five adits at different locations. At Kasholi adit, a cluster of houses are located vertically above it within a distance of 100 m. The SJVNL project authorities approached NIRM to monitor blast vibrations and to suggest methods to mitigate the adverse impact due to blasting at the Kasholi adit.

The Brail village is located on top of the adit and the nearest house is located at a distance of about 90 m. Rampur town is located on the left bank of Satluj river, which is around 250 m from the portal of the adit. Blast vibration and air overpressure were monitored at Brail village (Fig. 7.6) and Rampur town. Analysis of the data is under progress.

Fig. 7.6 Blast monitoring near a house at Brail village

7.13 Providing technical guidance for site grading at MRPL, Phase III Part B, Mangalore, Project No. RB0809, On-going

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

Surya Constructions was to excavate about 2.0 lakh cubic meter of hard rock as part of site grading work of Phase III Part-B of MRPL. NIRM prepared and submitted the procedures for controlled blasting. Controlled blasts were carried out (Fig. 7.7) under the technical guidance and blast vibrations were also monitored near critical structures. The suggestions, guidance and training imparted by NIRM have effectively addressed the field requirements.

Fig. 7.7 Preparation of blasting near bullet tank area

7.14 Ground vibration and air overpressure study due to mine blasting at Seliannalur Limestone Mine, India Cement Ltd., Tirunelvelli District, Tamil Nadu, Project No. RB0810, On-going

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

The cement plant of the India Cements Limited (ICL), situated at Sankarnagar in Tamil Nadu, is one of the oldest plants in Southern India. The mining activity in the Sellianallur limestone mines is being carried out by the ICL in two separate pits, namely north pit and south pit, near Therku Sellianallur Village. Development work is in progress in the south pit adopting controlled blasting with in-house monitoring of ground vibration. Owing to apprehensions of some of the villagers of Therku Selianalur that the blasting may cause damage to the water tank and other permanent structures, objected to the blasting activities and referred the matter to the District Authorities. NIRM conducted blasting investigations in March 2009 in the presence of Director of Mines Safety. Report preparation is under progress.

7.15. Technical note on application of controlled blasting techniques at the toe of the Tunga Bhadra dam and its effect on the dam for construction of a 1.4 MW mini hydel project on Raya Basavanna Canal, Khandaleru Power Company Limited, Karnataka. Project No. RB0813, On-going

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

The Government of Karnataka has awarded a contract to Khandaleru Power Company Limited for setting up of a 1.4 MW mini hydel project on the Raya Basavanna Canal at the toe of the Tunga Bhadra dam, Karnataka, The proposed mini Hydel project is to be constructed close to the existing power house. For this project, NIRM has agreed to provide technical guidance during both DPR (Stage-1) and construction stages (Stage-2). The work for Stage-1 is under progress.

8. MINE DESIGN

In India, large reserves of good quality coal are locked up in developed bord and pillar workings. NIRM has been making efforts for extraction of coal from difficult seams by designing innovative and modern methods of work. Ground control investigations, and systematic strata and support monitoring are essential for safe design of underground mining methods and to validate the designs. This department is actively involved in rock mass characterization, support design and strata monitoring. It is also essential to design safe and economic slope angles in various open pit mines with increasing depth of surface mining excavations. During 2008-09, the Mine Design Department undertook two S&T projects and a number of industry-sponsored projects in these areas .

8.1 Support design

8.1.1 Rock Mass Characterization, support design & strata monitoring in water-carrying tunnels, GC0705, On-going

(C. Nagaraj and V. Venkateswarlu)

The Irrigation and Catchment Area Development (I & CAD) Department, Government of Andhra Pradesh is developing the Galeru-Nagari Sujala Sravanthi (GNSS) project. Under this scheme, flood flow backwaters from Srisailam reservoir would be fed to the Owk Reservoir, and from where water will be taken through a 37 m wide, and 50 km long canal to feed the water to Gandikota reservoir on the other side of the hill. To cross the hill, it is required to drive a tunnel through the rock from 52.365 to 57.525 km Chainage. The proposed "Gandikota Tunnel" is located on the left bank of river Pennar (Latitude N14°15'/Longitude E78°17') at Lingapuram near Mylavaram, Jammalamadugu, in Kadapa District of Andhra Pradesh.

The 5.16 km long Gandikota tunnel was originally proposed to have 18 m diameter and designed to carry 20,000 cusecs (566.35 cumecs) of water. About half a kilometer of the tunnel was already driven from both the ends. However, the advancement of the tunnel heading could not keep pace as per the schedule. To speed up the drivage of the tunnel, the design was modified to a twin-tunnel system in June, 2008. In this design, there will be two D-shaped tunnels, each 11 m diameter. One of the tunnels would be straight and the second one would be driven 33 m away from this tunnel connecting at both the ends to the first tunnel (Fig. 8.1).

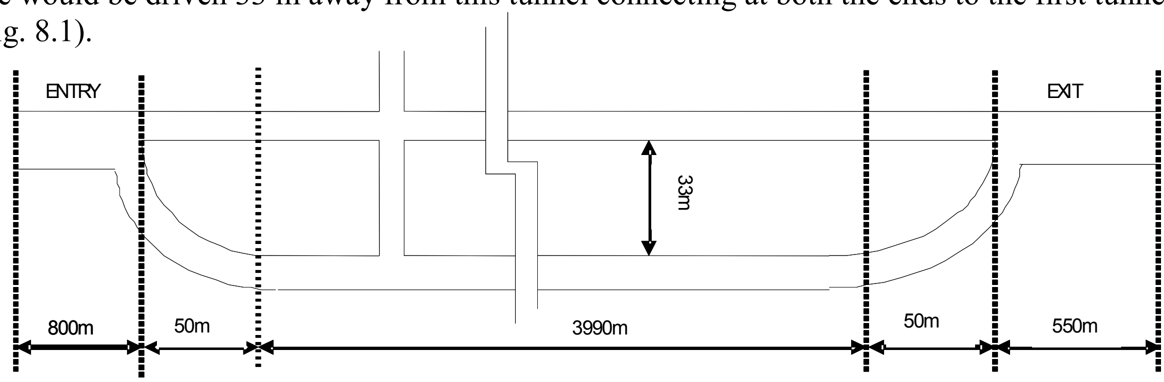


Fig. 8.1 The twin-tunnel system, Gandikota, Kadapa district, AP

NIRM conducted the studies and suggested the required permanent support for the tunnel in the form of 25 mm dia, 6 m long rock bolts. Engineering geological mapping of the exposed strata was carried out to know the orientation of the joints and the bedding planes. The RQD and the rock mass parameters were estimated. The ground conditions were evaluated using RMR and Q approaches. The core samples were tested by NIRM for the physico-mechanical properties.

Nine multi-point extensometers were fixed in the roof to monitor the strata movements. Rock bolt anchorage testing was carried out to evaluate the efficacy of the support systems being implemented.

8.1.2 Determination of in-situ strength of coal, GC0706, GC0801, Completed
(S. Benady & V. Venkateswarlu)

The Singareni Collieries Company Ltd. (SCCL) have recently added new coal reserves in Bhupalpalli Area and opened several mines in the area. It is planned to increase the coal output through introduction of high productive longwall technology in this virgin block. One such project is coming up at KTK-8 Incline, Bhupalpalli, namely Kakatiya Longwall Project (KLP). As part of the geotechnical evaluation of the ground conditions in the area, NIRM took up the in-situ strength determination in seam no.1 at KTK-5 incline and in seam no.3 in KTK-8 incline.

Coal specimens of different sizes were isolated within the large pillars in the development drivages, both along the dips and in the level galleries. Twelve samples in seam no.1 and twelve samples in seam no.3 were subjected to uniaxial loading (Fig. 8. 2).

The average in-situ strength of coal in seam no. 3 was 100 kg/sq.cm. The stiffness of the coal in this seam varied from 25,000 to 1,20,000 kg/cm. The strength of the coal in the mid portion of the seam was found to be higher. In contrast, the in-situ strength of coal in seam no. 1 was low, with an average value of about 80 kg/sq.cm. The average stiffness of the coal was also low at 34,000 kg/cm. These low values are attributed to the presence of a 0.3 m thick clay band in the seam.

Fig. 8.2 Test set-up for determining in-situ strength of coal

Similar studies were taken up for determination of in-situ strength of coal at GDK-10 Incline for augmenting the data-base for future longwalls of Adriyala project. Fig. 8.3 gives a summary of the test results.

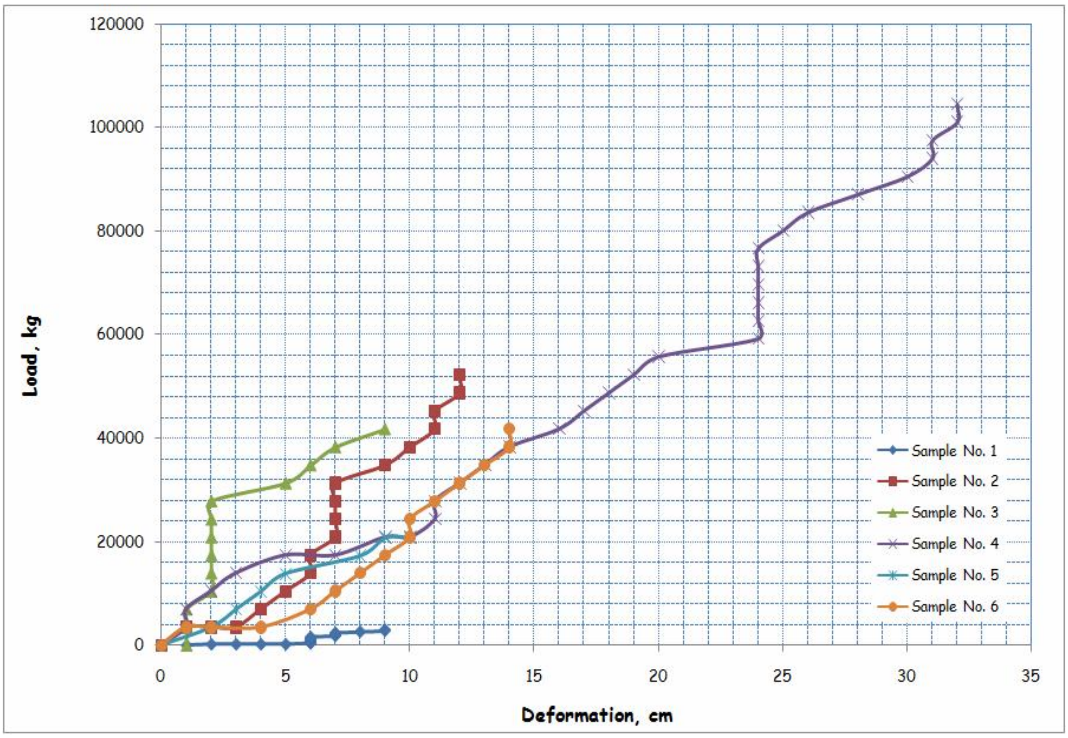


Fig. 8.3 Stiffness curves for coal blocks during in-situ strength tests in Seam No. 3, GDK-10 Incline, RG-III Area, SCCL

8.2 Stability of workings in hard rock mines

8.2.1 Study on surface subsidence at Hira Buddinni Gold Project, HGML, Raichur District, Karnataka, GC0803, On-going

(C. Nagaraj and V. Venkateswarlu)

The Hira Buddinni Gold Project is an exploratory underground satellite mine of Hutti Gold Mines Company Limited. The mine is located about 22 km from Hutti (Raichur Dist, Karnataka). The project commenced during 1995 and the mine development is completed up to 5th Level (150 m from the surface). The dip of the ore body is 80^{0} towards North and its average width is 3 m. It is proposed to start the mining operations by open stoping between 1st and 3rd Level. For this, the mine management requested NIRM to study the likely subsidence due to the stoping operations.

NIRM carried out studies related to surface subsidence. Rock cores from boreholes were collected and their physico-mechanical properties were determined. Based on these results and the geotechnical field data collected, the surface strain values, and other subsidence parameters are being estimated.

8.3 Strata control in coal mines

8.3.1 <u>Caveability of the roof strata in longwall panels *(S&T Project)*</u>, **GC0509,** <u>On-going</u>

(V. Venkateswarlu, Atul Gandhe, C. Nagaraj and S. Benady)

Longwall mining with caving is a very popular method of coal mining worldwide as it has a high potential of production and productivity with safety and conservation. Unfortunately, in India major collapses/ failures were experienced in mechanized longwall faces such as at Churcha, SECL, and Kottadih, ECL. In these mines, the overlying roof was massive and difficult to cave, and the estimated support resistance was found inadequate to cope up with caving of coal roof. To achieve successful strata control in longwall panels, understanding the caving behaviour of roof rocks is of prime necessity to decide on the support type and its capacity. Against this backdrop, three major research institutions, CMRI, NIRM and ISM, took up an S&T project funded by the Department of Coal, Government of India, to develop a suitable method for assessment of caveability of overlying roof rocks, and to develop an integrated approach for selection of the capacity of powered supports.

Data related to past longwall panels were collected from GDK-9 incline, VK-7 Incline and PVK Incline of SCCL. The first longwall panel identified for the field investigations is panel no. 3B at GDK-10A Incline, SCCL. NIRM carried out installation of strata monitoring instruments in the longwall panel since October 2008. Strata behavior observations are regularly monitored by a Resident Scientist at the project site. Stress cells and Tell-Tale Extensometers have been installed in the gate roads. Convergence stations were installed in the Tail gate road at every 5 m interval for monitoring roof convergence. Load on supports are being monitored using V-W type Load Cells in both the gate roads. Specially fabricated extensometers were installed in deep boreholes drilled from surface (Fig. 8.4) with anchors located up to the roof portion of the longwall pillar under extraction.

Fig. 8.4 Deep hole extensometers installed above the longwall panel

8.3.2 Stability of rhombus shaped pillars, GC0605,GC0806, On-going
(V. Venkateswarlu, Atul Gandhe and S. Benady)

Strata control problems are encountered at KTK-1, 5 and 8 Inclines, particularly due to steep gradients. To negotiate the steep gradients, development was carried out along apparent dip, forming rhombus shaped pillars and pillars with acute angled corners. The stability of such pillars is of concern to the mine management. To address the problem, NIRM has taken up a scientific study to understand the stability of the rhombus shaped pillars, to estimate the likely roof pressure, and to design a suitable support system.

At KTK-8 Incline, the rhombus-shaped pillars are proposed to be developed in no. 3 seam. These pillars were estimated to be stable with minimum dimensions of 44 m x 52 m, and maximum dimensions of 99 m x 53 m and having an acute angle of 35^o in the north side pillars and 41^o in the south side pillars, within the mine boundaries. However, the acute-angled corners may become weak, and may fail if not supported. In order to strengthen the corners, it was recommended to carry out bolting and stitching using 1.2 m long bolts/ropes in the sides for 3 m length from the tip of the corner.

The ground conditions in 1A seam of KTK-1 and 5 Inclines were also studied. Because of the presence of a 1 m thick clay bed in the top section of the seam, it was advised not to develop this seam under the steep gradients. Further studies in other seams and at other mines are in progress.

Similar investigations were taken up at Indaram Khani–1A incline of Srirampur Area, which is located within the high flood level on the left bank of the river Godavari. Strata control problems were experienced in no. 3 seam, particularly due to steep gradients (1 in 3 to 1 in 4). As the mine workings are below HFL, the galleries are restricted to 2.4 m width. To negotiate the steep gradients in the deeper horizons, it is proposed to develop the seam along apparent dip, forming rhombus shaped pillars. The mine management has introduced SDLs for loading operations to increase production. However, the width of galleries should be at least 4.2 m. The investigations were taken up by NIRM to evolve an appropriate support system for framing the SSR for wider galleries in a development district and a future depillaring panel in no. 3 seam, and also to study the stability of rhombus shaped pillars in one district.

8.4 Design of method of work in coal mines, GC0704, Completed
(Atul Gandhe and V Venkateswarlu)

At Godavari Khani 8A incline, the top seam no. 1 was developed on bord and pillar method and was extracted by conventional splitting and slicing method. It is now proposed to extract pillars in WS-4, WS-5 and WS-6 and for this, SCCL requested NIRM to suggest suitable design parameters. It is worth mentioning that NIRM had earlier designed wide stall method of partial extraction at Sarni mine of WCL, SMG-I at Mandamarri, and at GDK-8A itself for three panels, namely nos, WS-1, WS-2 and WS-3.

Since the geo-mining conditions such as depth, geological formations, surface features and working section of the seam in the proposed panels are differing from the previous panels, NIRM initiated fresh investigations to suggest the method of working and the support systems. For panel no. WS-4, it was recommended that only a total of 208 pillars below 70 m depth be reduced / extracted. The galleries in WS-4 panel can be widened to a maximum of 7 m, in conjunction with full column grouted bolts of 1.8 m length. The final height of extraction can be increased to 4.8 m by extracting the floor coal during retreat. The galleries below a depth of 89 m from the surface can be heightened up to 6 m.

The important surface features above the panel WS-8 include a Nallah and a road. The panel consists of 61 pillars of various dimensions, occurring at a depth of about 225 m. It was recommended that the original galleries may be widened to 7 m, and then deepened to a total working height of 4.8 m, and all the pillars in the panel would still have a minimum safety factor of 1.7 after widening and deepening. Widening around the two pillars no. 22 and 23 should not be carried out as reduction in their sizes may lower the factor of safety of these pillars as well as the adjacent pillars.

The analysis for WS-11 panel indicated that a total of 328 pillars under depth ranging from 74 m to 142 m can be reduced / extracted with varying height of extraction from 4 m to 6 m. The galleries in WS-11 panel can be widened to a maximum of 7 m in conjunction with full column grouted bolts of 1.8 m length.

It was suggested the roof in all the existing level and dip-rise galleries should be supported by at least 1.8 m long full-column cement grouted bolts at 1.5 m x 1.5 m pattern (that is, for a 5 m wide gallery, the number of bolts required would be 4 bolts at a bolt spacing of 1.5 m and a row spacing of 1.5 m). In the junctions, the bolts should be installed at 1 m x 1 m pattern. After widening, additional bolts should be provided at 1 m x 0.75 m spacing (in a staggered pattern of 2 x 1 bolts) in the widened portion of the galleries; that is, additional two rows of bolts to be provided at 1.5 m x 1 m pattern with one extra bolt in between the rows. In the junctions, four cable bolts of 5 m length, 16 mm diameter high tensile strand or 20 mm diameter wire rope, have to be installed at 3 m x 3 m grid.

8.5 Design of supports in coal mines, GC0604, On-going
(Atul Gandhe, S Benady & V Venkateswarlu)

Roof control problems are being experienced at KTK-2, KTK-3 and KTK-6 inclines of the Bhupalpalli area of SCCL. In view of this, studies were taken up to formulate the systematic support rules (SSR) for the development workings in all the three seams at these three inclines.

The strata at these mines are steeply dipping at 1 in 3 to 1 in 4. The stability of the galleries is affected due to the presence of varying thickness of clay bands in the working sections as well as in the roof sections having abnormal water seepage. There are a number of slip planes in the roof. In view of the adverse ground conditions, studies are being conducted to recommend systematic support systems at these mines.

8.6 Instrumentation and Strata Monitoring, GC0702, GC0802 & GC0805, On-going
(S Benady, Atul Gandhe & V Venkateswarlu)

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 regular basis, and has been involved in a large number of such projects.

At Godavari Khani 8A incline, SCCL, the top seam no. 1 was developed on bord and pillar method. The mine management worked panel no. 47 (WS-1), and subsequently the adjacent panel (WS-2), by wide-stall method using SDLs. Strata monitoring was carried out in the two panels, which were worked without any strata problems. The successful working of these panels provided an impetus to work the third panel (Panel # WS-3) by the same method. In this panel too, NIRM carried out instrumentation and monitored the strata behavior for complete operations. During the monitoring period, it was found that no roof movements were recorded in the workings ahead of pillars under extraction, and no bed separation was recorded at the junctions. The remote monitoring instruments also indicated that there was no deterioration of the roof or the pillar after widening and deepening of the galleries. This indicated the stability of the roof after widening and the efficacy of supports in the galleries and at the junctions.

Yet another panel (Panel # WS-4) is being monitored in the similar way but at a shallower depth. Strata monitoring instruments were installed and the behavior is being monitored regularly. No roof movements were recorded in the workings during the widening and deepening operations at the junctions. However, the convergence recorded by two RCIs fixed in the goaved out region was 6-9 mm during January-March 2009. Maximum changes in stress over the pillar as recorded by two stress cells were 0.4 kg/cm^2 and 0.7 kg/cm^2, which are negligible. The extraction / reduction of the pillars by wide-stall method in the panel WS-4 is progressing smoothly.

At GDK 10 incline, RG-III Area, SCCL, Seam no. 3, which was previously developed, is now being extracted by Blasting Gallery method. Strata monitoring has been taken up in the present working panel (panel no. 1D) to understand the strata behaviour during the extraction of the pillars and the stability of the workings (Fig. 8.5).

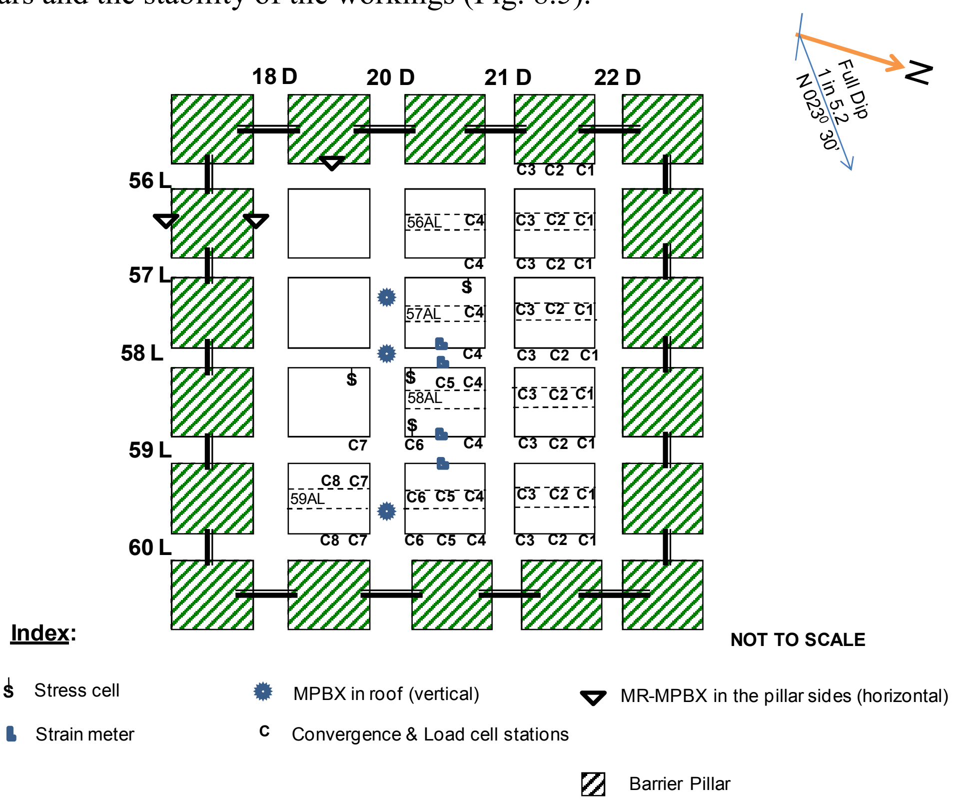


Fig. 8.5 Layout of instrumentation to monitor the strata behavior in BG panel 1D at GDK-10 incline, SCCL

8.7 Design of slopes in Goan iron ore mines, SS0701, On-going
(Atul Gandhe & V. Venkateswarlu)

Iron ore extraction is being carried out by opencast method at M/s Salgaocar Mining Industries Pvt. Limited, and M/s VS Dempo & Co Private Limited, 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 (Fig. 8.6). The soft formations are characterised by the presence of tension cracks during rainy season. The region receives heavy rainfall every year, which reduces the shear strength of the slope formations, causing slope failures. Studies were initiated to investigate the stability of the pit slopes at the mines of the two companies and to suggest suitable design parameters.

Fig. 8.6 Laterite at the top and soft clay below it, forming weak benches at an iron ore mine in Goa

For designing the ultimate angle of the pit slopes, NIRM carried out analysis based on limit equilibrium method using software GALENA (developed by the BHP, Australia). Soil samples were collected from the mine and the physico-mechanical properties of the soil/rocks were determined at the laboratory. These properties were the basic input parameters for the analysis.

The analysis for the individual benches at Cudnem mine of M/s VM Salgaocar in different lithological units under dry as well as fully saturated condition indicated that the maximum angle of the individual benches shall be 71^0, and the maximum height shall be 6 m (Fig. 8.7).

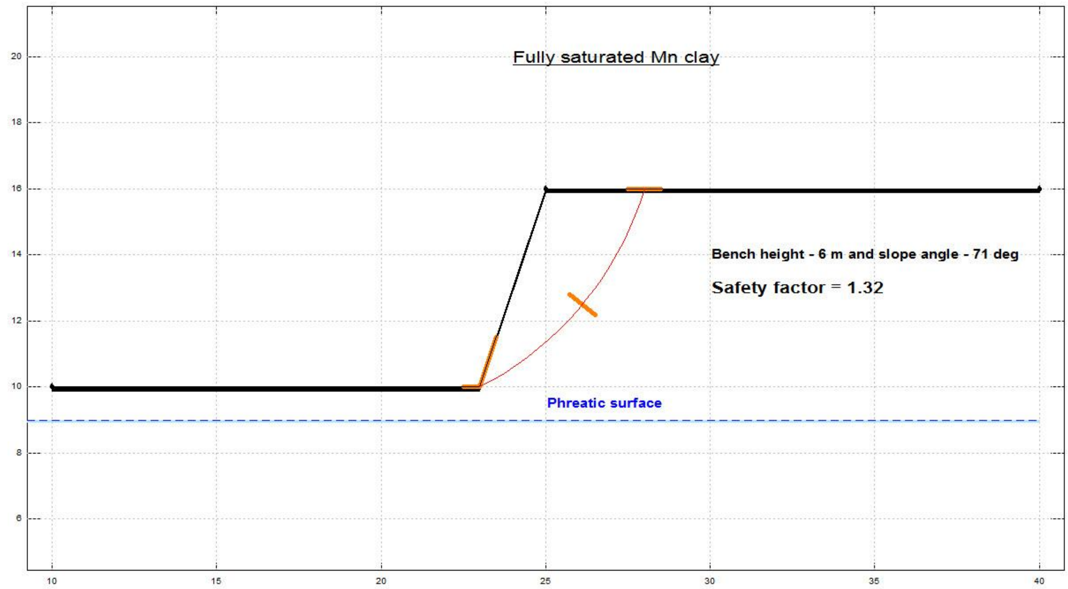


Fig. 8.7 Analysis of the individual bench slope parameters

The slope stability analysis was carried out for the overall pits under dry and saturated conditions. Critical failure surfaces were identified for the different slope profiles and the factor of safety was estimated. The existing slopes were found stable under dry condition with a safety factor of more than 2.0 (Fig. 8.8).

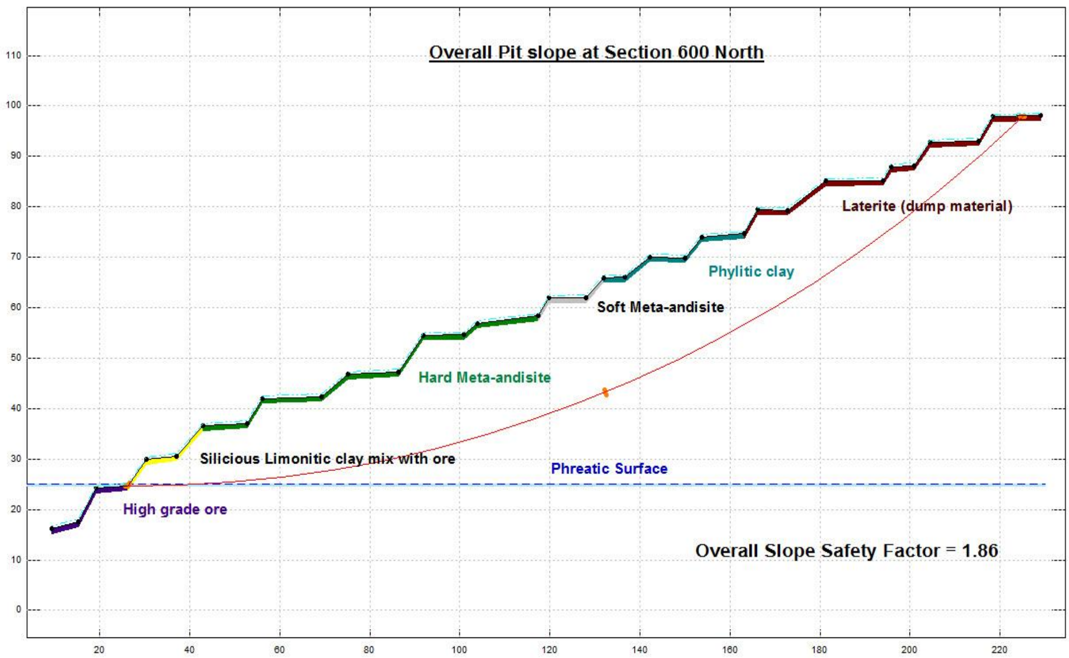


Fig. 8.8 Analysis of the stability of overall slope

9. DIMENSIONAL STONE TECHNOLOGY

9.1 Assessment and expert opinion on rock strata classification at Pattuvum and adjoining villages for Contract Package-3 of JBIC Assisted Kerala Water Supply Project, Kerala, Project No. GM0801, Completed

(A. Rajan Babu and P. C. Nawani)

The Kerala Water Authority (KWA) approached NIRM to assist in strata classification during trench excavation for laying pipelines in the Kannur district, Kerala. It was required to distinguish between: a) All types of soil strata excluding hard rock and b) Hard rock. Investigations were carried out to assess the ground strata at six places covering both field and laboratory studies. Massive, compact and hard laterite formation is observed in the exposed area. Generally, laterite is cut into bricks with cutting machines and used as building material. P-wave velocity and uniaxial compressive strength were mainly used as the criteria for rock classification. The rebound hardness using Schmidt hammer was also used to estimate the in-situ uniaxial strength of the strata. A total of six samples were taken from Kurumathur, Ezhome, Pariyaram and Kadanapalli villages to determine their uniaxial compressive strength and density. P-wave velocities and rebound hardness were also measured at these locations. Figs. 9.1 and 9.2 show the photographs taken during the field investigations.

The average P-wave velocities ranged from 1695 to 2195 m/s. Considering the P-wave velocity rippability classification, strata was grouped under the class “Difficult, Possible Local Blasting”. The average uniaxial compressive strength varied from 13 to 54 MPa and the in-situ estimated average UCS ranged from 20 to 88 MPa. Therefore, the strata were grouped into “Hard rock” category. The measured P-wave velocities and the determined compressive strength values suggest that the strata needs at least a 250 KW Tractor for ripping in ordinary conditions equivalent to a DL8 single shank Tractor of Caterpillar. It was recommended to delineate the ground strata based on uniaxial strength classification and seismic p-wave velocity method. Samples for laboratory testing may be taken at an interval of 1000 m to study their uniaxial compressive strength. The values exceeding 12.5 MPa can be treated as hard rock. Alternately, samples for laboratory testing may be taken at an interval of 1000 m and P-wave velocities may be measured at 500 m intervals. The strata conditions may vary widely and therefore it is recommended to conduct a separate study to delineate the strata along trench alignment and to finalise the exaction. In order to minimise the disputes, it is suggested that a geotechnical baseline report should be provided in the contract document as the common basis for all bidders. This method will provide sufficient indication to classify the strata as soil or rock.

9.2 Setting up of a Test House at Jaipur, Project No. GM0202, Completed

(A. Rajan Babu)

In addition to the final report submitted earlier, the scope of work included: 1) Layout of the building, 2) Type of testing facilities, 3) Equipment for conducting various tests, 4) Specification of the equipment with possible suppliers, 5) Tests standards to be observed, and 6) Staff requirements. On fulfilling the scope of work in all respects, the test house at Jaipur was commissioned successfully. The completion report was submitted in November 2008.

Fig. 9.1 P-wave velocity measurements in the trench

Fig. 9.2 Rock sample being extracted using laterite cutting machine

10. ENVIRONMENTAL ENGINEERING

Environmental audit is essential for mining and allied industries. The Environmental Engineering Department deals with assessment of air, water and soil qualities, noise survey and measurement of meteorological parameters. During 2008-09, this department was involved in one S&T project.

10.1 Study on blasting dust management system in an open cast coal mine, Ministry of Coal, Government of India, S&T Project No. EE0601R, On-going

(S. Roy, T. A. Renaldy and G. R. Adhikari)

Blasting produces large quantities of dust and aerosol, which can affect the surrounding environment, human beings, animals, and plants, the extent of which depends on the meteorological conditions at the mine site. Dust particles are classified according to their sizes. Total suspended particulate matter (TSP) refers to the particulate matter ranging from 0.1 to 100 μm in diameter. PM_{10} is the particulate matter smaller than 10 μm in diameter.

Blast design parameters such as hole diameter, burden, spacing, hole depth, and stemming column may influence the particulate matter generated during blasting. Meteorological parameters such as wind speed and direction, atmospheric stability, and mixing height affect the dispersion characteristics of particulate pollutants. To know the influence of these parameters, studies were carried out at Dudhichua Project, Northern Coalfields Limited, India in the post monsoon season. The scope of the investigations was: to quantify PM_{10} and TSP generated due to blasting, to assess the influence of blast design parameters on the particulate matter, to develop multiple regression model for the PM_{10} and TSP prediction, to find out a suitable blasting schedule using dispersion factors, and to develop emission factors for the blasting dust.

Respirable dust samplers, Instrumex IPM 115BL, were used for the measurements of particulate matter, both TSP and PM_{10}. This dust sampler utilises a two-stage collection system for fractionating the particulate matter sizes. The first stage consists of a cyclone through which the particles greater than 10 μm sizes are separated from the air stream by centrifugal forces acting on the solid particles. The separated particulate falls through the cyclone's conical hopper and collected in the sampling bottle placed at its bottom. PM_{10} is collected from the ambient air in the second stage by filtering the air stream through the glass microfibre filter. TSP contained both PM_{10} and the particles greater than 10 μm size.

Whatman GF/A filter papers of 203 mm x 254 mm size were used for collection of PM_{10} and plastic cups for the particulate matter greater than 10μm size. The filter papers were conditioned and desiccated before and after sampling. For the determination of particulate matter mass, initial and final weight of sampling bottles and filter papers was taken using 235S Sartorius balance with sensitivity of 0.00001g.

Dust samplers were installed at safe distances from the blast site at increasing distances along the downwind direction. Before their installations, a number of blasts were observed for accumulation period of dust toward downwind direction and accordingly 20 minutes monitoring periods were considered for the sampling of blasting dust. After this period the emitted dust was dispersed and diluted at higher height in different directions. Location of samplers varied as blasts were conducted at different locations. During the blasting period, all other activities of the mine were stopped. Therefore, blasting dust monitoring was not affected by the other activities. A total of 21 blasts at shovel-dumper and dragline benches were monitored during post monsoon.

In order to assess the influence of varying distances on suspended particulate matter concentrations, some blasts were monitored by installing the samplers at different distances from the blast site.

An Automatic Weather Station of Lawrence & Mayo (India) Pvt. Ltd. was installed on the roof of the time office building in the mine premises. This weather station consists of a data acquisition unit, sensors for wind speed, wind direction, air temperature, humidity, solar radiation and rainfall. The portable digital data bank is a part of the data acquisition unit, which automatically records the data at an interval of one minute.

A tri-axis SODAR of Global Environmental Technologies, India was installed at the project office. The tri-axis antenna provides high power transmission and large area of scattering of the acoustics waves. The intensity is displayed online on the computer monitor and the mixing height is given at hourly intervals. Thermal plumes and mixing height determined by the SODAR helps in the assessment of atmospheric stability class. The software allows for selection of operational parameters such as sampling rate, resolution etc. The measurement is automatic and continuous with time. Locations of respirable dust samplers, automatic weather station and SODAR are marked on the mine plan (Fig. 10.1). Wind rose diagram of post monsoon season is shown in Fig. 10.2.

Multiple regression analysis of blast design parameters with PM_{10} and TSP shows that blast design parameters have influence on dust concentrations. An increase in the explosive quantities increased the particulate emission. Wind rose diagram for post monsoon season indicated that WSW was the predominant wind direction. Maximum dispersion factor was observed for the period 12:00-13:00 hr which is best time for blasting to minimize dust impact on surrounding area. The predictive equations for emission factors developed in the present study can be used to implement emission control strategies at the mine.

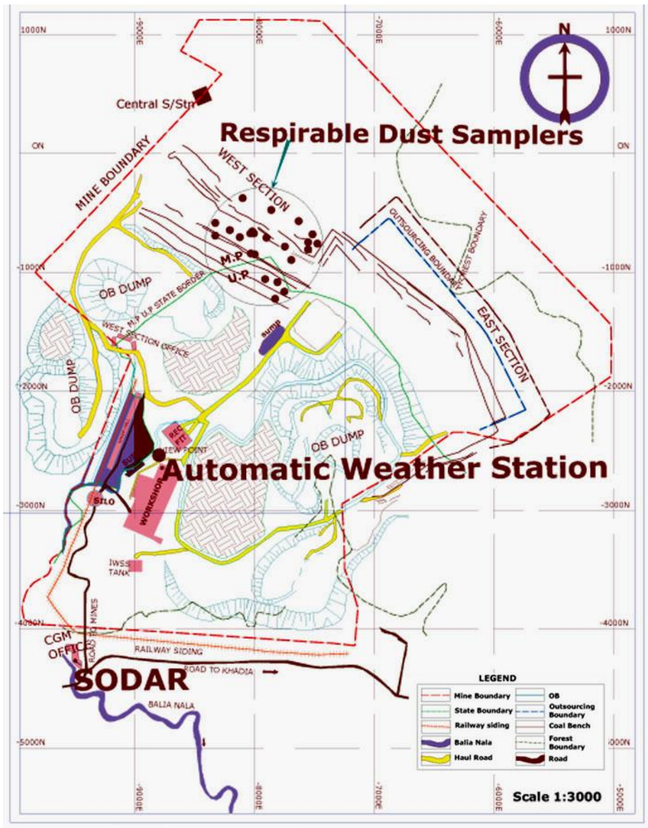


Fig. 10.1 Locations of instruments marked on the mine plan of Dudhichua project, NCL

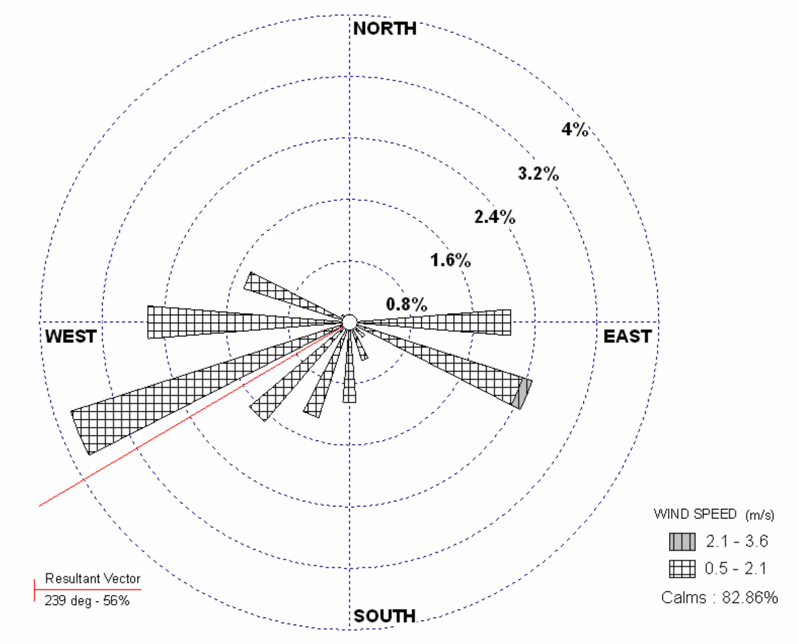


Fig. 10.2 Wind rose diagram of post monsoon season at Dudhichua project, NCL

11. TECHNICAL COORDINATION & PROJECT MANAGEMENT DEPARTMENT

(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
2. Project Management
3. Human Resource Development
4. Publications & Publicity
5. IPR & Technology Transfer
6. Library & Information

1. Technical Coordination

- Liaisoning between the Institute and the Industry/sponsoring agency
- Inter-departmental coordination within the Institute
- Techno-commercial communications related to projects etc
- 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
- Resource management (requirement of manpower and equipment)
- 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
- 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. Human Resource Development

- Co-ordination for deputation/nomination of Scientists and Staff to training programs, seminars/symposia within and outside India
- Organising training programmes, seminars/symposia
- Sponsoring Scientists for doctoral/Post-Doctoral studies and exchange visits
- Providing research facilities to external candidates from academic institutions

4. 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

5. IPR & Technology Transfer
- Facilitating to secure patents for innovative research
- Technology transfer to industrial houses for new products
- Marketing applications of new technologies

6. Library & Information

The NIRM library and information centre has a large collection of books, conference proceedings, thesis/dissertations, standards/specifications and technical reports. The library subscribes a large number of Indian and foreign journals. The collections in the library pertain to specialised fields of rock mechanics, mining engineering, engineering geology, engineering geophysics, mathematical sciences, tunnelling, seismology etc. The library caters to the needs of Scientists of NIRM. It can also be used by academic institutions and esteemed clients of NIRM.

GRSM & ASSOCIATES
Chartered Accountants

AUDIT REPORT

To
The Members of National Institute of Rock Mechanics,
Kolar Gold Fields.

We have audited the attached balance sheet of National Institute of Rock Mechanics, K. G. F. as at 31st March 2008 and also the Income & Expenditure Account for the year ended on that date annexed thereto. These financial statements are the responsibility of the Institute's Management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with auditing standards generally accepted in India. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion and we report that:

1. we have obtained all the information and explanations, which to the best of our knowledge and belief were necessary for the purpose of the audit
2. In our opinion proper books of accounts have been kept by the Institute so far as it appears from our examination of such books.
3. The balance sheet and income & expenditure account dealt with by this report are agreement with the books of account.
4. In our opinion and to the best of our information and according to the explanation given to us, subject to:
    i) No details & confirmation in respect of certain old outstanding receivable and payables were available.
    ii)

the said accounts give a true and fair view;

i) in the case of the balance sheet, of the state of affairs of the Institute as at 31.03.2008; and
ii) in case of Income and expenditure account, of the excess of Income over expenditure for the year ended on that date.

For GRSM & Associates
Chartered Accountants

Sd/-
Gopalkrishna Hegde
Partner

Place: Bangalore
Date: 12-09-2008

NATIONAL INSTITUTE OF ROCK MECHANICS
Champion Reefs Post, KOLAR GOLD FIELDS – 563 117.

SCHEDULE

ACCOUNTING POLICIES AND NOTES ON ACCOUNT FORMING PART OF BALANCE SHEET AND INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDING 31ST MARCH 2008.

1. ACCOUNTING POLICIES :-

A. Method of Accounting:

The Institute has maintained its accounts on cash basis, other than the below mentioned items, which have been accounted on accrual basis.

1) Grant-in-aid for Capital and Recurring Expenditure.
2) Anticipated expenditure on projects towards printing and presentation of reports.

B. Fixed Assets:

Fixed Assets are capitalised at acquisition costs.

C. Foreign Exchange Transactions:

All imports of capital items by the Institute are through advance payments. Thus foreign exchange transactions are entered in the books at the actual conversion rate. Hence, no adjustments are required for fluctuation in exchange rates.

D. Revenue Recognition:

1. The income from Research & Development projects is recognised on completed contract basis.
2. The Government Grant are accounted as Grants-in-Aid against the recurring expenditure are recognized, when there is reasonable assurance that the same will be received on the basis of Sanction Letter by the Ministry of Mines which are received after the date of Balance Sheet.

E. Treatment of Government Grant:

The Ministry of Mines has not released "Non-Plan" and 'Plan" Grant for the year 2007-08.

[** Grant received from Ministry of Mines under "Non-Plan" is utilised to meet "Pay & Allowances". Grants received under 'Plan" is utilised to meet capital expenditure.

The Capital Grant received for 'Plan' is allocated to income over the period in the same proportion as the depreciation is charged on the assets purchased from the Capital Grant. Balance of capital grants appear as Deferred Government Grants in balance sheet under "Other Funds". **]

F. Retirement Benefits:

The Institute has made arrangement with Life Insurance Corporation of India for payment of gratuity under the Cash Accumulation Group Gratuity Scheme. The premium paid under this head is charged to "Pay & Allowances".

Regarding Provident Fund accumulation, this Institute has been enrolled with the Employees Provident Fund Organization, Bangalore. The Institute's contribution towards the Provident Fund is charged to "Pay & Allowances".

G. Depreciation:

Depreciation is charged on straight-line basis as per the method specified by the Government of India, Department of Economic Affairs vide their letter No.4/24/63-GS dated 27th September 1968.

As per this letter, depreciation on additions to Fixed Assets during the year has to be charged at full rate if they are put into use before 30th September, at half of the rate, if they are put into use between 1st October and 31st December and at one fourth of rate, if assets are put to use after 31st December of the relevant financial year. Upto 1998-99, the one-fourth rate of depreciation for assets put to use for less than three months was not implemented. This has been followed from 1999-2000 onwards.

2. NOTES ON ACCOUNTS: -

1. Capital Reserve represents value of assets transferred free of cost by BGML during 1988-89.

2. The land on which the properties transferred during the year 1988-89 by BGML to the Institute has been retained in BGML books, subject to obtaining the direction from the Government of India, on the transfer of land and other formalities. As the Conveyance Deed for transfer of land and building to the Institute could not be executed, the Governing Body has approved the proposal for entering into lease agreement, instead. Necessary adjustments in the accounts if required will be done on execution of lease agreement.

3. The approval of the Central Government that the Institute is a notified association for carrying on Research and Development activities under the section 35(1)(ii) of the Income Tax Act 1961, read with rule 6 of the Income Tax Rules 1962, was up to 31st March 2005. The application for renewal of the same has been submitted to the Income Tax Department and is under active consideration. In view of this, no provision for income tax for the year has been made in the books of accounts.

4. Provision for purchases of Capital equipments/assets have been made in the books of accounts for 2007-08, since a definite liability has arisen before the close of the financial year due to issue of purchase orders after completion of the detailed tendering process.

5. A departmental enquiry was instituted on an alleged misappropriation of funds during 1994-98. The institute estimates the value of such misappropriation to be about Rs.46,68,645/-. The misappropriation was by falsely creating expenses /asset and the

amounts were charged off to the Income & Expenditure Account as expenses/ depreciation over the years. Any recovery in future from the concerned person will be treated as income in the year of recovery of money. In addition to the above, a case on the same person for forgery is pending before the CBI Special Court, Bangalore.

6. It is the normal practice of the Institute to charge off the expenses of manpower component of respective S&T projects and transfer to a pool account of NIRM to meet out shortfall in "Pay & Allowances " and other expenses.

7. As per the decision of 36th Governing Body Meeting held at Chamber of Secretary, Ministry of Mines, New Delhi, on 27-09-1999, the Institute has decided to present in addition to the general purpose financial statements, a separate set of financial statements for its Institutes Activities and Research/ Sponsored Project activities from the current year, to reflect the performance of the projects.

8. The balances of parties' account are subject to confirmation.

9. The previous year figures have been re-grouped, re-classified or renamed wherever necessary to confirm with the current year presentation.

10. The figures pre-fixed with the (+) or (-) under the column head "Variation during the year" in Balance Sheet as on 31-3-2008 represents the transaction carried out during the year including the value for written off adjustments and corrections.

Controller of Administration　　　　　　　　　　Director

Member

Refer our report of even date
For G R S M & ASSOCIATES
Chartered Accountants

Place: Bangalore　　　　　　　　　　(GOPALKRISHNA HEGDE)
Date:12-09-2008　　　　　　　　　　Partner

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS
BALANCE SHEET AS AT 31ST MARCH 2009

Consolidated Account

LIABILITIES						ASSETS					
Sl. No.	Particulars	Sch No.	Balance as on 01-04-2008	Variation during the year (+) (-)	Balance as on 31-03-2009	Sl. No.	Particulars	Sch No	Balance as on 01-04-2008	Variation during the year (+) (-)	Balance as on 31-03-2009
			Rs. Ps.	Rs. Ps.	Rs. Ps.				Rs. Ps.	Rs. Ps.	Rs. Ps.
1	2	3	4	5	6	7	8	9	10	11	12
1	**CAPITAL RESERVE**		3244334.00	0.00	3244334.00	1	**CURRENT ASSETS**				
	Internal Capital Reserve		5042413.00	0.00	5042413.00						
							a) Cash in Hand		169243.50	-45702.50	123541.00
2	**OTHER FUNDS**						b) Cash at Bank		10255960.58	-2243252.37	8012708.21
							d) Stock - Stationery Items	5	125170.49	-74478.00	50692.49
	a) Deferred Government Grant		26145304.92	591329.00	26736633.92		e) Sundry Debtors	6	325459.00	0.00	325459.00
	b) Income & Expenditure A/c.		9072771.80	-13958615.50	-4885843.70						
						2	**INVESTMENTS**				
							a) Short term deposits against project advances received	7	48437195.00	-24717371.00	23719824.00
	c) Institute's Development Fund		93000000.00	0.00	93000000.00		b) Institute Development Fund	8	93000000.00	0.00	93000000.00
3	**CURRENT LIABILITIES**					3	**LOANS AND ADVANCES**				
	a)Advances received against on-going projects	1	102132271.1	2424869.63	104557140.8		a) Advances - Staff	9	616150	602828	1218978
	b)Sundry creditors - pay roll deductions	2	139042.20	-74627.00	64415.20		b) Advances - Suppliers	10	8208050	-6147975	2060075
	c) Sundry Creditors - Staff	3	566318.05	-351000.00	215318.05						
	d)Sundry Creditors - Others	4	3331942.06	-1980787.00	1351155.06	4	**DEPOSITS**	11	29900.00	367510.00	397410.00
						5	**OTHER CURRENT ASSETS**		2664785.05	10494868	13159653.05
							Expenses on Ongoing Projects	12	58018669.46	3613033.00	61631702.46
						6	**Project Asset**	13	0.00	574883.00	574883.00
						7	**FIXED ASSETS**	14	20823814.09	4226826.00	25050640.09
	TOTAL		**242674397.17**	**-13348830.87**	**229325566.30**		**TOTAL**		**242674397.17**	**-13348830.87**	**229325566.30**

Details of variation during the year 2008-09 (For Deferred Government Grant)

Plan Grant received during the year for capital expenditure	4700000.00
Less: Depreciation for the year 2008-09 reduced from deferred Capital Grants	-4108671.00
Variation during the year	**591329.00**

Details of variation during the year 2008-09 (For Block of Fixed Assets)

Payments made for purchase of Fixed Assets during the year	8335497.00
Less: Depreciation for the year 2008-09	-4108671.00
Variation during the year	**4226826.00**

Fixed Assets	**31-03-2008**	**31-03-2009**
Gross Block	84,131,539.91	92467036.91
Less: Depreciation	63,307,725.82	67416396.82
Net Block	**20,823,814.09**	**25050640.09**

As per our Report of even date
for UDUPA, POOJARI & SADASHIVA
Chartered Accountants

Sd/-	Sd/-	Sd/-	Sd/-
(A.N.NAGARAJAN)	(DR. P C NAWANI)	Member	(CA.SAHADEV G.POOJARI)
Controller of Administration	Director	Governing Body	Partner

Place : Bangalore
Date: 20-08-2009

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS

Consolidated Account

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2009.

EXPENDITURE				INCOME			
Sl. No.	Head of Account	2008-09	2007-08	Sl. No.	Head of Account	2008-09	2007-08
		Rs. Ps.	Rs. Ps.			Rs. Ps.	Rs. Ps.
1	2	3	3	6	7	8	8
1	Pay & Allowances	33271617.00	17715623.00	1	Grant-in-Aid received from Ministry of Mines	0.00	0.00
2	Expenditure on Completed Project	13599417.00	11447372.00	2	Amount Received agaisnt Completed Projects	30884577.00	26538194.00
3	Other Staff Payment	629948.00	291821.00	3	Miscellaneous Income	8324789.00	15355390.08
4	Administrative Expenses	4613238.00	2747788.70	4	Transfer from Capital Grant towards Depreciation	4108671.00	3431505.00
5	Upkeep of Assets	1042776.50	518346.00				
6	Contingent expenditure on Capital Assets	0.00	99862.00				
7	Depreciation on Fixed Assets	4119656.00	3431505.00				
8	Excess of Income over Expenditure		9072771.38	5	Excess of Expenditure over Income	13958615.50	
	Total:-	**57276652.50**	**45325089.08**		**Total:-**	**57276652.50**	**45325089.08**

As per our Report of even date
for UDUPA, POOJARI & SADASHIVA
Chartered Accountants

Sd/-
(A.N.NAGARAJAN)
Controller of Administration

Sd/-
(DR.P.C.NAWANI)
Director

Sd/-
Member
Governing Body

Sd/-
(CA.SAHADEV G.POOJARI)
Partner

Place : Bangalore
Date: 20-08-2009

NATIONAL INSTITUTE OF ROCK MECHANICS

Champion Reefs Post, KOLAR GOLD FIELDS

Receipt and Payment Account for the year ending on 31st March 2009.

RECEIPT SIDE				PAYMENT SIDE			
Sl. No.	**Head of Account**	**Amount**	**Amount**	**Sl. No.**	**Head of Account**	**Amount**	**Amount**
		Rs. Ps.	**Rs. Ps.**			**Rs. Ps.**	**Rs. Ps.**
1	**2**	**3**	**4**	**5**	**6**		**8**
1	**Opening Balance as on 1.4.2008**						
	a. Cash on Hand		169243.50	1	**Fixed Assets**		
	b. Cash at Bank		10255960.58		Transactions	857446.00	857446.00
	Govt Grant Capital A/c	4700000.00	4700000.00				
2	**Current Liabilities**		40616810.63	2	**Current Liabilities**		19887170.00
	a) Against projects	33776227.63			a) Against projects	11283925.00	
	b) Against others	6840583.00			b) Against others	8603245.00	
3	**Investments**	41037195.00	41037195.00	3	**Investments**	41319824.00	41319824.00
4	**Current Assets**			4	**Current Assets**		
	a) Sundry Creditors		500330.00		**a) Sundry Creditors**		13914488.00
	a) Pay Roll Deduction				a) Pay Roll Deduction		
	b) Others	48303.00			b) Others	8526156.00	
	c) Against projects	452027.00			c) Against projects	5388332.00	
	b) Loans & Advances		4399814.00	3	**b) Loans & Advances**		8880520.00
	a) Staff	4093786.00			a) Staff	8447913.00	
	b) Others				b) Others	65097.00	
	c) Deposits				c) Deposits	367510.00	

	d) Suspenses A/c	306028.00					
	c) Direct Expenses		188502.00		**c) Direct Expenses**		42087483.50
	a) Pay & Allowances	50000.00			a) Pay & Allowances	33545232.00	
	b) Administrative Expenses	125547.00			b) Administrative Expenses	7176467.00	
	c) Upkeep of Assets	12955.00			c) Upkeep of Assets	731387.00	
	d) Consumables & Contingency				d) Consumables & Contingency	604397.50	
					e) Stipend RA/RF	30000.00	
4	**Indirect Income**		8268087.00	**4**	**Indirect Income**		52762.00
	a) Interest on SB/TDR/IDF	8010732.00			a) Interest on SB/TDR/IDF	7445.00	
	b) Miscellaneous	211702.00			b) Miscellaneous	45000.00	
	c) Interest on advances	15154.00			c) Interest on advances	317.00	
	d) Income from Projects	30499.00			d) Income from Projects		
5	**NIRM Institute Development Fund**	97500000.00	97500000.00	**5**	**NIRM Institute Development Fund**	72500000.00	72500000.00
				6	**Closing Balance as on 31-03-2009**		
					a) Cash on Hand		123541
					b) Cash at Bank		8012708.21
	Total:-		**207635942.71**		**Total:-**		**207635942.71**

As per our Report of even date
for UDUPA, POOJARI & SADASHIVA
Chartered Accountants

Sd/-	Sd/-	Sd/-	Sd/-
Controller of Administration	Director	Member	(CA.SAHADEV G POOJARI)
		Governing Body	

Place : Bangalore
Date: 20-08-09

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

BALANCE SHEET AS AT 31ST MARCH 2009

Institute A/c

LIABILITIES						ASSETS					
Sl. No.	**Particulars**	**Sch No.**	**Balance as on 01-04-2008**	**Variation during the year (+) (-)**	**Balance as on 31-03-2009**	**Sl. No.**	**Particulars**	**Sch No**	**Balance as on 01-04-2008**	**Variation during the year (+) (-)**	**Balance as on 31-03-2009**
			Rs. Ps.	**Rs. Ps.**	**Rs. Ps.**				**Rs. Ps.**	**Rs. Ps.**	**Rs. Ps.**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	**CAPITAL RESERVE**		3244334.00	0.00	3244334.00	1	**CURRENT ASSETS**				
	Internal Capital Reserve		5042413.00	0.00	5042413.00		a) Cash in hand		15850.00	53677.00	**69527.00**
							b) Cash at bank		7257639.49	-23915971.91	**-16658332.42**
2	**OTHER FUNDS**						c) Short term deposits against project advances received	4	10600000.00	12319824.00	**22919824.00**
	a) Deferred Government Grant		26145304.92	591329.00	26736633.92	2	**LOANS AND ADVANCES**				
	b) Income & Expenditure A/c.		9072771.38	-32558296.50	-23485524.70		a) Advances - Staff	5	350740.00	61155.00	**411895.00**
	c) Institute Development Fund		93000000.00	0.00	93000000.00		b) Advances - Others	6	7493785.00	-5695924.00	**1797861.00**
							c) Income Tax A Y 2006-07	7	0.00	7891905.00	**7891905.00**
3	**CURRENT LIABILITIES**										
	a) Sundry Creditors - Pay Roll Deductions	1	139042.20	-74627.00	64415.20	3	**DEPOSITS**	8	29900.00	367510.00	397410.00
	b) Sundry Creditor - Staff	2	565021.05	-351000.00	214021.05						
	c) Sundry Creditors -Othes	3	2388537.61	-2145980.00	242557.61	4	**OTHER CURRENT ASSETS**	9	9803.00	7018.00	16821.00
						5	**INVESTMENTS**				
							Institute Development Fund	10	93000000.00	-29838700.59	**63161299.41**
	…					6	**FIXED ASSETS**	11	20823814.09	4226826.00	**25050640.09**
	TOTAL		**139581531.58**	**-34522681.50**	**105058850.08**		**TOTAL**		**139581531.58**	**-34522681.50**	**105058850.08**

Details of variation during the year 2008-09 (For Deferred Government Grant)

Plan Grant received during the year for capital expenditure	4700000.00
Less: Depreciation for the year 2008-09 reduced from deferred Capital Grants	-4108671.00
Variation during the year	**591329.00**

Details of variation during the year 2008-09 (For Block of Fixed Assets)

Payments made for purchase of fixed assets during the year		8335497.00
Less: Depreciation for the year 2008-09		-4108671.00
Variation during the year		**4226826.00**
	31-03-2008	**31-03-2009**
Gross Block	84,131,539.91	92467036.91
Less: Depreciation	63,307,725.82	67416396.82
Net Block	20,823,814.09	25050640.09

As per our Report of even date
for UDUPA, POOJARI & SADASHIVA
Chartered Accountants

Sd/-	Sd/-	Sd/-	Sd/-
(A.N.NAGARAJAN)	(Dr.P.C.NAWANI)	Member	(CA.SAHADEV G.POOJARI)
Controller of Administration	Director	Governing Body	Partner

Place : Bangalore
Date: 20-08-2009

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS

Institute A/c

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31ST MARCH 2009.

EXPENDITURE				INCOME			
Sl. No.	**Head of Account**	**2008-09**	**2007-08**	**Sl. No.**	**Head of Account**	**2008-09**	**2007-08**
		Rs. Ps.	**Rs. Ps.**			**Rs. Ps.**	**Rs. Ps.**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Pay & Allowances	33271617.00	17715623.00	**1**	Surplus from projects transferred to Institute account	0.00	21869320.00
2	Other Staff Payment	629948.00	291821.00	**2**	Grant-in-Aid received from Ministry of Mines	0.00	0.00
3	Administrative Expenses	4613238.00	2747788.70	**3**	Miscellaneous income	6999283.00	8576892.08
4	Upkeep of Assets	1042776.50	518346.00	**4**	Transfer from Capital Grant towards Depreciation	4108671.00	3431505.00
5	Depreciation on Fixed Assets	4108671.00	3431505.00				
6	Contingent expenditure on Capital Assets	0.00	99862.00				
7	Excess of Income over Expenditure	0.00	9072771.38	**5**	Excess of Expenditure over Income	32558296.50	0.00
	Total:-	**43666250.50**	**33877717.08**		**Total:-**	**43666250.50**	**33877717.08**

As per our Report of even date
for UDUPA, POOJARI & SADASHIVA
Chartered Accountants

Sd/-	Sd/-	Sd/-	Sd/-
(A.N.NAGARAJAN)	(DR.P.C.NAWANI)	Member	(CA.SAHADEV G.POOJARI)
Controller of Administration	Director	Governing Body	Partner

Place : Bangalore
Date: 20-08-2009

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS

PROJECT ACCOUNT

BALANCE SHEET AS AT 31ST MARCH 2009

LIABILITIES						ASSETS					
Sl. No.	Particulars	Sch No.	Balance as on 01-04-2008	Variation during the year (+) (-)	Balance as on 31-03-2009	Sl. No.	Particulars	Sch No	Balance as on 01-04-2008	Variation during the year (+) (-)	Balance as on 31-03-2009
			Rs. Ps.	Rs. Ps.	Rs. Ps.				Rs. Ps.	Rs. Ps.	Rs. Ps.
1	2	3	4	5	6	7	8	9	10	11	12
1	**CAPITAL RESERVE**					1	**CURRENT ASSETS**				
2	**OTHER FUNDS**						a) Cash in Hand		153393.50	-99379.50	54014.00
	Income From Completed Projects			18599681.00	18599681.00		b) Cash at Bank		2998321.09	21672719.54	24671040.63
							c) Stock - Stationery Items	4	125170.49	-74478.00	50692.49
3	**CURRENT LIABILITIES**						d) Sundry Debtors - MTL	5	325459.00	0.00	325459.00
	a) Advance received against on-going projects	1	102132271.14	2424869.63	104557140.77	2	**INVESTMENTS**				
	b) Sundry Creditors - Others	2	944701.45	103228.00	1047929.45		a) NIRM Institute Development Fund	6		29838700.59	29838700.59
							b) Short Term Deposits against Project Advances received	7	37837195.00	-37037195.00	800000.00
	c) Sundry Creditors - Suppliers	3	0.00	61965.00	61965.00						
						3	Expenses on Ongoing Projects	8	58018669.46	3613033.00	61631702.46
						4	**LOANS AND ADVANCES**				
							a) Advances - Staff	9	265410.00	541673.00	807083.00
							b) Advances - Suppliers	10	714265.00	-452051.00	262214.00
						5	**Other Current Assets**	11	2654982.05	2595945.00	5250927.05
						6	**Fixed Assets**	12		574883.00	574883.00
							Gross Block as on 31-03-09 Rs.585868.00				
							Less: Depreciation 10985.00				
							Net Block as on 31-03-09 Rs.574883.00				
	…..										
	TOTAL		**103092865.59**	**21173850.63**	**124266716.22**		**TOTAL**		**103092865.59**	**21173850.63**	**124266716.22**

As per our Report of even date
for UDUPA, POOJARI & SADASHIVA
Chartered Accountants

Sd/-
(A.N.NAGARAJAN)
Controller of Administration

Sd/-
(Dr.P.C.NAWANI)
Director

Sd/-
Member
Governing Body

Sd/-
(CA.SAHADEV G.POOJARI)
Partner

Place : Bangalore
Date: 20-08-2009

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS

PROJECT ACCOUNT

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31ST MARCH 2009.

EXPENDITURE				INCOME			
Sl. No.	**Head of Account**	**2008-09**	**2007-08**	**Sl. No.**	**Head of Account**	**2008-09**	**2007-08**
		Rs. Ps.	**Rs. Ps.**			**Rs. Ps.**	**Rs. Ps.**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Expenditure on completed projects	13599417.00	11447372.00	1	Amount received against completed projects	30036076.00	25123194.00
2	Depreciation on Fixed Assets - Project	10985.00	0.00	2	Manpower charges against S & T Projects	848501.00	1415000.00
3	Excess of Income over Expenditure	18599681.00	21869320.00	3	Interest received on Short Term Deposits (Projects)	1325506.00	6778498.00
	Total:-	**32210083.00**	**33316692.00**		**Total:-**	**32210083.00**	**33316692.00**

As per our Report of even date
for UDUPA, POOJARI & SADASHIVA
Chartered Accountants

Sd/-	Sd/-	Sd/-	Sd/-
(A.N.NAGARAJAN)	(DR.P.C.NAWANI)	Member	(CA.SAHADEV G.POOJARI)
Controller of Administration	Director	Governing Body	Partner

Place : Bangalore
Date : 20-08-2009

Annexures

Annexure -1

ORGANISATION CHART

Annexure - 2

MEMBERS OF THE GENERAL BODY

Chairperson

Ms. Santha Sheela Nair, IAS
Secretary to the Government of India
Ministry of Mines
III Floor, A Wing, Room No. 320
Shastri Bhawan, Dr Rajendra Prasad Road
New Delhi - 110 001

Members

Shri S. Vijay Kumar, IAS
Addl. Secretary to the Govt. of India
Ministry of Mines
I Floor, D Wing, Shastri Bhawan
Dr Rajendra Prasad Road
New Delhi - 110 001

Shri Sanjiv Mittal, IAS
Jt. Secretary & Financial Advisor
Ministry of Mines
III Floor, A Wing, R.No.321A
Shastri Bhawan
Dr Rajendra Prasad Road
New Delhi - 110 001

Dr. K. Ayyasami
Director (Technical)
Ministry of Mines
III Floor, D Wing, Room No. 311
Shastri Bhawan
Dr Rajendra Prasad Road
New Delhi - 110 001

Director General
Geological Survey of India
27, Jawaharlal Nehru Road
Kolkata – 700 016
West Bengal.

Director General of Mines Safety
Diretorate General of Mines Safety
Dhanbad ─ 826 001
Jharkhand

Controller General
Indian Bureau of Mines
Indira Bhavan, Civil Lines
Nagpur - 440 001

Shri S. K. Dodeja
Director (Projects)
National Hydro-Power Corporation
NHPC Office Complex, Sector-33
Faridabad - 121 003
Uttara Pradesh

Shri Ravi Shanker
Director General(Retd) – GSI
B - 5, Sector K, Aliganj
Lucknow - 226 024

Shri B. K. P. Sinha
1/15, H I G
Rajasthan Housing Board Colony
Goverdhan Vilas
Udaipur - 313 001
Rajasthan

Prof. A. K. Ghose
Apartment No. 3B,
104, Regent Estate
Kolkata – 700 092
West Bengal

Dr. P. C. Nawani
Director
National Institue of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Shri K. B. Dubey
Director (Projects)
NTPC Ltd
SCOPE Complex, Core-7, 5th Floor
7, Institutional Area, Lodhi Road
New Delhi - 110 003

Shri A. K. Bhandari
Advisor (TPPC)
Ministry of Mines
CGO Complex, Block 11 (Eleven)
5th Floor, Lodhi Road
New Delhi - 110 003

Dr. J. Mukhopadhyay
Director
National Institute of Miners' Health
JNARDDC Campus
Opposite to Wadi Police Station
Amravati Road, Wadi
Nagpur - 440 023

Secretary (Non–Member)
Sri A. N. Nagarajan
Secretary
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Annexure -3

MEMBERS OF THE GOVERNING BODY

Chairperson

Ms. Santha Sheela Nair, IAS
Secretary to the Government of India
Ministry of Mines
III Floor, A Wing, Room No.320
Shastri Bhawan, Dr Rajendra Prasad Road
New Delhi - 110 001

Members

Shri S. VijayKumar, IAS
Addl. Secretary to the Govt. of India
Ministry of Mines
I Floor, D Wing, Shastri Bhawan
Dr Rajendra Prasad Road
New Delhi - 110 001

Shri Sanjiv Mittal, IAS
Jt. Secretary & Financial Advisor
Ministry of Mines
III Floor, A Wing, Room No.321A
Shastri Bhawan
Dr Rajendra Prasad Road
New Delhi - 110 001

Dr. K. Ayyasami
Director (Technical)
Ministry of Mines
III Floor, D Wing, R.No.311
Shastri Bhawan
Dr Rajendra Prasad Road
New Delhi - 110 001

Director General
Geological Survey of India
27, Jawaharlal Nehru Road
Kolkata - 700 016
West Bengal

Director General of Mines Safety
Diretorate General of Mines Safety
Dhanbad - 826 001
Jharkhand

Controller General
Indian Bureau of Mines
Indira Bhavan, Civil Lines
NAGPUR - 440 001

Shri S. K. Dodeja
Director (Projects)
National Hydro-Power Corporation
NHPC Office Complex, Sector-33
Faridabad - 121 003
Uttara Pradesh

Shri Ravi Shanker
Director General (Retd) - GSI
B-5, Sector K, Aliganj
Lucknow - 226 024

Shri B K P Sinha
1/15, H I G
Rajasthan Housing Board Colony
Goverdhan Vilas, Udaipur - 313 001
Rajasthan

Prof. A. K. Ghose
Apartment No. 3B
104, Regent Estate
Kolkata - 700 092
West Bengal

Dr. P. C. Nawani
Director
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields-563 117

Member (D&R)
Central Water Commission
Room No. 401(S) Sewa Bhawan
R. K. Puram
New Delhi - 110 066.

Shri P. R. Mandal
Advisor (Projects)
Ministry of Coal
III Floor, Room No. 309-A
Shastri Bhawan
New Delhi - 110 001

Secretary (SSI & Mines)
Government of Karnataka
Vikas Soudha
Bangalore - 560 001

Secretary (Non –Member)
Sri A. N. Nagarajan
Secretary
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Annexure - 4

MEMBERS OF THE PEER REVIEW COMMITTEE

Chairman
Shri Ravi Shanker
Director General (Retd) – GSI
B-5, Sector-K, Aliganj
Lucknow - 226 024

Members

Prof. A. K. Ghose
Apartment No. 3B
104, Regent Estate
Kolkata - 700 092
West Bengal

Shri B K P Sinha
1/15, H I G
Rajasthan Housing Board Colony
Goverdhan Vilas
Udaipur - 313 001
Rajasthan

Member (D&R)
Central Water Commission
Room No. 401 (S), Sewa Bhawan
R. K. Puram
New Delhi - 110 066

Shri K. B. Dubey
Director (Projects)
NTPC Ltd, NTPC Bhawan,
SCOPE Complex, Core-7
5th Floor, 7, Institutional Area
Lodhi Road
New Delhi - 110 003

Shri B. P. Singh
Director of Mines Safety (S&T)
Directorate General of Mines Safety
Dhanbad - 826 001
Jharkhand

Shri A. N. Sahay
Director Technical (RD&T)
Central Mine Planning &
Design Institute Ltd
Gondwana Place, Kanke Road
Ranchi - 834 008
Jharkhand

Dr. P. C. Nawani
Director
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Shri A. K. Bhandari
Advisor, TPPC
Ministry of Mines, Govt of India
5th Floor, Block Eleven
CGO Complex, Lodhi Road
New Delhi - 110 003

Annexure - 5

SUPPORTING ORGANIZATIONS / CLIENTELE
(2008-2009)

Central Government Ministries & Departments

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

State Government / Public Sector Organisations

Himachal Pradesh Power Corporation Limited (HPPCL)
Department of Mines & Geology, Govt of A. P.
Bangalore Metro Rail Corporation Ltd (BMRCL)
Central Mine Planning & Design Institute Limited (CMPDI)
Hindustan Zinc Limited (HZL)
Himachal Pradesh State Electricity Board (HPSEB)
Hutti Gold Mines Limited (HGML)
Kerala Water Authority (KWA)
Kudremukh Iron Ore Company Limited (KIOCL)
Manganese Ore India Limited (MOIL)
Meghalaya State Electricity Board (MeSEB)
National Hydroelectric Power Corporation (NHPC)
NTPC Ltd.
Rail India Technical & Engineering Services (RITES)
Sardar Sarovar Narmada Nigam Limited (SSNNL)
Satluj Jal Vidyut Nigam Limited (SJVNL)
Singareni Collieries Company Limited (SCCL)
Tehri Hydro Development Corporation (THDC)
Karnataka Bhagya Jala Vidyut Nigam Limited (KBJNL)
Uranium Corporation of India Limited (UCIL)
Uttarakhand Jal Vidyut Nigam Limited (UJVNL)

Private Companies

Alliance Mineral Private Limited (AMPL)
Delta Construction Systems (DCS)
Energy Infratech Private Limited (EIPL)
Engineering Projects (India) Ltd. (EPIL)
Essel Mining & Industries Limited (EMIL)
Ferro-Alloys Corporation (FACOR)
Forbes Gokak Limited (FGL)
G. Venkat Reddy & Company (GVR)
India Cements Limited (ICL)

Private Companies (Contd..)

Indian Oil Corporation Limited (IOCL)
L&T - AM JV
Patel-SEW Joint Venture (PSJV)
Salgaocar Mining Industries Private Limited (SMIPL)
Shivgiri Associates
STG Stone Crushers
Surya Constructions
V. S. Dempo & Co. Private Limited (Dempo)
Zoom Mineral Development Private Limited (ZMDPL)
R K Marbles Private Limited
Khandaleru Power Company Limited (KPCL)

International Organisations

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

Annexure – 6

LIST OF PUBLICATIONS

1. Adhikari, G. R., Venkatesh, H. S., Theresraj, A. I. and Balachander, R. "Assessment and control of stemming ejection at surface Mines," *Journal of Visfotak Explosives Safety & Technology Safety*, September 2008, pp. 25-31.
2. Balsubramaniam, V. R., Jha, P. C., Nelliat, S., and Sivaram, Y. V. "GPR survey for evaluating the efficacy of reinforcement in civil structure" *National Seminar on Energy Security and Exploration for Non-Fossil Fuels*, AEG, February 4-6, 2009, Hyderabad.
3. Biju John and Rajendran, C. P. "Evidence of episodic brittle faulting in the cratonic part of the Peninsular India and its implications for seismic hazard in slow deforming regions." *Tectonophysics* Vol. 471(3-4), 2009, pp 240-252.
4. Jha, P.C., Balsubramaniam, V. R., Nelliat, S., and Sivaram, Y.V. "Use of GPR survey to analyse the caving risk in opencast coal mines developed over old underground mines," *International Symposium on Rock Mechanics and Geo-Environment in Mining and Allied Industries*, February 12-14, 2009, IT-BHU, Varanasi.
5. Naithani, A. K., Bhatt, A. K. and Krishna Murthy K. S. "Geological and geotechnical investigations of Loharinag-Pala Hydroelectric Project, Garhwal Himalaya, Uttarakhand," *Journal Geological Society of India* (in press).
6. Nawani, P. C. "Engineering geological investigations for water resources projects," *Seminar on Emerging Trends in Geotechnology - Challenges and Opportunities*, Global Institute of Technology, Bangalore, November 7-8, 2008.
7. Nawani, P. C. "Prediction of change in stress pattern, rock mass behaviour and stability of underground excavations using microseismics," *Journal of Engineering Geology*, Vol. XXXV (1-4), 2008, pp. 61-76.
8. Nawani, P.C. and Naik, Sripad "Need for a long term stability monitoring of Varunavat landslide treatment in Uttarkashi town, Uttarakhand Himalaya," *National Seminar on Disaster Management, Department of Disaster Management*, Govt. of Uttarakhand, June 27, 2008.
9. Rajan Babu, A. "Development and planning of granite quarries with reference to joints and their influence on block splitting," Indian Stone, *Journal of All India Granite and Stone Association*, 2008, pp. 18-29.
10. Rajan Babu, A. "Significance of eco-friendly dimensional stone quarrying," *Stonedge- Journal of Indian Dimensional Stone Industry*, May-June 2008, pp. 8-19.
11. Rajan Babu, A. and Nawani, P. C. "Extraction of dimensional blocks using advanced explosive splitting techniques," *Journal of Indian Dimensional Stone Industry,* March 2009, pp. 24-32.
12. Rao Nagaraja G.M. "Data on Engineering Properties of Dimensional stones," *Indian Stone,* January 2009.
13. Rao Nagaraja, G.M., Rao, M. V. M. S, Prasana Lakshmi, K. B., Chary, Vijaya Kumar, N. A. "Scaling of AE energy and its application in the investigation of brittle fracture of rock – *Journal of Non-destructive Testing & Evaluation*, Vol. 7, Issue 4, March 2009, pp. 30-35.
14. Rao Nagaraja, G.M., Udayakumar S., Rao, M. V .M. S., Prasana Lakshmi, Chary, K. B. and Vijaya Kumar, N. A. "Stress induced micro-crack damage in Latur

granite: a case study", *Workshop on Rock Mechanics & Tunnelling Techniques,* 24-26 April 2008, Manali.

15. Rao Nagaraja, G. M. and Jayanthu, S. "Analysis of acoustic emission trends in Kaiser Effect of rocks - a new approach," *International Symposium on Rock Mechanics & Geo-Environment in Mining and Allied Industries*, IT-BHU, Varanasi, February 12-14, 2009.
16. Roy, S. and Adhikari, G. R. "Seasonal variation in the suspended particulate matter vis-à-vis meteorological parameters at Kolar Gold Fields, India," *International Journal of Environmental Engineering* (in press).
17. Roy, S. and Singh, T. N. "Influence of rock and explosives properties and blast design parameters on dust generation during blasting in opencast coal mines: an approach," *Mining Engineer's Journal*, Vol. 10, No. 4, November 2008, pp. 10-14,
18. Sivakumar, C. Willy, Y. A. and Nawani, P. C. "Optimization of distressing blast location and time using microseismic data in a longwall coal mine," *Synergy in Mineral Sector for Sustainable Development - Vision 2020*, NITK Surathkal, October 4-5, 2008.
19. Sivakumar, C., Murthy, S. N., Rao, Y. V. and Nawani, P. C. "Application of microseismic technology in underground space technology in India - a review," *Synergy in Mineral Sector for Sustainable Development - Vision 2020*, NITK Surathkal, October 4-5, 2008.
20. Sivakumar, C., Srinivasan, C., Murthy, S. N. and Rao, Y. V. "Microseismic monitoring of longwall strata to provide real time instability indications to mine management at Rajendra coal mine in India," *Proceedings of the 42nd U. S. Rock Mechanics Symposium,* San Francisco, 29 June -2 July, 2008.
21. Sivakumar, C., Srinivasan, C., Willy, Y. A. and Murthy, S. N. "Real time microseismic monitoring to study geomechanics of underground structures," *12th International Association for Computer Methods and Advances in Geomechanics,* Goa, October 1-6, 2008.
22. Srinivasan C., Y. A. Willy and Sivakumar, C. "Strong Motion studies in the mines of Kolar Gold Fields, *Proceedings of the 30th Monitoring Research Review: Ground-based Nuclear Explosion Monitoring Technologies*, Portsmouth, Virginia 23-25 September, 2008.
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24. Srinivasan, C., Willy, Y. A. and Sivakumar, C. "Seismicity in the flooded mines of Kolar Gold Fields," *Proceedings of the 7th Asian Seismological Conference,* Tsukuba, Japan, 24-28 November, 2008.
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Annexure - 7

NEWS LETTER

Dr. C. Srinivasan delivered an invited talk on "Seismology and microseismology networks for monitoring earthquakes, mining areas and rockburst scenario" at RRSSC-B, Indian Space Research Organization, Bangalore on 23 April 2008.

Dr. H.S. Venkatesh during visit to various project sites of THDC and NTPC in Uttarkhand area delivered lectures on 23 -28 June 2008.

Dr. P. C. Nawani and Sripad Naik delivered talks on "Need for long term stability monitoring of Varunavat parvat landslide treatment in Uttarkashi town, Uttarakhand Himalaya," at the National Conference on Mass Instability and Earthquake Risk Management in Mountaneous Regions, organized by Disaster Mitigation and Management Centre, Govt. of Uttarakhand, 27-28 June 2008.

Dr. H.S. Venkatesh delivered five lectures on various aspects of blasting at Engineering Staff College of India Campus, Hyderabad from 18 to 20 August 2008.

Mr. R. K. Sinha, attended a training course on advanced FLAC3D, organized by Itasca Consulting at Marriot, Goa, from 30 Sept-01 Oct 2008.

Dr. P. C. Nawani presented a key paper entitled "Engineering geological investigations for water resources projects" at the Seminar on Emerging Trends in Geotechnology: Challenges and Opportunities held on 7-8 November 2008 at Global Academy of Technology in Bangalore. At the same seminar, Dr. G. R. Adhikari presented a paper on "Lessons learnt from drill and blast tunnel case studies." The seminar was attended by Dr A. K. Naithani, Yogendra Singh, Rabi Bhusan, Debprasad Sahoo, L. G. Singh and Devendra Singh.

Mr. S. Roy attended National Seminar on "Environmental Management in Mining & Allied Industries" at BHU, Varanasi, Uttar Pradesh, on 7-8 November 2008.

Dr P. C. Nawani, Director along with Miss Divyalakshmi and Mr. Devendra Singh, Scientists attended a Seminar on GIS Applications in Bangalore on 12 November 2008.

An orientation programme for new Scientists was held at NIRM from 24 to 28 November 2008.

Dr. P. C. Nawani delivered an invited lecture entitled "Prediction of change in stress patterns, rock mass behaviour and stability of underground excavations using microseismics" in the International Seminar on Challenges in Engineering Geology organised by ISEG at Hyderabad during December 03-05, 2008. Mr. C. Shivkumar presented case studies on "Stability of underground excavations using microseismics." Dr. Ajay Kumar Naithani, presented a paper "Seismic slope instability assessment using RS & GIS techniques: a case study from Garhwal Himalaya."

Mr. D. S. Subrahmanyam attended a seminar on "Crustal evolution and metamorphism" conducted by Bangalore University on 4- 5 December 2008.

Dr. C. Srinivasan delivered an invited talk on" Management of disasters due to mining activities" on 12 December 2008 at Administrative Training Institute, Mysore.

A field training programme on Engineering Geology was organized by NIRM at Tapovan-Vishnughad from 15 to 27 December 2008. In this programme, Mr.

Devendra Singh, Mr. L.G. Singh and Mr. Rabi Bhusan were trained by Dr. Ajay Kumar Naithani and Mr. S. K. Mohanthy.

Dr. P.C. Nawani who was elected as the President of the prestigious "Indian Society for Engineering Geology (ISEG)" for 2009 and 2010, chaired the 1st meeting of the Council of the Society held at Lucknow on 6 January, 2009. Dr. V. Venkateswarlu was nominated as one of the Council Members of ISEG.

Mr. G. C. Naveen and Mr. Sultan Singh Meena participated in the International Stone Exhibition at Jaipur on 8 -11 January 2009.

Mr. G. D. Raju, and Miss K. S. Divyalakshmi attended an international training programme on "Comprehensive Landslide Disaster Management using GIS" during 12-24 January 2009. The programme was organized by NIDM, UNU-ITC School for Disaster Geo-Information Management, Netherlands and GSI at NIDM, New Delhi. Dr. P. C. Nawani and Mr. Sripad Naik were invited as Guest Speakers.

Dr. S. Sengupta was nominated as Governing Body Member for Indian Society of Rock Mechanics and Tunnelling Technology.

Mr. D. S. Subrahmanyam delivered an invited lecture "Rock mechanics investigations required for construction of underground structures" at Bangalore University on 24 Feb 2009.

Mr. D.S. Subrahmanyam, Mr. D. Joseph and Mr. G. Shyam attended a workshop organised by National Instruments in Bangalore on 21 November 2008.

Dr. H.S. Venkatesh was nominated as a committee member to review/recommend "Environment Impact of Hydro Electric Projects in hilly terrains of Uttarakhand."

Mr. V. R. Balasubramaniam and Mr. S. Nelliat attended the National Seminar on Energy Security and Exploration for Non-fossil Fuels, AEG, February 4-6, 2009, Hyderabad.

Miss Praveena Das Jennifer attended a Seminar on "How to Build Low Cost, High Performance Data Logging Solutions" organised by National Instruments, Bangalore, February 17, 2009.

Dr. C. Srinivasan was invited on 19 March 2009 as an expert committee member for procurement of seismological equipment by Karnataka State Disaster Monitoring Cell.

Annexure - 8

Director
Dr. P. C. Nawani

Departments

Engineering Geology

Mr. S. K. Mohanty
Dr. A. K. Naithani
Mr. D. T. Rao
Dr. Biju John
Miss. K.S. Divyalakshmi
Mr. Ravi Dimri
Mr. Rabi Bhusan
Mr. Debprasad Sahoo
Mr. L. Gopeshwor Singh
Mr. Devendra Singh
Mr. Yogendra Singh

Engineering Geophysics

Dr. P. C. Jha
Mr. V. R. Balasubramaniam
Mr. Sandeep Nelliat
Mr. Y. V. Sivaram

Geotechnical Engineering

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

Rock Fracture & Materials Testing

Dr. G. M. Nagaraja Rao
Dr. G. Budi
Mr. S. Sathyanarayana
Mr. S. Udayakumar
Mr. M. Victor
Miss Praveena D. Jennifer
Mr. D. Sampath
Mr. Abdul Majeed
Mr. G. Mohandoss
Mr. Syed Asgar
Mr. A. Yesupadam

Engineering Seismology

Dr. C. Srinivasan
Mr. Y. Ahnoch Willy

Microseismics and Automation

Mr. C. Sivakumar

Mine Design

Dr. V. Venkateswarlu
Mr. Atul Gandhe
Mr. C. Nagaraj
Mr. Sagaya Benady
Mr. S. Kumaraswamy
Mr. Ritesh Lokhande
Mr. N. Selvaraj

Rock Blasting & Excavation Engineering

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

Numerical Modelling

Mr. Sripad
Mr. Bijay Mihir Kunar
Mr. G. D. Raju
Mr. K. Sudhakar
Mr. P. S. Varma

Dimensional Stone Technology

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

Environmental Engineering

Mr. Surendra Roy
Mr. T. Amrith Renaldy
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. M. R. Muralidharan (U/S)
Mr. Y. L. Visweswaraiah
Mr. A. Narayanaswamy
Mr. J. V. Sastry
Mrs. S Lourdu Mary
Mr. N. Jothiappa
Mr. S. Ravi
Mr. J. Raja
Mrs. C. V. Lalitha
Mr. V. Suresh
Mr. M. S. Nagaraj
Mr. T. Anjaneyappa
Mr. P. Venkata Reddy

Persons who resigned

Jayaram Naick Bukke
Sanjaykumar Raut

National Institute of Rock Mechanics

(Ministry of Mines, Government of India)

NIRM, as it is popularly known, was established in July 1988 under the aegis of Ministry of Mines, Government of India, as an Autonomous Research Institute to aid to the growing needs of the Mining and Civil Construction Industry in the area of Rock Engineering for design and development.

Since its inception, the Institute has grown in strength and stature to mature as a professional body providing research and consultancy support in almost entire spectrum of rock mechanics with International standard. All Our activities are ISO 9001:2008 compliant. Key to our success lies in 'Excellence through Innovation'.

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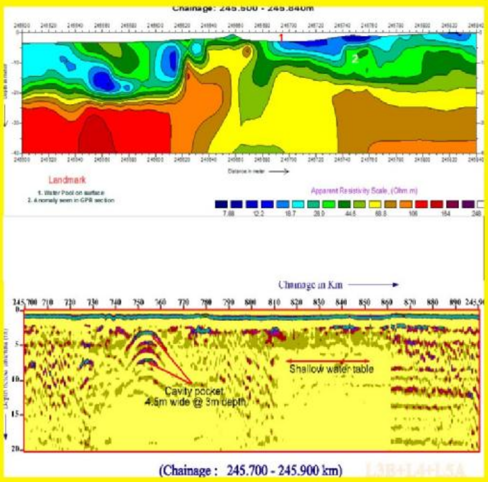
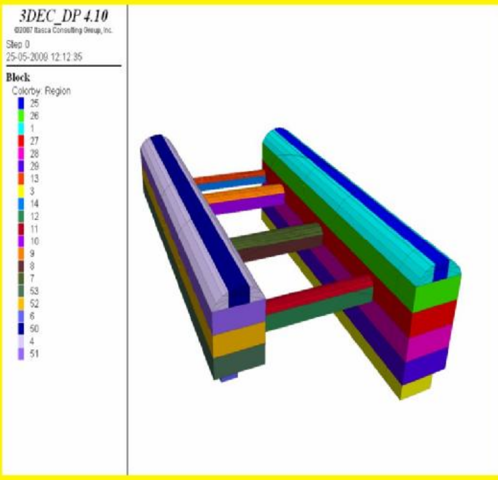
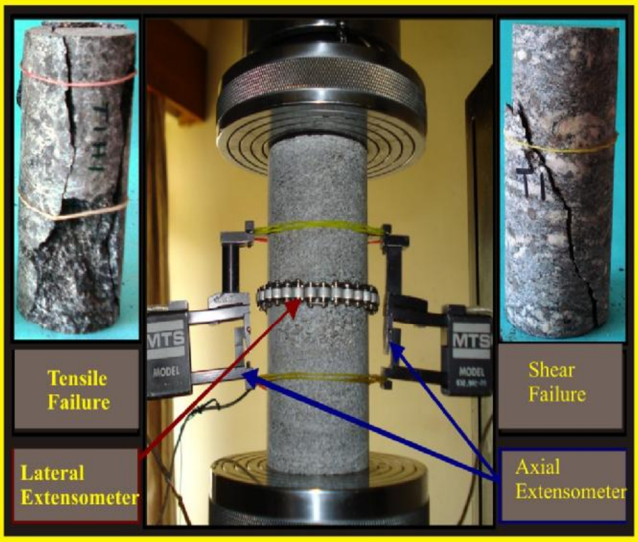
Numerical Modellling	Mr. Sripad	080-25619697	nmd.nirm@gmail.com







A view of automatic weather station

A view of SODAR installed at the mine site

राष्ट्रीय शिला यांत्रिकी संस्थान

National Institute of Rock Mechanics

(Ministry of Mines, Government of India)

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