Annual Report

वार्षिक प्रतिवेदन

2007-08

राष्ट्रीय शिला यांत्रिकी संस्थान

NATIONAL INSTITUTE OF ROCK MECHANICS

(Ministry of Mines, Govt. of India)

An ISO 9001:2000 Certified Research Institute — आईएसओ 9001:2000 प्रमाणित अनुसंधान संस्थान

Champion Reefs Post - 563 117
Kolar Gold Fields
Karnataka, India

चैंपियन रीफ डाकघर - 563 117
कोलार गोल्ड फील्ड्स
कर्नाटक, भारत

Quality Objectives

- **To become a global R&D organisation providing high quality, need based, value added services in the emerging areas of rock engineering and rock mechanics for mining, excavation engineering and allied industries for improving production and safety.**

- **To develop innovative technologies and retain them through intellectual property rights.**

- **To disseminate the research and expertise through publication of papers in national and international journals and seminars.**

- **To develop human resources through training and workshops.**

Quality Policy

NIRM is committed –

- **To achieve high quality R&D work and to provide services to the total satisfaction of customers with strict adherence to contractual specifications.**

- **To register sustainable growth by conducting widely acknowledged research in the areas of rock engineering to make NIRM a global center of excellence.**

- **To enhance the knowledge and skill of the employees through self development on continuous basis.**

"NIRM is committed to comply with ISO 9001:2000 and to continually improve the Quality Management System".

वार्षिक प्रतिवेदन
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ANNUAL REPORT
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(An ISO 9001: 2000 Certified Research Institute)

राष्ट्रीय शिला यांत्रिकी संस्थान

National Institute of Rock Mechanics

(Under Ministry of Mines, Govt. of India)

CHAMPION REEFS

KOLAR GOLD FIELDS - 563 117

Karnataka, India

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Director's Report

The National Institute of Rock Mechanics (NIRM), under Ministry of Mines, Government of India, carries out research and provides consultancy services in the field of rock mechanics and rock engineering. NIRM has been carrying out detailed field and laboratory investigations to improve production, productivity and safety for coal and non-coal mines, hydroelectric & tunnelling projects, and other construction projects.

It is my privilege to present the 20th Annual Report of this institute for the year 2007-08. During this year, NIRM executed four research projects funded by the Ministry of Coal and the Department of Science & Technology. In addition, the Institute has carried out a number of In-house projects. It also worked on 32 consultancy projects, including 15 projects for state government/public sector organisations and 17 projects for private companies.

During this period, NIRM Scientists published 28 technical papers and participated in various seminars/symposia. They organised a training course on dimensional stone technology, delivered several invited lectures/talks and co-guided undergraduate & graduate students from academic institutions for their theses.

The role of NIRM has been well recognised not only in India but also in other countries like Bhutan, Nepal and Oman. The institute is gearing up to provide comprehensive package for hydroelectric projects in preparing detailed projects reports (DPR) related to geological and geotechnical investigations and also for carrying out detailed investigations in construction stage. The available expertise in underground space technology is being extended for construction of rapid mass transportation systems and underground storage facilities. In order to cater to the needs of our esteemed clients and to meet the future challenges, NIRM has opened a branch in Bangalore in August 2008 and is also in the process of recruiting more than 25 scientists.

NIRM has achieved an external cash flow of Rs. 230 lakhs from its consultancy projects and S&T projects. The Institute Development Fund has surged to Rs. 930 lakhs out of the targeted amount of Rs. 1200 lakhs.

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 am also grateful to the Department of Science & Technology and the Ministry of Coal for S&T grants. Special thanks are due to our clients who supported NIRM through sponsored projects.

The growth and success of NIRM would not have been possible without the sincere and dedicated work of our Scientists and staff. With their cooperation, I sincerely hope that NIRM can soon be transformed into an institute of international standing.

11 September 2008 Dr. P. C. Nawani

1. ENGINEERING GEOLOGICAL INVESTIGATIONS

For design of any excavation in civil engineering projects like hydroelectric projects, railway tunnels etc., it is essential to carry out engineering geological mapping and rock mass classification in order to characterize the site. During 2007-08, NIRM conducted investigations at two projects.

1.1 Tapovan-Vishnugad hydroelectric power project, Uttarakhand, Project No. GC0701.

(S.K. Mohanty and V. Venkateswarlu)

Tapovan-Vishnugad hydroelectric power project is a 520 MW, run-of-the river scheme. It envisages the construction of a barrage on Dhauliganga river near Tapovan, and an underground power house near Helang. The tunnelling operations involve an 11.7 km long and 6.24 m diameter circular head race tunnel (HRT) and three horse-shoe shaped adits of 6.75 x 6.75 m size. Mapping of the geological and structural features and on the basis of rock mass classification done, the requirement of support systems was provided to project authorities on a day-to-day basis.

The project area is located within the tectonic block bounded by Main Central Thrust (MCT) in the south and Vaikrita Thrust in the north. The project forms a part of Dhauliganga and Alaknanda valley where rocks of Central Himalayan crystalline comprising medium to high grade metamorphites are exposed. The HRT has four kinks due to the prevailing topographical variations, and has a vertical cover varying from 200 m near the Surge shaft site to 1200 m near the Bend 4 site. The HRT is expected to encounter metabasics and schists with fine-grained augen gneiss bands; augen gneiss with schist and quartzite bands; and fine- to medium-grained quartz mica gneiss and augen gneiss with schist and quartzite bands of Tapovan formation, and coarse-grained garnet-biotite-kyanite gneiss of Joshimath formation.

The major rock types/litho-units encountered at the intake adit portal are the metabasics of Tapovan formation. The metabasics are foliated and fractured. The rock mass is characterized by prominent one sub-horizontal foliation joint, two sub-vertical joints and a few random joints. A large number of discontinuity data were collected at the intake adit portal. A summary of the orientation of all the discontinuities is given in following table **:**

Feature	Strike	Dip	Dip direction
Foliation joint	N 110° – N 290°	10°	N 020°
Joint 1	N 126° – N 306°	81°	N 216°
Joint 2	N 175° – N 355°	73°	N 265°
Random joint 1	N 100° – N 280°	70°	N 010°
Random joint 2	N 165° – N 345°	76°	N 075°

The rock mass at the intake adit portal is characterized by a prominent sub-horizontal foliation joint, two sub-vertical joints and a few sub-vertical random joints. They are continuous and persistent, rough or irregular and planar with slightly altered joint walls, and have non-softening mineral coatings and sandy particles along them. The rock mass is completely dry in nature, but at places is locally damp without any evidence of flowing water. The stresses at the surface of the slopes may be considered as normal. The rock mass is classified using Q system and based on the numerical value it ranges from 4.3 to 3.7 i.e. 'Fair' to 'Poor Rock' (Class III to IV).

At the intake adit portal face a support system comprising rock bolts, chain link fabrics and shotcrete was designed to support rock mass at the back slope. The rock bolts tend to reinforce and mobilize the inherent strength of the rock mass by constraining the movement of the individual blocks of rock. The galvanized chain link fabric prevents injury to personnel and damage to equipment from smaller pieces of rock or spalled flakes. The shotcrete imparts ductility to an otherwise brittle material and acts to restrict movement of the rock mass externally. These are often used in combination to obtain the best possible effect on rock mass stabilization.

1.2 Rock mass characterization, support design and strata monitoring in water-carrying tunnels, Kadapa, A.P., Project No. GC0705

(C. Nagaraj and V. Venkateswarlu)

The Department of Irrigation and Catchment Area Development, Government of Andhra Pradesh, is developing the Galeru-Nagari Sujala Sravanthi project. Under this, the water from the Owk reservoir will be taken through a tunnel into Gandikota reservoir on the other side of a hill. The proposed "Gandikota Tunnel" is a D-shaped tunnel, 5.275 km in length, and 18 m in diameter. The rock cover at the middle of the tunnel would be about 120 m, with low stress conditions.

Studies were undertaken to suggest the permanent supports for the tunnel. Engineering geological mapping of the exposed strata mainly quartzite and shale (Fig. 1.1) 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.

Core samples were tested for physico-mechanical properties. The average value of the density was found to be 2.5 g/cc, and the uniaxial compressive strength was ranging from 170 to 235 MPa. The average RQD of the strata was 38%. The joint surfaces are smooth to rough, fresh, unaltered, but slightly open. The strata is generally dry. The joints are persistent but discontinuous, having a rough, planar surface. Spacing of the joints is about 60 cm. The joints are mostly tight and devoid of any water seepage.

Fig. 1.1 Surface exposure of quartizite and shale at the tunnel portal, Gandikota, A.P.

Based on the engineering geological investigations in the tunnel, the Q-value and RMR were estimated to be 4.22 and 65 respectively. The likely rock loads were 10-16 t/m^2. For the 18 m wide tunnel under the prevailing 'Fair' rock mass conditions, rock bolting was recommended as the effective support system. The recommended bolt length is 6 m with a minimum diameter of 25 mm. The recommended spacing was 2 m x 2 m on a regular grid pattern. Bolts grouted with resin capsules are expected to provide more than 16 t anchorage.

The adequacy of the rock bolting needs to be monitored, as for a large diameter tunnel (18 m dia.) the failures can be averted if the rock bolts pierce through the 'the plastic zone' developed. Accordingly length and diameter of the rock bolts can be revised.

Three multi-point extensometers were fixed in the roof and strata movements were monitored periodically.

2. ENGINEERING GEOPHYSICAL INVESTIGATIONS

Geophysical investigations are essential to supplement various geological and geotechnical investigations for site characterization. With modern facilities, the Engineering Geophysics Department is carrying out subsurface mapping of the geological conditions using seismic and GPR techniques. During 2007-08 this department completed four industry sponsored projects and one is in progress.

2.1 Vertical electric sounding for evaluation of subsurface geological conditions at Thambalapalli, A.P., Project No. EG0701

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

Zoom Mineral Development Pvt. Ltd. requested NIRM to carry out Vertical Electric Sounding (VES) at one of their proposed granite quarry sites Thambalapalli Mandal in Chittoor district of Andhra Pradesh. The prospective zone was 1100 m x 900 m in size and based on results of VES survey, the exploration and development of quarry was to be carried out. Five points were identified by the client within the prospective area for the VES survey. The objective of the survey was to get information on the subsurface strata at those locations.

VES section at these five locations is shown in Fig. 2.1. Based on this VES output, it was found that out of five locations, the rock quality was uneconomical for quarrying at three locations and suitable for quarrying only at two locations. Further, it was recommended that seismic refraction survey should also be carried out for better information on the lateral variation of strata and cross-verification of the results.

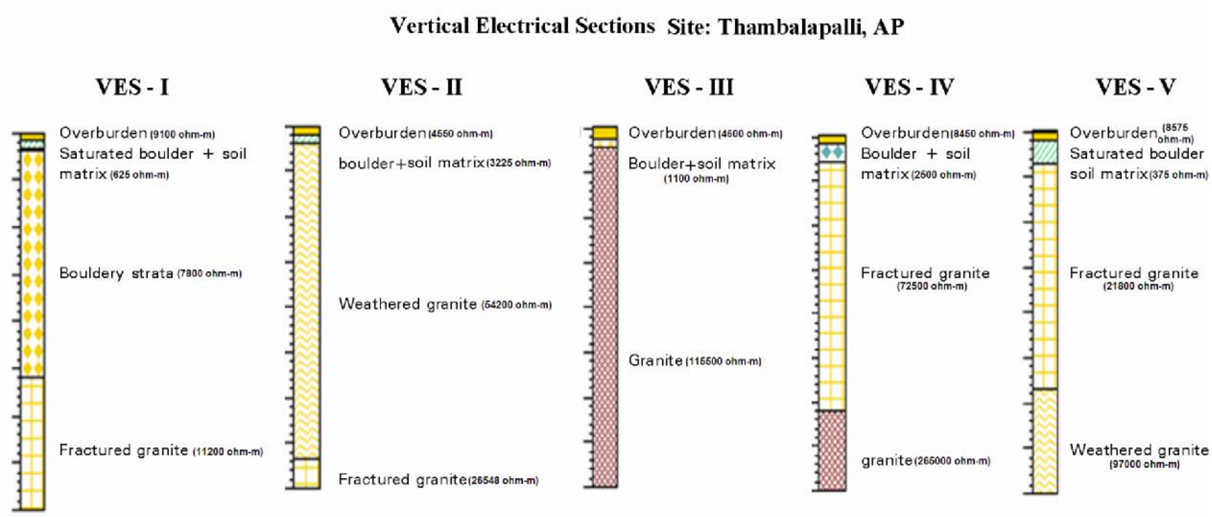


Fig. 2.1 VES sections at five locations in the proposed quarry area

2.2 Evaluation of foundation of Elevated Tollway by Cross-hole tomography at NH-7, Bangalore, BETL, Project No. EG0702

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

National Highways Authority of India (NHAI) envisages widening the North-South and East-West corridors. Bangalore Elevated Tollway Limited (BETL) is constructing an elevated four lane highway on the Bangalore Hosur section of the NH-7 from Silk Board Junction to Electronic City Junction covering a stretch of around 10 km. The elevated highway is proposed to be raised on 247 pillars with pile foundation.

Core drilling was done by NHAI at all pile locations to confirm the strata conditions. At 4-6 locations, the drilling results did not confirm uniform strata around the four corners of the pillar. Hence, open foundation was suggested at these locations. Accordingly when excavations were made for open foundation, it was observed that at one of the locations, the granitic gneiss (base rock) was steeply dipping at around 60º leading to suspicion that there might be a fault plane or any other weak zone in the near vicinity which could be detrimental to the stability of the pillar. Hence, NHAI requested confirmatory investigations of the subsurface strata conditions up to a depth of 10 m below founding levels. Three such sites were identified for comprehensive investigations and referred to NIRM for geophysical survey.

The objectives of geophysical investigation was to examine the continuity of hard rock below the foundation level, map the presence of geological discontinuities, if any and evaluate the feasibility of the open foundation in the backdrop of a likely differential settlement in the wake of steeply dipping rock strata.

After a preliminary site visit and discussions with the project authorities, it was recommended to carry our cross-hole seismic tomography at all these pier locations. Given the sensitivity of the objectives, it was decided to go in for three-dimensional tomographic imaging and set the survey layout in cross-diagonal setting (Fig. 2.2).

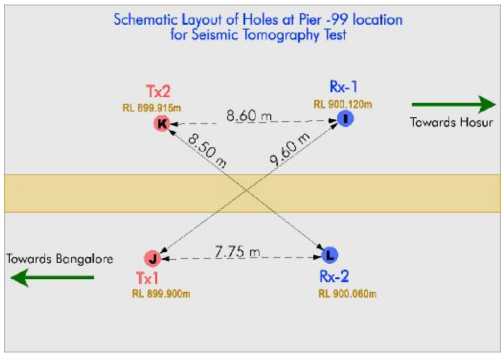


Fig. 2.2 Borehole locations for 3D seismic tomography at piers

The survey results revealed that out of the three pier locations, pier-99 had no anomalous trend in the geological setting nor any weak plane was present within the zone of influence. Pier-59 had one low velocity patch which can be easily addressed by anchoring during construction. However, pier-70, had an almost inversion of geological setting in the foundation with steeply dipping bedding plane. Fig. 2.3 shows 2D tomographic section across one diagonal pair of pier-99 indicating inversion of geological setting and 3D tomographic section across one diagonal pair of pier-99 indicating a low velocity (V_p< 3000 m/s) layer patch amidst surrounding host rock with a velocity of over 4000 m/s.

Given the seismic velocity difference of the order of 1000 m/s under in-situ conditions, the difference in rock strength within the foundation zone might be of the order of 50-60 MPa. Such a situation of rock disposition in the foundation might lead to differential settlement and ultimate failure of pillar in the long run. Hence it was recommended to adopt suitable design modification like anchoring to cater to this anomalous situation.

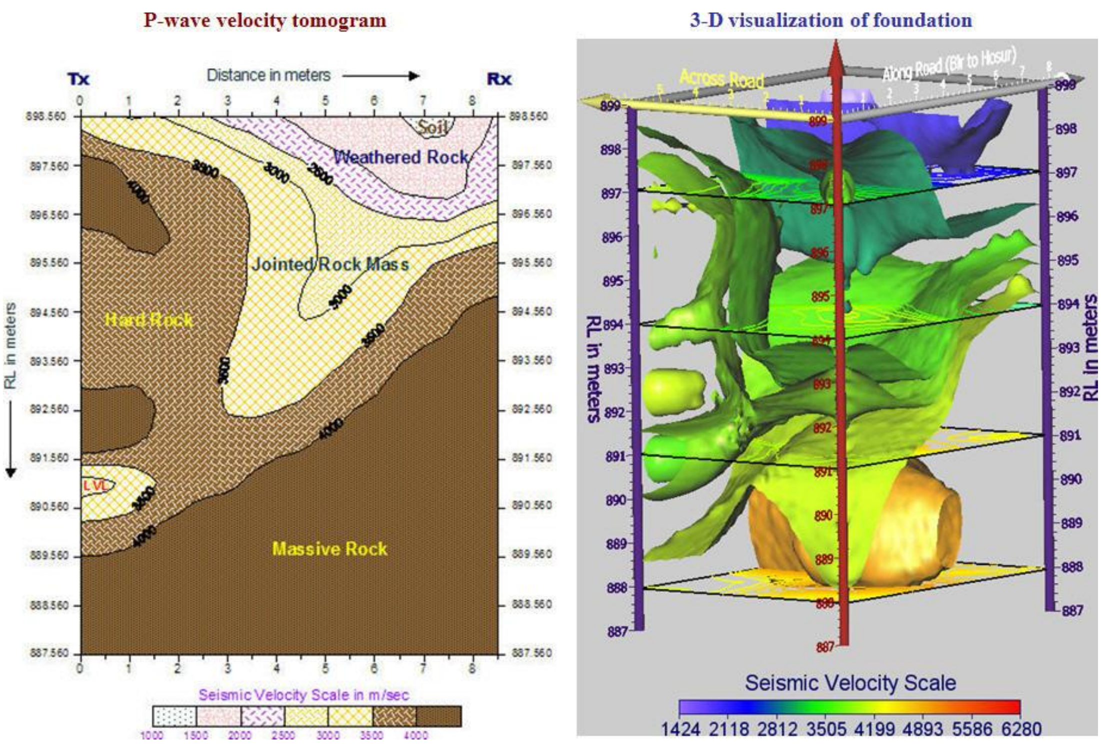


Fig. 2.3 Sample tomographic sections in 2-D and 3-D formats

2.3 Mapping of subsurface strata conditions at Naitwar-Mori HEP, Uttarkashi district, Uttarakhand, Project No. EG0703
(P. C. Jha, V. R. Balasubramaniam, N. Sandeep and Y.V. Sivaram)

Naitwar-Mori HEP (NMHEP) project is envisaged as a run-of-the river project on the river Tons in the Uttarkashi district of Uttarakhand. It is proposed to construct an gravity dam on this river near the Naitwar village. The dam site is located about 700 m downstream of the confluence of Rupin and Tons rivers. The water will be diverted through HRT to a surface powerhouse about 5 km downstream of the dam site. In order to finalise the design of various subsurface and other appurtenant surface structures, NMHEP authorities proposed a seismic refraction survey for mapping the profile of the overburden-rock contact. Accordingly, the survey was carried out for a length of 2300 m along 20 lines across tail race tunnel, powerhouse and dam sites. A schematic plan of the survey lines is shown in Fig. 2.4.

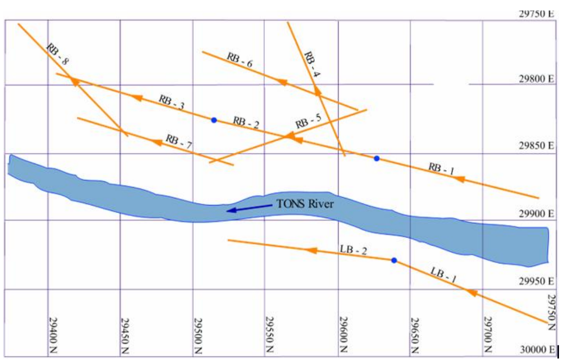


Fig. 2.4 Plan of the seismic survey lines at NMHEP project site

The results of seismic refraction survey showed that the river borne material (alluvial terrace deposits) at the dam site was 5-15 m thick whereas it was 2-10 m in the powerhouse site. Weathered rock and jointed rock layers were more dominant at the powerhouse location (Fig. 2.5). The quality of hard rock comprising granite gneiss and schist was found to be improving consistently with depth and no anomalous trend or features were seen in any of the seismic sections. Hard rock layer was invariably observed in the bottom 5-10 m portion of all the sections.

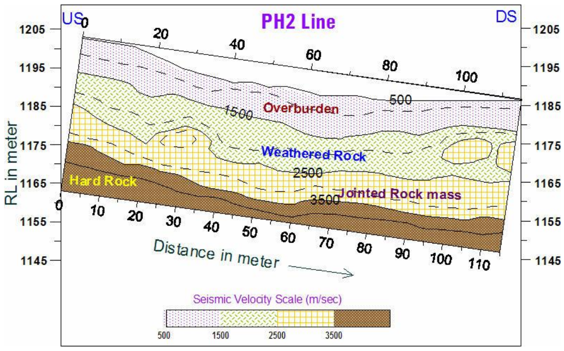


Fig. 2.5 Seismic section showing various strata layers up to a depth of 30 m

2.4 Mapping of subsurface strata conditions at two thermal power project sites, at Andal in West Bengal and Koderma in Jharkhand, Project No. EG0704

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

M/s Constell Consultants Pvt. Ltd (CCPL) entrusted NIRM seismic refraction survey work at two sites, namely, Andal near Durgapur in West Bengal and Koderma in Jharkhand, where thermal power plant of 2 x 500 MW capacity each is proposed for construction. The objective for seismic survey was to map the subsurface details like the quality of rocks, thickness and the dynamic shear modulus of the soil (overburden) up to a depth of 40 m. The subsurface properties were for the proposed power plants required as inputs to the design guidelines.

Seismic survey was done using both P-wave and S-wave source. The survey results revealed that the subsurface at the Andal site consisted of hard sandstone with a seismic velocity of the order of 3000 m/s at a depth of 20-25 m from the surface. The dynamic shear modulus of the soil (overburden) was of the order of 90-100 MPa.

The Koderma site had favourable geological conditions as the overburden was very thin. Weathered granitic geniss was exposed at surface. Seismic survey revealed the presence of hard granitic gneisses with a seismic velocity of over 3500 m/s at a depth of 15-20 m from surface. The dynamic shear modulus of soil layer (overburden) was around 140 MPa.

2.5 Mapping of subsurface strata conditions at Demwe HEP, Arunachal Pradesh, Project No. EG0705

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

A hydro-electric project with a proposed generation capacity of 1200 MW at Demwe in the Lohit district of Arunachal Pradesh is in the DPR stage. As part of its requirement, seismic refraction survey was requisitioned by the client at strategic locations of the Lower and Upper Demwe HEP sites. After a preliminary site visit, the survey plan was frozen and accordingly work order was issued by the client.

So far, the survey has been done for a total line length of 2950 m. Data processing work is in progress.

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 2007-08, the Geotechnical Engineering Department completed three sponsored projects for hydropower sector and initiated one in-house project for basic research.

3.1 Determination of in-situ stress and deformability parameters in the vicinity of the proposed powerhouse chamber from the exploratory drift (with rock cover of 100 m) at Malana H.E. Project, Stage-II, Himachal Pradesh, Project No. GE0601C

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

3.2 Determination of in-situ stress parameters by hydrofrac method in the vicinity of the proposed powerhouse chamber from the construction adit (with rock cover of 416 m) at Malana Stage-II H.E. Project, Himachal Pradesh, Project No. GE0701C

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

Energy Infratech Pvt Ltd (Formerly Erudite Engineers Pvt. Ltd) is developing Malana hydroelectric project in Himachal Pradesh to generate 100 MW of power from Malana Khad. The project is located at about 30 km from Bhunter town in District - Kullu of Himachal Pradesh. The project envisages construction of an underground powerhouse which is proposed on left bank of Malana Khad about 100 m upstream from weir site of Malana Hydro-electric Project Stage-I. The superincumbent cover over the powerhouse structure is expected to range from 300 to 350 m. The entire power house complex will be housed in strong to very strong, moderately jointed, off-white to gray coloured quartzite of Manikaran Member. The rocks exposed in and around the project area belong to Pre-Cambrian meta-sedimentary group comprising generally gneiss schists, shales and quartzite. Granite rocks are rare and occur in bands with gneiss, schist and shales.

The Malana H.E. Project site is located to the south of the MCT. The almost N-S trending Sundernagar Fault, which has displaced MCT significantly, occurs 21 km west to the site. The neotectonic Kaurik Fault System defined by number of half-graben faults is exposed NNE to the site seems to be active as it is considered that rupturing along the fault system had triggered Kinnaur earthquake of 1975.

Distribution of in-situ stress in terms of magnitude and orientation affects the geometry, shape, excavation sequence and orientation of an underground cavern. Thus it is essential to have site-specific values of in-situ stress tensors around the proposed Malana underground powerhouse for favourable orientation, optimum design and design of support system for the powerhouse. NIRM was engaged for the determination of in-situ stress by hydrofrac method and deformability parameters by Goodmanjack method at the proposed powerhouse location with the following scopes:

- Determination of in-situ stress by hydrofrac method and deformability parameters by Goodman jack method from the exploratory drift with a rock cover of 100 m in the vicinity of the powerhouse.

- Determination of in-situ stress parameters by hydrofrac method in the vicinity of the proposed powerhouse chamber from the construction adit between tail race tunnel and pressure shaft with a rock cover of 416 m.

For the investigation of the in-situ stress parameters around the proposed locations of powerhouse chamber, hydrofracturing were carried out in two boreholes one each drilled inside exploratory drift and construction adit. The deformability of rock mass was determined using Goodmanjack equipment in a horizontal borehole at the exploratory drift only.

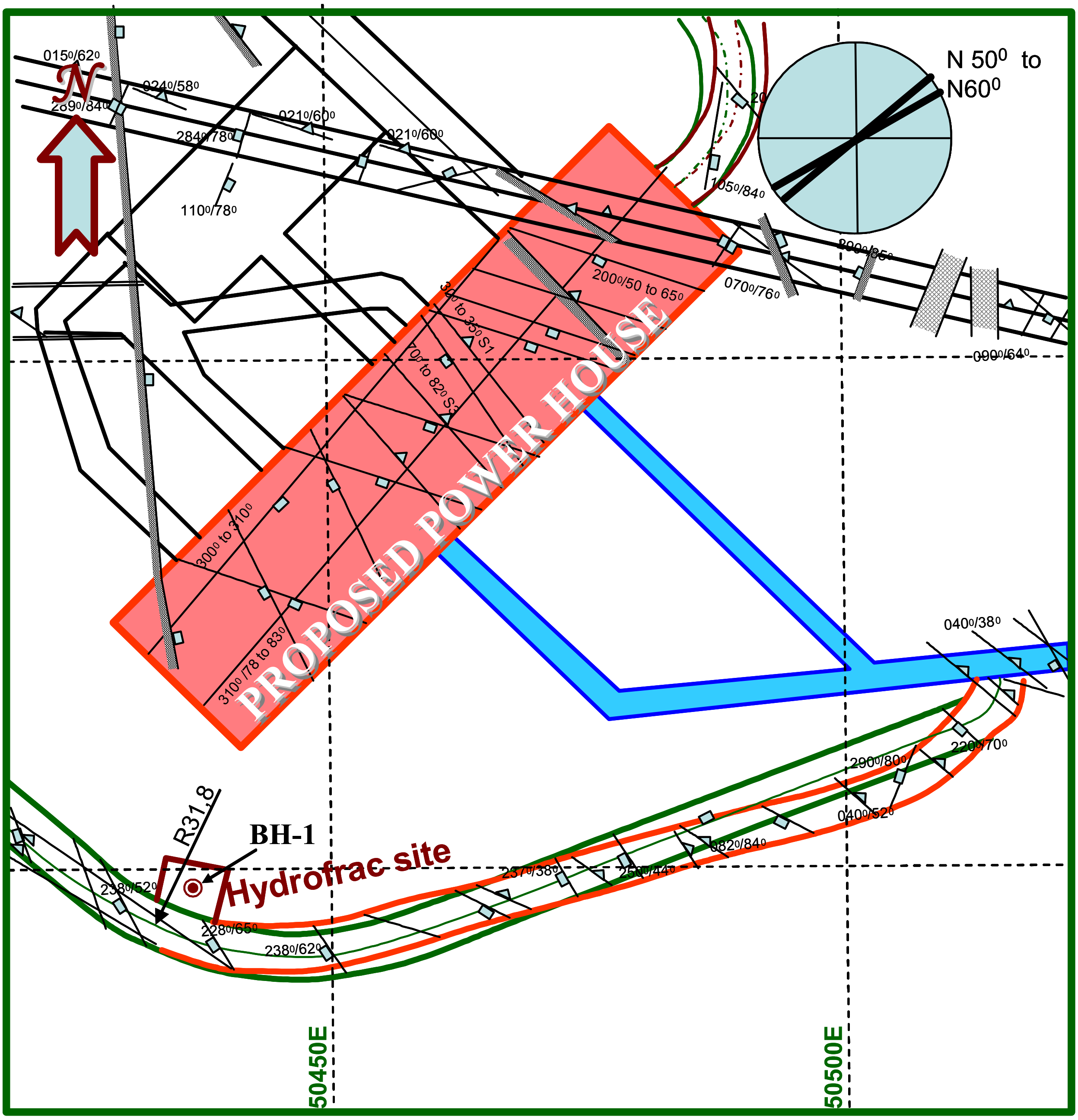


Fig. 3.1 Orientation of powerhouse cavern vis-à-vis in-situ stress direction at Malana Hydroelectric Project, Stage-II, H.P.

The result of in-situ stress determined is given as follows:

Parameter	Over burden of 100 m	Over burden of 416.79 m
Vertical stress (σv) MPa	2.65	11.03
Maximum principal horizontal stress (σH) MPa	3.15 ±0.1665	15.45 ±0.4255
Minimum principal horizontal stress (σh) MPa	2.10 ±0.1110	10.30 ±0.2837
Orientation of maximum principal horizontal stress (σH)	$N50^0E$	$N60^0E$
K = (σH) / (σv)	1.18	1.40

The following are the conclusions drawn and recommendations made:

- The K value of 1.18 to 1.40 indicates a medium stress magnitude.
- The principal horizontal stress direction ranges from N 50^0 - N 60^0.

The orientation of powerhouse cavern vis-à-vis in-situ stress direction is shown in Fig. 3.1. It is recommended that the powerhouse be oriented between $N50^0$ - N 60^0 for maximum stability vis-à-vis in-situ stress.

The result of in-situ deformability determined at the exploratory drift in vicinity of power house is given as follows:

Parameter	Value
Ed, GPa	9.28
Ee, GPa	15.77
Ee/Ed	1.70

The results show that the average moduli value near the powerhouse area is 9.28 GPa which places the rock in class II (good category).

3.3 Determination of in-situ deformability and in-situ shear parameters of rock mass of dam foundation for the design of the proposed concrete gravity dam, Mangdechhu H.E. project, Bhutan, Project No. GE0703

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

National Hydroelectric Power Corporation (NHPC) has been entrusted to prepare a detailed project report for 720 MW Mangdechhu hydroelectric project located on river Mangdechhu in Trongsa District of Central Bhutan. The project envisages construction of a 57 m high concrete gravity dam across river Mangdechhu on granitic gneiss rock.

For the design of concrete gravity dam, rock mechanics parameters like in-situ deformability and shear characteristics of foundation rock mass along with shear characteristics of rock-concrete interface are required which are critical to stability of dam. NIRM was engaged by NHPC to conduct different in-situ investigations inside an exploratory drift at the proposed dam axis (Fig. 3.2) to obtain these parameters and give expert comments and recommendations. The scopes of the investigations were:

- Determination of in-situ deformability parameters inside the exploratory drift on the left bank of proposed dam axis.
- Determination of in-situ shear characteristics for rock-rock interface and rock-concrete interface inside the exploratory drift on the left bank of the proposed dam axis.

The results of different in-situ investigations are given as follows:

Deformability modulus of rock mass
(Plate loading/jacking method)

Location	Ed GPa	Ee GPa	Ee/Ed
PL1	8.56	15.57	1.82
PL2	7.64	17.44	2.28
PL3	6.36	10.46	1.64

Shear parameters of the rock mass
(Direct shear method)

Peak shear parameters		Residual shear parameters	
Cohesion (c) kg/cm^2	Angle of internal friction ( )	Cohesion (c) kg/cm^2	Angle of internal friction ( )
6.17	32.60	4.28	28.80

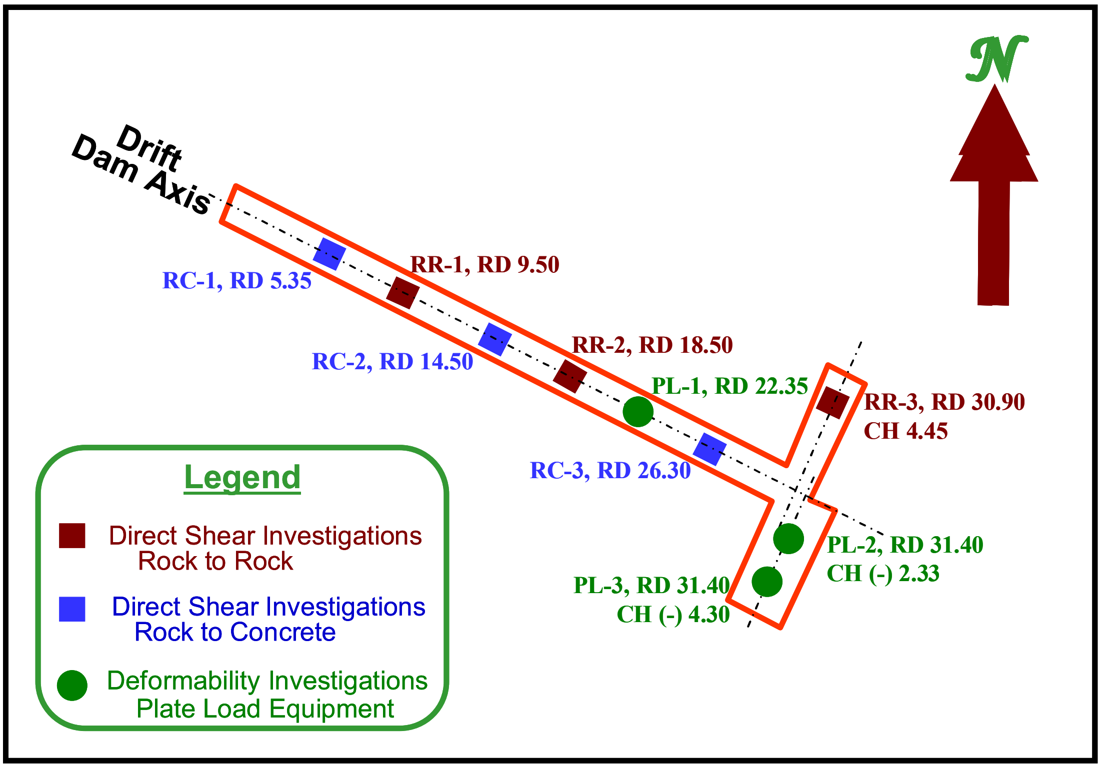


Fig. 3.2 Location of different in-situ investigations inside the exploratory drift at the proposed dam axis, Mangdechhu Hydroelectric Project, Bhutan

Shear parameters of the concrete - rock interface (Direct shear method)

Peak shear parameters		Residual shear parameters	
Cohesion (c) kg/cm^2	Angle of internal friction ( )	Cohesion (c) kg/cm^2	Angle of internal friction ( )
2.65	38.30	1.72	33.80

The following conclusions are drawn from the results:

- The deformability moduli (Ed) for the rock mass varies from 6.36 to 8.56 GPa, i.e. the rock mass can be categorised in class II to III or fair to good.
- The ratio Ec/Ed = 3.98, where Ec is the modulus of concrete (30 GPa). This makes it in 'safe' category' for gravity dam behaviour.

The cohesion (c) 6.17 kg/cm^2 and angle of internal friction ( ) 32.6^o are on the lower side than expected for this type of rock. A closer look of the rock mass revealed fractured rock mass at investigation sites (difficulties faced in the preparation of the rock blocks due to fractured nature of the rock mass). The fractured nature of rock mass and direction of shear force being parallel to the major joint set, the lower values of cohesion and angle of internal friction seem to be justified. The rock mass is classified as fair category.

The cohesion (c) 2.65 kg/cm^2 and angle of internal friction ( ) 33.80 for concrete-rock interface are also on the lower side for the same reason as described above. The destruction of primary asperities during casting of concrete on the rock might have contributed to lower values. Further, most of the tests were conducted within the high to moderate weathered/distressed zone, as shown in Fig. 3.2; as in granitic terrain weathering and distressing profile is usually very deep. These are the reasons for low values of shear parameters of rock mass.

3.4 Influence of stress ratio of two principal horizontal stresses on the preferred direction of hydrofrac under polyaxial stress condition for different anisotropic rocks. In-house Project No. IN0801

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

Objectives of the investigation:

- To investigate the limitations and conditions applicable for implementation of the classical hydraulic fracturing theory in anisotropic rocks
- To identify the horizontal stress ratio at which the direction of hydraulic fracture is stress controlled rather than controlled by anisotropy 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.

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 ropes and non-destructive testing of mining machinery parts as per the requirement of mines safety. During 2007-08, the Rock Fracture Mechanics Department completed two projects and work was in progress for three other projects.

4.1 Data bank of physico-mechanical properties of rocks, Project No. IN0501

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

NIRM had determined physico-mechanical properties of different varieties of granite as per the ASTM standard for more than 10 years. Apart from the visual appearance in terms of color and texture, physico-mechanical properties of dimensional stones are essential to determine their suitability for a particular application. A careful evaluation of critical and non-critical properties are required for every dimensional stone product.

- If the stone is only for aesthetic appearance then the properties are not of much relevance.
- If the stone is to be used as a tile inside the airport then abrasion resistance is the prime requirement apart from the strength values.
- If the stone is to be used for road pavement then compressive strength is the primary consideration and other properties are less important.
- For interior wall cladding, properties such as water absorption, abrasion resistance and strength are not critical.

Granites were classified into three types: black, multi color, and grey/white and the range of properties for these three varieties of granites are given Table 4.1.

Table 4.1 Physico-mechanical properties of for different varieties of granites

Property	Black colour	Multi colour	Gray colour
Density, kg/m^3	2997-3097	2613-2842	2589-2699
Absorption,%	0.02-0.13	0.03-0.37	0.09-0.41
Compressive Strength, MPa	166-314	125-238	146-256
Flexural Strength, MPa	20-36	7-23	5-21
Modulus of Rupture, MPa	25-41	9-23	8-28
Abrasion Resistance	104-172	64-153	65-183

The laboratory results indicate that most of the Indian Granites meet the minimum requirements as per ASTM standard – C-615. In general, Black Granite has better properties as compared to the other two types. A few of the granite samples do not meet all the physical requirements as per ASTM standard limiting their use for some typical applications.

4.2 Laboratory geotechnical investigations for Mangdechhu HEP, Bhutan, Project No. RF0702

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

As part of geotechnical investigations for construction of the dam and power house by NHPC at Mangdechhu in Bhutan, rock properties were required for design and modeling. Drill core samples from dam, head race tunnel and power house locations were sent to NIRM to determine various properties.

A total of nine rock types were investigated and the properties were determined as per the ISRM recommended method. Uniaxial compressive strength, elastic constants, tensile strength, cohesion and friction angle were determined under water saturated conditions for the samples collected from the drift in the power house. As required, unit weight, porosity and water absorption were also determined. Table 4.2 gives the properties of power house drift

For most of the samples, porosity was less than 1% and water absorption was less than 0.5%. As these values were very low there was no perceptible change in the mechanical properties under dry and water saturated conditions.

Table 4.2 Rock properties under dry and saturated conditions, Mangdechhu project, Bhutan

Rock type	Uniaxial compressive strength, MPa#	Uniaxial compressive strength, MPa*	Young's modulus, GPa*	Poisson's ratio*	Tensile strength, MPa*	Cohesion, MPa*	Friction angle, deg. *
Quartizite with Schist intercalations	75-265	82-230	20-62	0.17-0.23	4.46-11.25	34.42-42.89	52.97-62.01
Micaceous quartzite with veinlets of pegamatite	116-191	152-259	37-73	0.13-0.23	8.40-14.50	21.16-51.42	49.26-65.02
Pegmatite	129-161	128-152	29-41	0.23-0.25	7.38-8.76	31.27-45.05	49.68-55.29
Micaceous quartzite with pegamatite veins	137-290	141-275	34-64	0.12-0.23	7.29-15.83	22.87-35.27	50.59-58.54

Note: #Properties under dry condition; *Properties under saturated condition

4.3 Laboratory rock mechanics investigations on basalt, Project No. RF0601

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

Three types of basalt were investigated for various properties as classified below:

Type of basalt	Observations
Non-Vesicular	Does not contain any intrusions.
Partially Vesicular	Vesiculars are present randomly.
Vesicular	Contains a large number of vesiculars.

Rock core samples were prepared with a length-to-diameter ratio of 2 and tested using the MTS compression testing machine. All the tests were carried out under displacement control and the displacement was measured with a pair of LVDTs. The following observations were made:

- Non-vesicular samples showed higher uniaxial compressive strength (81 MPa) compared to vesicular samples (64 MPa), depending on the degree of vesicularity.
- Non-vesicular basalt exhibited higher Young's modulus (43 GPa) compared to vesicular basalt (25 GPa). However, there was no substantial variation in Poisson's ratio (0.21-0.23).
- Shear strength of non-vesicular basalt varied from 20.89 to 31.54 MPa,

whereas that of vesicular basalt varied from 21.26 to 28.81 MPa.

- Average tensile strength of non-vesicular basalt (8.21 MPa) was slightly higher than that of vesicular basalt (7.17 MPa).

4.4 Laboratory geotechnical investigations of dimension stones of Sabarkantha, Gujarat, Project No. RF0701

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

The Department of Mines & Geology of Gujarat is carrying out investigations to identify granite deposits for export potential. For preparing the feasibility report, NIRM was requested to carry out the laboratory investigations on the properties of granites. A total of 36 varieties of granite were received and their properties are given below:

Property	Range
Compressive strength, MPa	143-259
Flexural strength, MPa	6.64-20.86
Modulus of rupture, MPa	9.02-22.29
Abrasion resistance	74-154
Gloss reflectivity	80.6-95.39

4.5 Laboratory investigation of rock core samples for LPG underground project

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

RITES is preparing a project report for the LPG underground facility in Mangalore for HPCL. Geostock, France is the project consultant. Laboratory investigations were carried out on borehole samples for various parameters required for modeling and designing the underground storage facility. All the tests were conducted under displacement control using the MTS compression testing machine. Triaxial tests are being conducted under multiple failure method to estimate the cohesion and friction angle. Overall properties of core samples from two boreholes are given in Table 4.3.

Table 4.3 Properties for rock core samples for LPG underground project, Mangalore

Rock properties	Vertical borehole	Inclined borehole
Density, kg/m^3	2643-2837	2656-2675
Porosity, %	0.12-0.33	0.03-0.21
P.-wave velocity, km/sec	5.54-5.77	5.72-6.94
Uniaxial compressive strength, MPa	78-178	89-255
Young's modulus, GPa	62-82	79-123
Poisson's ratio	0.13-0.24	0.14-0.25
Tensile strength, MPa	10.90-15.94	11.23-22.48

4.6 Testing of rocks and dimension stones

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

Sandstone and coal samples were tested for physico-mechanical properties as per the ISRM suggested method for Advanced Mining Technology, Hyderabad.

Granite blocks were received from Alliance Minerals Pvt. Ltd, Chennai and GMT Metrology Pvt. Ltd, Hosur and the properties were determined as per the ASTM specification.

Property	Surf Green	Tan Brown	Black granite
Bulk specific gravity	2.64	2.72	3050
Absorption, %	0.21	0.14	0.08
Flexural strength, MPa	12.50	7.92	28.31
Modulus of rupture, MPa	12.57	10.44	27.07
Compressive strength, MPa	181	172	235
Abrasion resistance	111	108	-

4.7 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 86 wire ropes received from 11 organisations were tested.

Chains were tested for BEML, Mysore. Some of the special attachments used in railway wagon were tested for Faiveley Transport India Ltd, Hosur.

Another major activity of the laboratory included the in-situ non-destructive testing of mining machinery parts. Ultrasonic flaw detection and magnetic particle tests were carried out for various organizations including Hutti Gold Mines Limited, Ferro Alloys Corporation Limited, Singareni Collieries Company Limited, Hindustan Zinc Limited, and Manganese Ore India Limited.

5. ENGINEERING SEISMOLOGY

Design, fabrication, installation and monitoring of seismic/micro-seismic networks is essential for evaluating stability of underground and opencast excavations. During 2007-08, the Seismology Department processed the data from broad band seismic station and designed a microseismic system for monitoring stability of long wall workings in underground coal mines.

5.1 Establishment of broad band seismic station at KGF, S&T Project No. SI0601

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

A Broad Band Station, installed at the Central Seismic Station (KGF Observatory) by the Department of Science and Technology under the World Bank assisted project on seismology, is working satisfactorily. The data retrieved from the system is archived and after preliminary analysis, it is sent to IMD, National Seismological Data Center, New Delhi. The earthquake recorded at the KGF Observatory from Anantapur, A.P. is shown in Fig. 5.1 Arrangements have been made to connect VSAT at the KGF Observatory for transmitting seismic data to NGRI, Hyderabad.

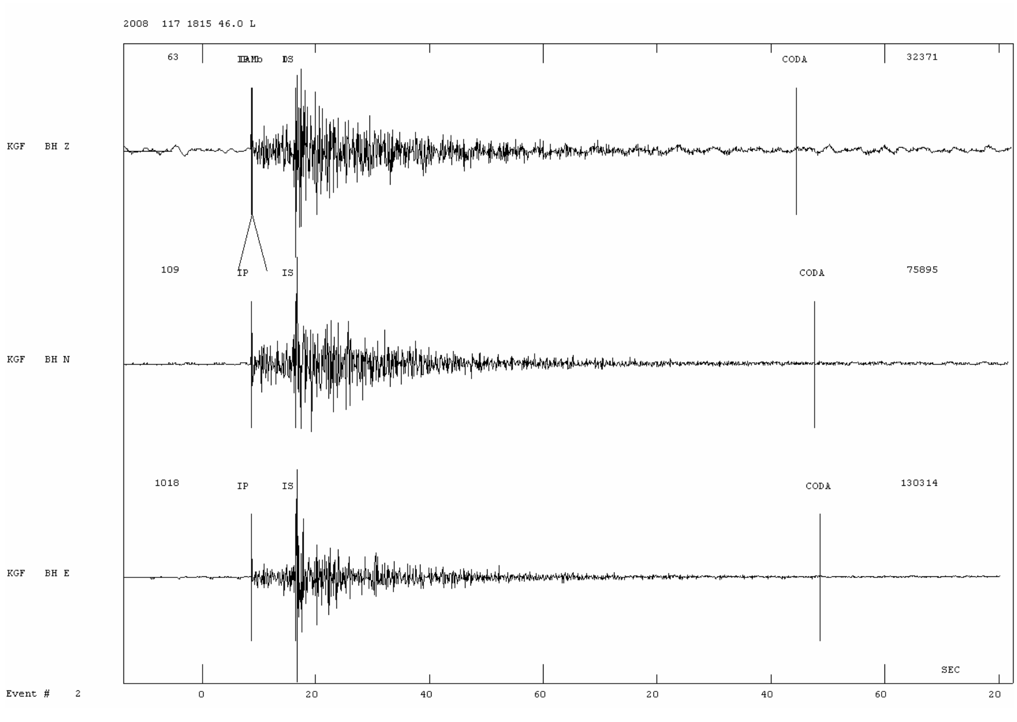


Fig. 5.1 Earthquake recorded on 17 – 01 – 2008 at 18:16:17 hrs

A strong motion accelerograph installed at the NIRM campus is working satisfactorily. During this year, 187 rockbursts were recorded. The peak ground acceleration (PGA) of both horizontal components have been used to obtain the attenuation relationships for the KGF region. These relationships were developed for peak horizontal ground acceleration for short distances and low magnitudes. For this, all rockbursts falling within a radial distance of 5 km and having magnitudes less than 3 have been considered. Using it with the data sets, two step multi regressions were used to analyze the decay of individual magnitude classes with distance. The regressions have been carried out using the models with separable and inseparable and magnitude and distance terms. The two models used in the study are:

Model I:
$\ln(y)=c_1+c_2m-c_3\ln(r)-c_4r+€$
Model II:
$\text{Log}(y)=a_1+a_2m-a_3\log(r+a_4\exp(a_5m))+€$

where y is the peak ground acceleration, r is the hypocentral distance and m is local magnitude M_L and all other parameters are regression coefficients. The comparison of the results of the two models suggests the inclusion of inseparable terms as given in Model II. The attenuation characteristics of the ground motion at shorter distances and low magnitudes were compared with the attenuation relationship for moderate earthquakes available for distances in the range of 10 to 100 km. The comparison reveals the difference in the observed peak ground horizontal accelerations with respect to the strain levels involved in the generation of the respective earthquakes.

Fig. 5.2 shows the distribution of magnitudes and the distance for the strong motion records of KGF region.

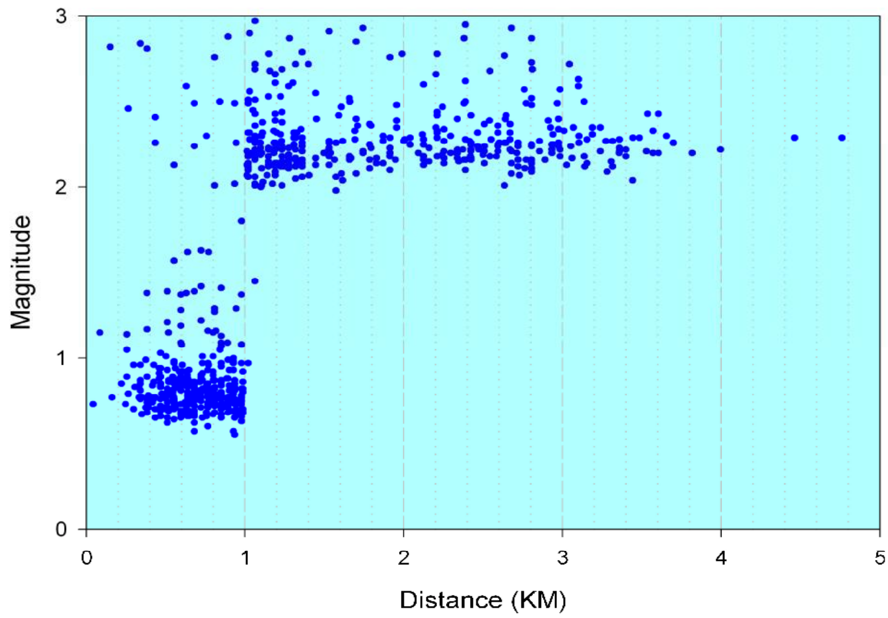


Fig. 5.2 Magnitude - distance distribution of peak ground horizontal acceleration

5.2 Microseismic investigations in underground coal mines, In-house Project No. IN0704
(C. Sivakumar and C. Srinivasan)

Microseismic study of underground longwall roof strata in real time requires capturing the fracture information well in advance during structural failure. The advanced high dynamic range micro-seismic instrumentation with latest computer methods/algorithms will help to investigate strata behaviour in real time. An 18-channel micro-seismic monitoring system with necessary specifications was designed to investigate main falls in longwall panels. Further work to optimize the system for reducing the hardware cost without compromising its accuracy and sensitivity is in progress.

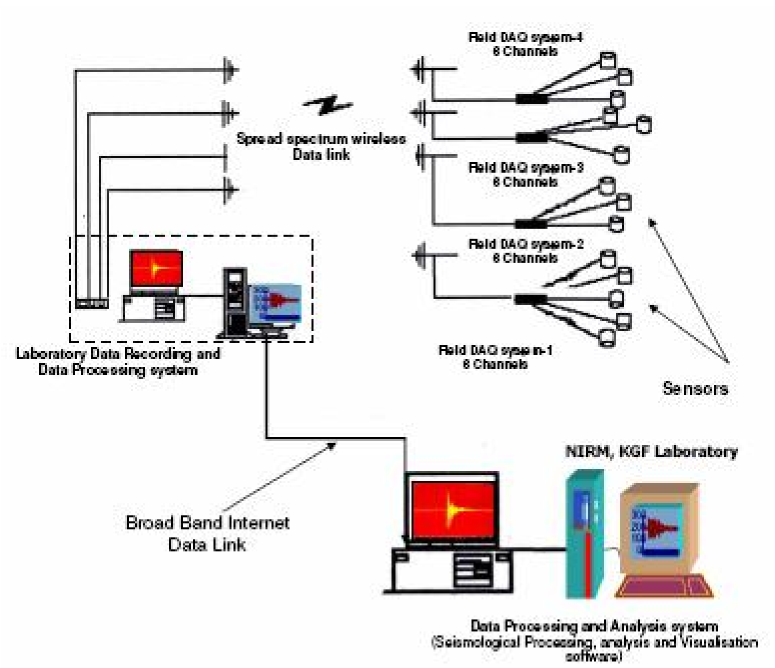


Fig. 5.3 Microseismic monitoring instrumentation

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 2007-08, the Numerical Modelling Department undertook projects involving numerical analysis, instrumentation and monitoring work.

6.1 Three dimensional numerical modelling of underground caverns of Loharinag Pala, Uttarakhand, Project No. NM0704

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

NTPC Ltd is executing Loharinag-Pala hydroelectric project (4 x 150 MW) in the state of Uttarakhand. It is a run-of-the river project on river Bhagirathi, a tributary of Ganga located in District Uttarkashi. The project proposes to ultilise 482.5 m of gross head for the generation of power. The scheme involves construction of 73 m long barrage, desilting chamber complex, 14 km long head race tunnel and powerhouse complex along with other associated structures. It is proposed to construct three desilting chambers of 250 m x 15.5 m x 20 m (excavated geometry). These chambers are separated by rock pillars of 34.5 m and the center to center distance between the chambers is 50 m. The overburden varies from 180 to 430 m. The rocks exposed in the exploratory drift are gneiss and jointed biotite gneiss with small mica schist bands which will also be encountered in the chambers.

A three dimensional model with the actual geometry of all three chambers and top and bottom adit was developed using 3DEC (Fig. 6.1). In this model, various stages of excavation and support are simulated. The model considers elasto-plastic analysis using Mohr-Coulomb and Hoek-Brown failure criteria. The model will be updated as more geological data is made available with the progress of the excavation. Some of the results of modelling are given below:

- Vertical displacement along chambers was 20 - 41 mm.
- Maximum vertical displacement of 41.86 mm was observed on the right side of the crown at RD 187 in Chamber -1 at the center of the crown.
- Horizontal displacement along the Chamber -1 was 3 mm to 16 mm.

After installation of supports, the analysis reveals that:

- The reduction in the displacements is 4 - 7 % in Chamber - 1, 4 - 9 % in Chamber -2 and 4 - 7 % in Chamber -3.
- The maximum compressive stresses are reduced and varies between 27 and 87 MPa.
- The factor of safety of the hopper and silt flushing tunnel improves further.
- The factor of safety of the pillars in between the pillars also improves further.

The comparison of displacements before and after installation of supports at all three chambers is shown in Fig. 6.2.

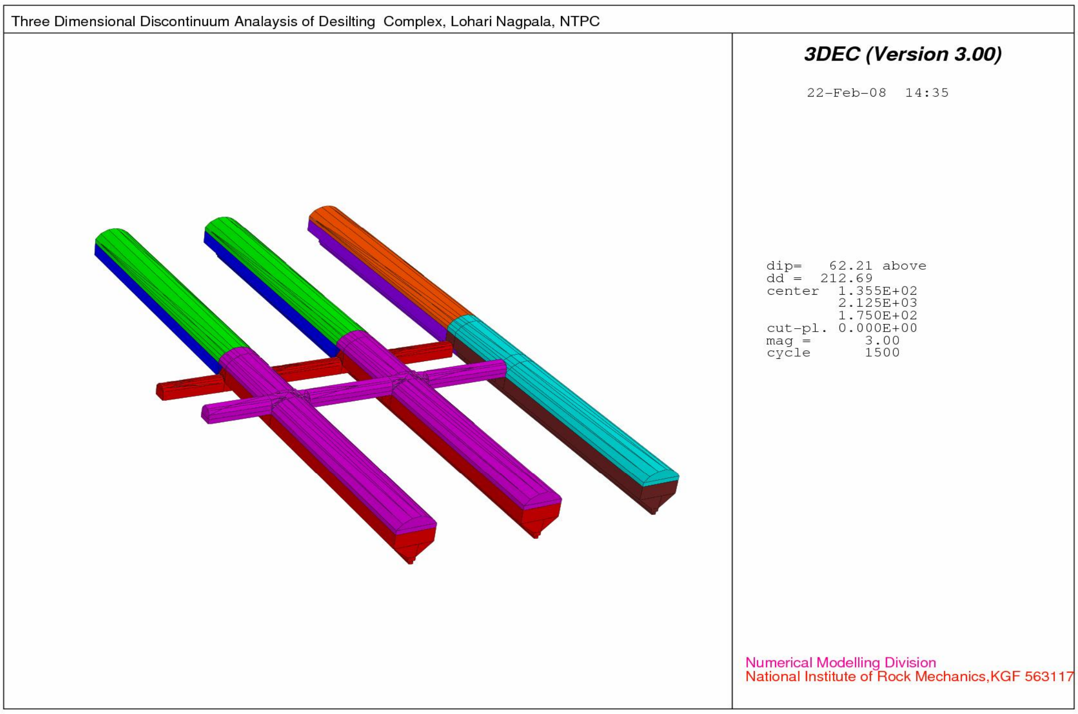


Fig. 6.1 Three dimensional model of Loharinag Pala desilting chambers

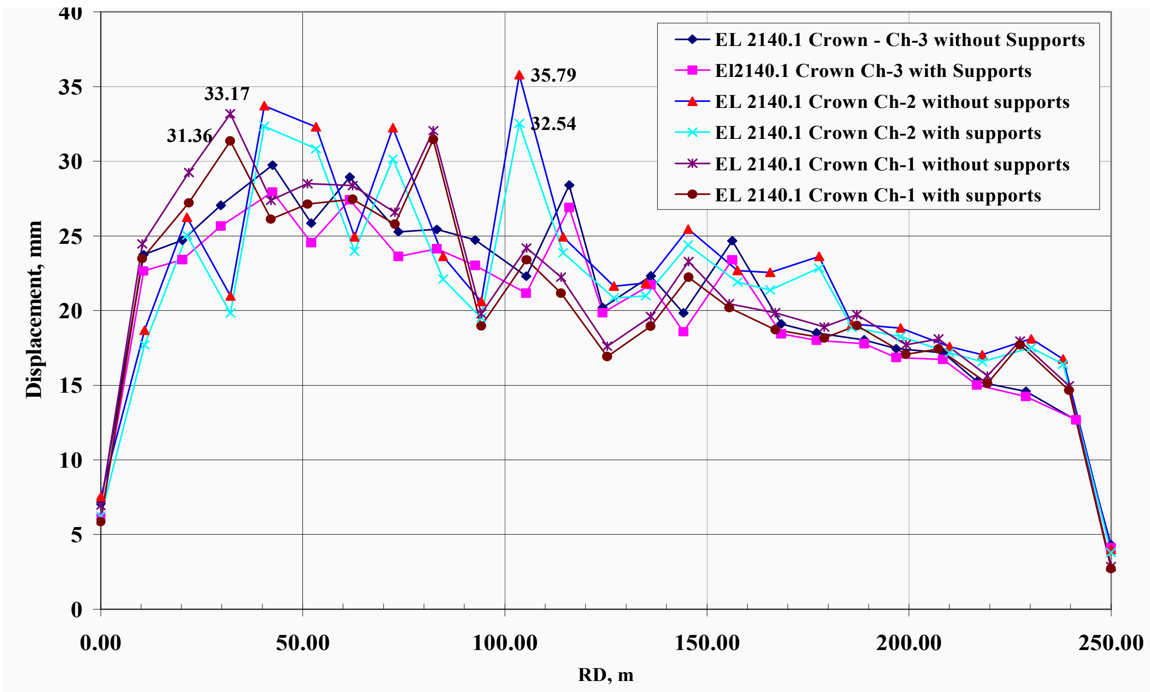


Fig. 6.2 Comparison of displacements at the crown before and after installation of supports

6.2 Instrumentation and monitoring

6.2.1 Instrumentation, monitoring and data analysis of underground powerhouse complex and desilting chambers of Tala HEP, Bhutan, Project No. NM0702
(Sripad, K. Sudhakar, G. D. Raju and P. C. Nawani)

Tala Hydroelectric Project (THEP) is a joint venture project between the Government of India and the Royal Government of Bhutan for the construction of 1020 MW run-of-the river scheme. Instrumentation work was carried out at all the underground excavations of Tala HEP. Instrumentation is being carried out since the year 2000 and is continuing even after the commissioning of the project.

During excavation of the crown portion

Four sections each along the length of machine hall and transformer hall caverns were selected for instrumentation. It was decided to install multi point bore hole extensometers of magnetic type in the center of the crown and left and right sides of the crown for measuring the deformations in the surrounding rock mass. At the same sections, the load on the rock bolts was measured using vibrating wire anchor load cells. The load cells were installed on the ribs at EL 533 level at six locations in machine hall and six locations in transformer hall. The measurement of pore water pressure was done by piezometers. The convergence of the ribs was monitored with reflective paper targets using total station.

During benching

Based on the 3D numerical modeling studies, instrumentation was carried out at four locations (EL 525, 520, 515 and EL 506) in the machine hall. At transformer hall, instrumentation was carried out at EL 525 and EL 520 at four locations. Convergence of the side wall of the cavern was measured. Load on the rock bolts was measured using anchor load cells. Instrumented bolts were used to measure the stress levels at various depths in the rock mass.

Instrumentation in the invert

After the reported upheaval at the invert of the machine hall cavern, an extensive instrumentation plan was prepared for turbine pits in order to monitor the time dependent behavior of the invert and to monitor the efficacy of the supports installed on the turbine pit floor. Accordingly, 20 m long multi-point-borehole extensometers of magnetic type were installed at the intersection of centre line of the cavity and TRT manifolds at pits and were further supplemented by prism target observations using total station. The monitoring continued till the instruments showed stabilization trends.

The instrumentation layouts in the machine hall cavern and desilting chamber are shown in Fig. 6.3. 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. It may be noted that in most of the locations, the load on the rock bolt decreased or the increase was minimal during the last one year. The maximum load measured was 41.3 tons at RD 150 downstream at EL 520 and shows a stabilizing trend.

Analysis of instrumented bolt data also indicates that there was no appreciable change in the stress levels on the rock bolts. At RD 65 downstream, there was a tensile stress of 394.5 tons during December 2005 which later reduced to 338.7 tons and thereafter it is showing a stabilizing trend.

The convergence observations at EL 525 at machine hall cavern are shown in Fig. 6.4. The maximum convergence was 359.3 mm at RD 65 and is tending towards stabilization and caverns are undergoing time dependent deformations.

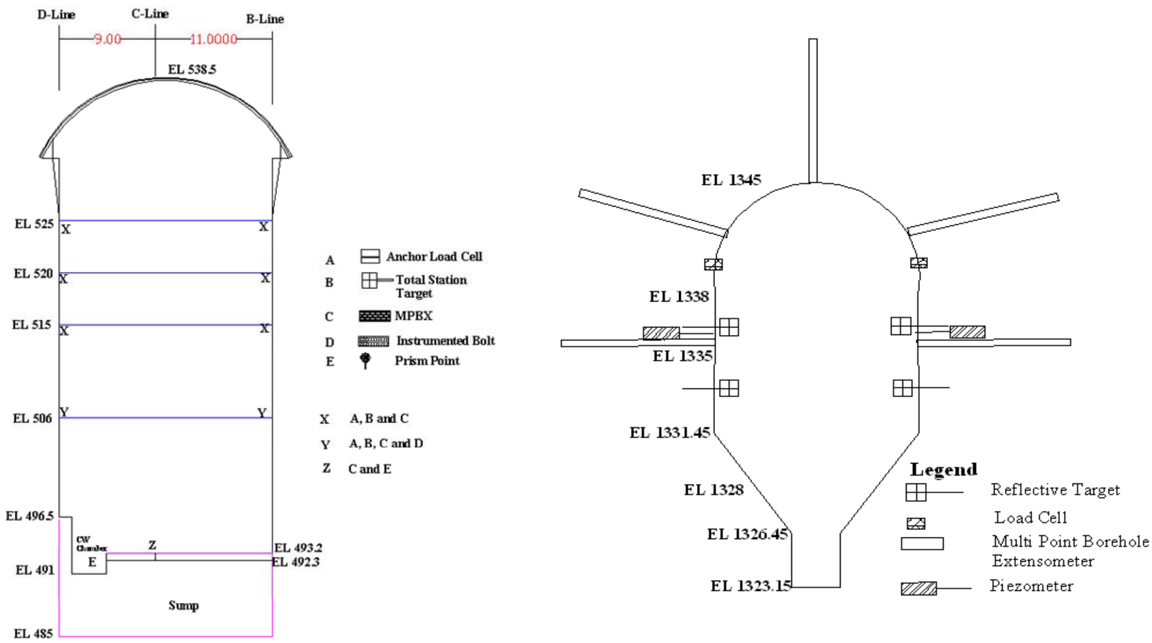


Fig. 6.3 Location of instruments in the machine hall cavern and desilting chamber at Tala HEP

Observations for a period of more than 500 days indicated that the floor heave, which occurred during the initial periods, was completely arrested on completion of RCC.

The cavern is currently undergoing time dependent deformations and is tending towards stability. The observations at transformer hall, bus ducts and other locations also indicated a stabilising trend.

At desilting chambers, the load cells and piezometers were connected to a junction box and terminated at a remote location for monitoring during the operation stages. The pore water pressures in the surrounding rock mass shows the trend as expected.

There were 166 instruments available for monitoring in powerhouse complex and desilting complex during the operation period.

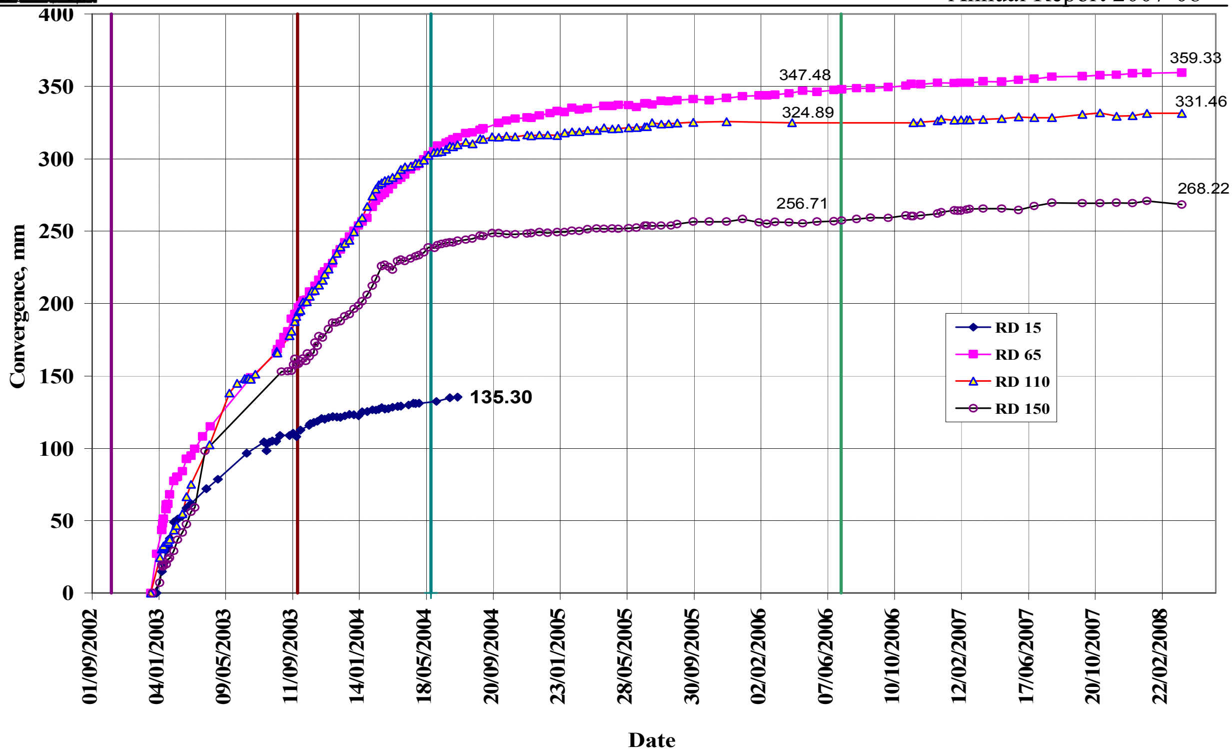


Fig. 6.4 Convergence of side walls of the machine hall cavern at EL 525 at Tala HEP

6.2.2 Analysis of instrumentation data of dam at Tala HEP, Bhutan, Project No. NM0703

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

The dam at Tala HEP is instrumented with several types of instruments for assessing its health. The project authority has entrusted the work for analysis of the data collected by them.

The instruments installed during the construction stage of the dam are: temperature meter, pore pressure meter, concrete pressure cell or stress meter, vibrating wire strain meter, joint meter/crack meter, multi point borehole extensometer, normal and inverted plumb line, up lift pressure meter, automatic water level recorder and strong motion accelerograph. Most of the instruments are vibrating wire type and the data is being acquired through a data acquisition system.

Vibrating-wire piezometers were installed in Block 2 and 5 to record pore pressure. Fig. 6.5 shows the observations for Block 2 at the dam.

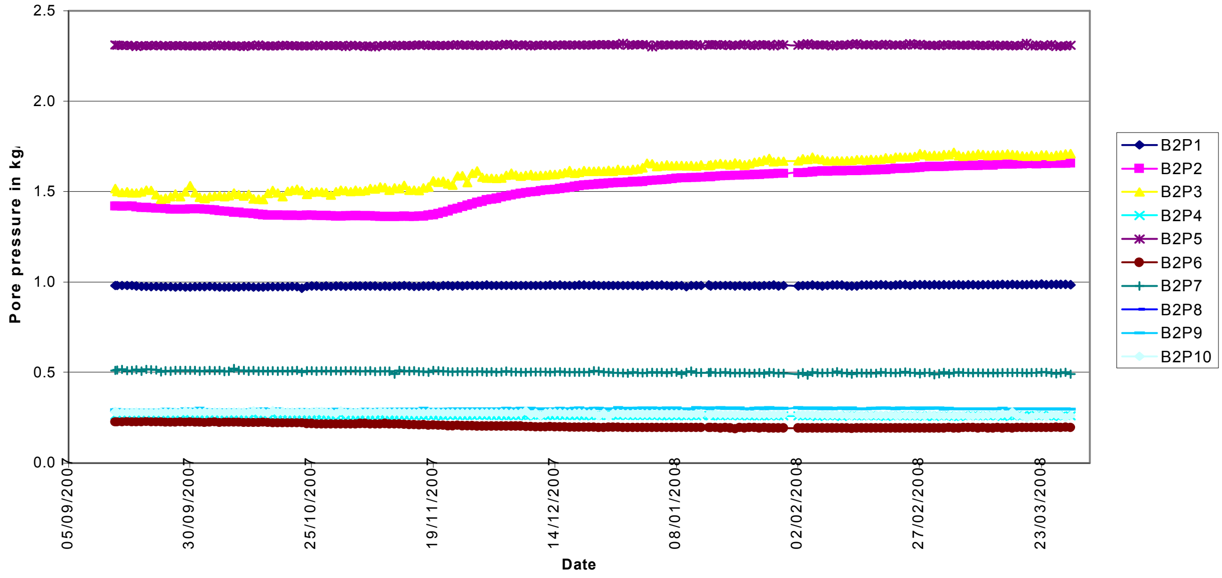


Fig. 6.5 Pore pressure observations at Block No 2 at the dam at Tala HEP

6.2.3 Deformation monitoring of underground powerhouse cavern of Sardar Sarovar Project, Gujarat, NM0707

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

The underground powerhouse complex of Sardar Sarovar Project consists of a 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 a few interconnecting tunnels and access tunnels, which are close to the powerhouse. The present investigation is continuation of monitoring of the rock mass behavior of the power house cavern since 2000. The monitoring is being carried out using magnetic ring multi point borehole extensometer (MPBX), reflective targets and total station.

Some of the important observations during the last one year are as follows:

- The maximum displacement observed at 7 to 9 m depth from machine hall side wall, as measured at bus duct gallery, varied between 8 and 12 mm. The MPBX installed towards draft tube shows displacements in the range of 4-6 mm. The extensometers at EL 0.0 m and EL 17.5 m on both upstream and downstream walls showed displacements of 4-7 mm, showing a stabilizing trend.
- The displacements at 7 to 9 m depth in the vicinity of bus galleries show an increasing trend.
- The wall movements were measured at EL0.0 m and EL17.5 m on both downstream and upstream side.
- The displacements measured on the columns and beams are within 3 mm, showing a stabilising trend.
- The measured side wall displacements correlate well with the predictions made by NIRM earlier with 3D numerical modeling.

6.2.4 Analysis of instrumentation data of machine hall and desilting complex of NJHEP, Project No. NM0708
(Sripad, GD. Raju, K.Sudhakar and P.C. Nawani)

The Nathpa Jhakri Hydroelectric project of SJVNL consists of underground powerhouse complex of 1500 MW located at Jhakri with four numbers of 525 m long with a cross section of 27 x 17 m each separated by 46 m rock pillar at Nathpa. The project was commissioned and desilting chambers was impounded in November 2003.

Stress analysis of powerhouse and desilting complexes were carried out and the supports were designed. To ascertain the stability of the caverns during operation, SJVNL carried out instrumentation using piezometers and extensometers. The data supplied by SJVNL is being analyzed.

6.3 Three dimensional stability analysis (discontinuum) of the right bank cut slopes of Koteshwar HEP, Rishikesh, NM0706
(Sripad, G. D. Raju, K. Sudhakar and P.C. Nawani)

Koteshwar Hydroelectric project, is under construction, envisages a 97.5 m high concrete gravity dam across river Bhagirathi and surface powerhouse with an installed capacity of 4 x 100 MW on the right bank at a distance 125 m downstream of the dam axis. A diversion tunnel of 8 m diameter has been constructed to divert non-monsoon discharge during the construction period. The dam is provided with 4 spillway bays of size 18 m x 16 m with radial gates to pass the peak design flood. The overflow spillway and energy dissipation arrangement will be located centrally in the river channel. The water from the reservoir will be drawn from four penstocks of 6.2 m diameter.

Two dimensional models using UDEC were formulated to study the individual sections on the right bank slope. A model was constructed with the actual geometry of the slopes. The actual slope profile was taken as the outer boundary and the model was subjected to gravity loading under existing in-situ stress conditions.

The results are being analysed using 3D discontnuum models for deducing the initial inference drawn from 2D modelling results.

6.4 Support design for tunnel at Nettempadu lift irrigation scheme, A.P., Project No. NM0701
(Sripad, G. D. Raju and K. Sudhakar

Delta Construction Systems is executing Nettampadu Lift Irrigation Scheme, Stage-II for Govt of A.P. The scheme has the following underground components:

- Pump house of 49.6 m x 18.6 m and 70 m deep.
- Surge pool of 49.6 m x 25.6 m and 65 m deep.
- Horse shoe tunnel of 5.6 m diameter, 2400 m long.
- Three inclined shafts, 100 m long each, at 45^{o}.

Conventional drill and blast method is adopted in all the above excavations. The objective of the study included:

- Stress analysis of the pump house and surge pool for estimating the support requirement.

- Support design and methodology of excavation for the tunnel portion.

The tunnel has three faces. There was no problem with the adit faces with the existing support system and methodology. Rock spitting/rock ejection with loud sounds soon after the blasting of the face resulted at zero point face after advancing

10 m from the portal. It was not safe for mucking or any other activities at the face. This affected the safety and the progress of work.

Q-system was used for design of support systems for granite rocks encountered in the tunnel which were classified as fair to good. Coupled with the numerical modeling analysis, the following support system was recommended and implemented at the site:

- Shotcrete of 50 mm thickness wherever necessary.
- 25 mm diameter, 3 m long rock bolts at spacing of 1.5 m. Grouting with resin end along with quick setting cement for the rest of the hole.

The above support design worked well with the adit faces. However, in most of the reaches, the rock mass was stable even without shotcrete and spot bolting. The support methodology adopted in the adit faces was tried at zero point face also but the progress was very poor and this called for modifications in the support methodology. The recommendations are as follows:

- Apply shotcrete of 25 mm thickness immediately after mucking.
- Install directional systematic rock bolts of 25 mm diameter, 3 m long with 1 m spacing staggered both ways, with resin end anchoring and quick setting cement for rest of the hole.
- Apply another layer of 25 mm thick shotcrete up to the spring level of the tunnel.
- Keep the unsupported span within 1.5 m. In addition, drill 3-4 pressure relief holes (51/76 mm diameter, 3-4 m long) in two rows in each face blast.
- Install 2 m long, 25 mm diameter rock anchors on the walls wherever rock bursting is active.
- The recommendations are to be followed in all rock mass conditions till rock bursting like phenomenon persists.
- For the pump house and surge pool, the support system was recommended based on numerical analysis.
- 32 mm diameter, 3 m long rock bolts at 1.5 m spacing to be installed followed by a layer of 100 mm shotcrete at soil portion
- Any anchoring for the crane beam columns in the center pillar should be anchored beyond 6 m from the pump house.

7. ROCK BLASTING AND 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 2007-08, the Rock Blasting and Excavation Department completed three industry sponsored and two in-house projects, and one sponsored project was in progress.

7.1 The effect of ground vibration due to blasting in nearby villages at Loharinag-Pala HEP, Uttarakhand, Project No. RB0606

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

Loharinag - Pala Hydroelectric Project (4 x 150 MW) of the National Thermal Power Corporation Limited is located on the right bank of river Bhagirathi in Uttarkashi district of Uttarakhand. The development of this project started with the construction of approach roads to three adits for excavation of head race tunnel. While carrying out blasting to construct approach roads, complaints were received from the surrounding villages. Ground vibration and air overpressure were monitored in the villages closer to the blasts to assess the impact of blasting. In total, ten blasts were monitored.

As some of the frequencies of the ground vibration were lower than 8 Hz, the permissible level was 5 mm/s (DGMS Circular of 1997). The measured peak particle velocities near or in the villages were lower than the permissible levels for all the blasts conducted during the study period. The air overpressure levels in all villages other than Rishi Kund village were within the permissible levels. Since this village was the closest to the blasts, the air overpressure exceeded the safe level of 133 dB in two cases, which might be due to the use of detonating cord.

In all, 41 sets of ground vibration and 34 sets of air overpressure data were analysed to derive site-specific predictor equations. Suitable remedial measures for control of ground vibration and air overpressure were suggested.

7.2 Study on ground vibration, air overpressure, flyrock & optimum charge and blasting pattern for controlled blasting, Sankari Works, T.N., Project No. RB0605

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

Veerachipalayam Limestone Quarry and Karumapurathanur Limestone Quarry, Sankari Works belonging to The India Cements Limited was planning to re-open their mines which were temporarily closed down due to modernisation of their cement plant from wet to dry process. The mining technology being adopted involved controlled blasting to develop only cracks so that rock breaker could break and sort out limestone from rejects at the face itself. A study was conducted to control ground vibration, air overpressure and flyrock and to establish suitable blast design parameters.

After considering the site conditions and the purpose of blasting, eight blasts were designed and experimented in each quarry. Ground vibration and air overpressure were monitored with four seismographs. The blasts were covered with conveyor belts and truck tyres to control flyrock. All the blasts were safe with respect to ground vibration and air overpressure. There was no flyrock as the specific charge was very low and the blasts were muffled. The degree of cracking was adequate to enable the breaker to break the rock fragments without any toe problem.

Using the data generated, predictor equations were derived for ground vibration and air overpressure. As the dominant frequency of the ground vibration was greater than 20 Hz, peak particle velocity up to 10 mm/s was permissible for the structures, not belonging to the mines. The maximum charge per delay for different distances was suggested to control both ground vibration and air overpressure within the permissible levels. Blast design parameters were also suggested to achieve the desired degree of cracking.

7.3 Monitoring of ground vibration due to quarry blasting at Visaka Cement Quarry, Tandur, A. P., Project No. RB0701

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

The Visaka Cement Industry Ltd is operating two limestone mines to feed their one million tonne per annum cement plant. The average requirement of limestone is about 5000 tonnes per day and in order to meet this, blasting operations are being carried out. To assess the impact of the blasting on the structures around these mines, ground vibration and air overpressure were monitored in four visits, once in six months over a period of two years.

There were no private structures located within 3 km from both the pits. Only one village, Sangam Kalan, was located at about 3 km from Pit 2. The structures belonging to the owner were located beyond 1 km from the mine workings.

Ground vibration and air overpressure were monitored with four or more seismographs at different distances and blast details were collected. Radial distances required for the analysis was measured using a laser based distance measuring system. Locations of instruments were decided based on the blasting sites vis-à-vis the Sangam Kalan village. The data generated were analysed and equations were derived for prediction. The permissible particle velocity was decided based on the DGMS Circular and the observed frequencies of blasts. All the blasts monitored were safe in terms of ground vibration and air overpressure. Control measures for ground vibration and air overpressure were recommended.

7.4 Technical advice for controlled blasting at Gokak small hydroelectric project, Belgaum, Karnataka, Project No. RB0607

(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 (4.5 MW) in Belgaum, Karnataka. The construction activity involves blasting parallel to the existing canal/buried penstock, blasting near existing powerhouse, opening in the weir structure etc. Controlled blasting was to be followed close to the structures.

A preliminary visit to the project site was made and pre-tender blast design specifications were submitted. A procedure for controlled blast design for excavation of powerhouse adjacent to the existing powerhouse was submitted and field-tested.

7.5 Prediction and control of ground vibration and air overpressure from construction blasting, In-house Project No. IN0702

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

Prediction of ground vibration and air overpressure from construction blasts for a known charge per delay at a specified distance is necessary for planning safe blasting operations. For this purpose, vibration and air overpressure data generated by NIRM from different projects over the last 15 years were compiled and analysed. The data were grouped into three categories: surface-to-surface, underground-to-underground and underground-to-surface, and empirical equations were derived for each of them. Figs. 7.1 and 7.2 show the same for surface-to-surface category. As the dominant frequency of ground vibration is greater than 8 Hz, the permissible vibration level is 10 mm/s for residential structures while it is much higher for underground structures depending on rock mass quality. Guidelines for control of ground vibration and air overpressure were developed for safe blasting at construction sites.

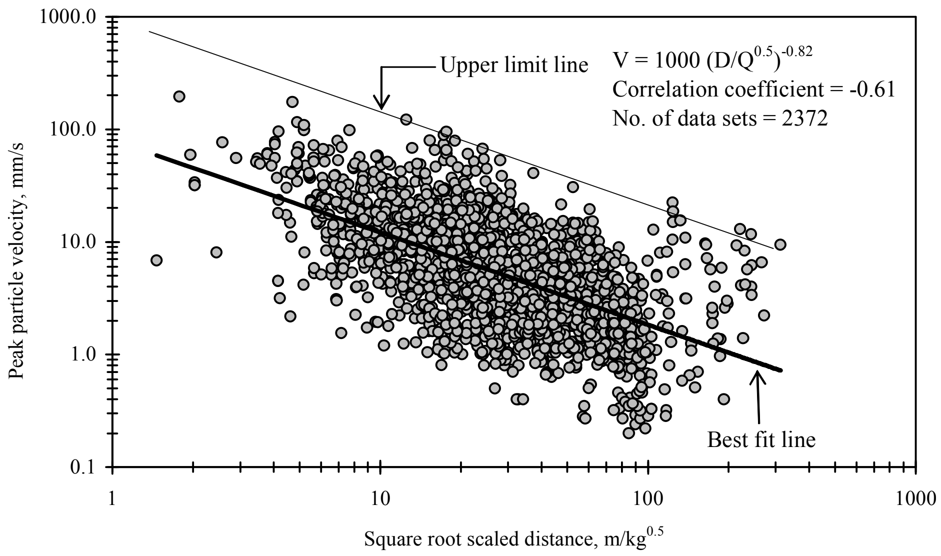


Fig. 7.1 Peak particle velocity versus scaled distance for surface-to surface category

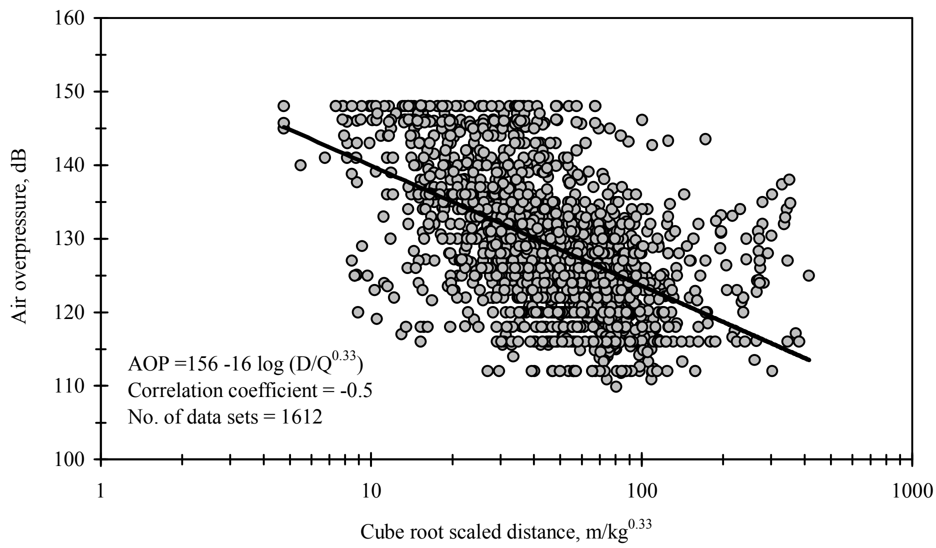


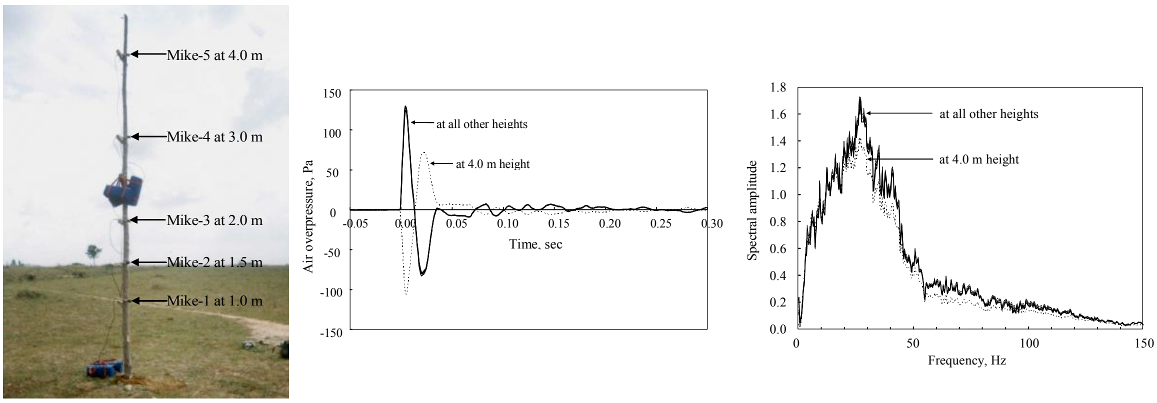
Fig. 7.2 Air overpressure versus cube root scaled distance for surface-to-surface category

7.6 Experiments on air overpressure, In-house Project No. IN0703

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

To compare the response of microphones of seismographs, a set of experiments was designed nd conducted at KGF. Five units of Minimate Plus were deployed at the same location and at the same height. Air overpressure was created by exploding festive crackers 'atom bombs' one after another at different distances. Figures on the back cover show the experimental set-up, waveforms and frequency spectra for one of the shots recorded by all the five microphones. The waveform of Mike-5, which is the mirror image of other waveforms, is acceptable. Thus, the experiments ascertained that microphones were accurate within their tolerance.

Another set of experiments was conducted in order to study the influence of mounting height of the microphone on air overpressure measurements. The experiments were conducted out at a stone quarry at Tekkal in Kolar District, Karnataka, using the same five seismographs. The microphones were placed at different heights, though a mounting height greater than 2.0 m is rarely used in practice. Fig. 7.3 shows the experimental set-up, waveforms and frequency spectra for one of blasts. It was found that the mounting height had negligible influence on air overpressure measurements.



a) Experimental set up b) Comparison of air overpressure c) Comparison of frequency spectra

Fig. 7.3 Experiments on the influence of microphone mounting height on air overpressure.

8. GROUND CONTROL AND 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 mining the coal from difficult seams by designing innovative and modern methods of work. Ground control studies, and systematic strata and support monitoring are essential for safe design of mining of such deposits and to validate the designs. It is also imperative to design safe and economic slope angles in various open pit mines with an increasing depth of surface mining excavations. During 2007-08, the Ground Control and Mine Design Department undertook several S&T projects and a number of industry-sponsored projects.

8.1 Determination of in-situ strength of coal at GDK-10 inclines, RG-2 Area, SCCL, Project No. GC0706

(S. Benady, S.B. Mishra and V. Venkateswarlu)

The Singareni Collieries Company Limited (SCCL) have planned to increase the coal output through introduction of high production longwall technology in virgin blocks, in collaboration with Council for Scientific and Industrial Research Organisation, Australia. The first such project being taken up is Adriyala Longwall Project, situated in the dip side boundary of GDK-10A/GDK-10 inclines, Ramagundam-III Area of SCCL.

As part of the geotechnical evaluation of the longwall project, the in-situ strength was to be determined. Coal specimens of size 30 cm x 30 cm x 30 cm were prepared in the large pillars and were subjected to uniaxial loading using a high capacity hydraulic jack, and the deformations were recorded (Fig. 8.1).

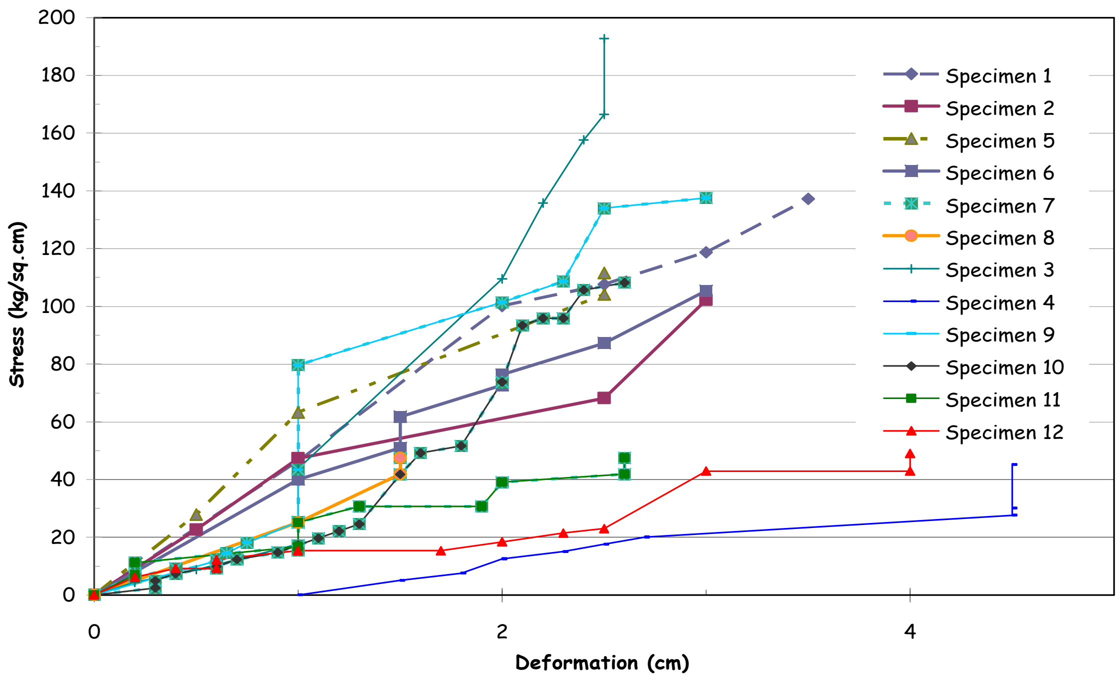


Fig. 8.1 In-situ strength of coal in GDK-10 and GDK-10A Inclines

The ratio of load at failure to the surface area of loading gives the in-situ strength of the coal. The ratio of load to the amount of deformation indicates its stiffness.

Due to the presence of thin clay band in the middle of seam I, the minimum in-situ strength was 35 kg/cm^2, the maximum was 105 kg/cm^2 and the average strength was 57 kg/cm^2. On the other hand, the average in-situ strength of the coal in Seam III was 132 kg/cm^2. This coal with stiffness of 40,000 and 50,000 kg/cm was stiffer than Seam I whose stiffness values ranged from 30,000 to 40,000 kg/cm.

8.2 Strata control in coal mines

8.2.1 Optimization of pillar dimensions in steeply inclined seams S&T Project Nos.GC9907 & GC0703

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

An S&T project, funded by the Department of Coal, Government of India, was initiated in 1999 in collaboration with SCCL to optimize the design parameters for pillars in steeply inclined seams. As no mechanized system is available for extraction of coal seams dipping more than 1 in 2.5 (21.8^o), bord and pillar method was planned using manual loading. However, there were practical problems with basket loading in such steep gradients.

Kakatiya Khani No. 5 (KTK-5) Incline in Bhoopalpalli Area was selected for experimentation. Based on numerical modeling, it was recommended to develop rectangular pillars of size 10 m x 26 m (Phase-I). The development of the experimental panel started in April, 2005 (Phase-II). Required instruments were installed and strata was monitored till the end of the development. The monitored data indicated normal and stable strata conditions in the experimental panel. Therefore, it was recommended to take up the depillaring operations.

The depillaring operations in the panel were carried out from November 2006 to August 2007 (Phase-III). During this period, strata behaviour and the performance of the supports were monitored. The data from the instruments indicated normal strata conditions.

The roof strata above the seam was moderately caveable in nature; therefore, induced blasting was carried out periodically. With this, regular falls had taken place in the goaf during the depillaring operations. Physical observation of the roof and sides in the panel indicated that the general ground conditions were satisfactory, and there was no significant disturbance or deterioration of the roof or the pillars anywhere in the panel. Based on the investigations it was concluded that rectangular pillars with a width/length ratio of 1:2 can be effectively worked without any strata control problems. It was recommended to adopt the system in manual working panels wherever the seam has a steep gradient.

8.2.2 Caveability of the roof strata in longwall panels, S&T Project, No. GC0509

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

Longwall mining with caving is a very popular method of underground mining worldwide. This method has a high potential of production and productivity with safety and conservation. Unfortunately, major collapses/failures were experienced in mechanized longwall faces in India such as at Churcha, SECL, and Kottadih, ECL. The overlying roof was massive and difficult to cave, and the support resistance initially estimated was found inadequate to cope up with the caving of coal roof.

Understanding the caving behaviour of roof rocks is of prime necessity to decide on the support type and its capacity to achieve successful strata control in a longwall panel. Against this backdrop, an S&T project funded by the Department of Coal, Government of India was taken jointly by three major research institutions, CMRI, NIRM and ISM. The objectives were to develop an integrated approach for selection of the capacity of powered supports and formulate strata and support behaviour monitoring schemes for longwall operation in Indian coal mines.

In this project, numerical modelling techniques will be applied to study the sequence and nature of caving of overlying rocks in longwall panels. Based on these, it is proposed to develop suitable methods for the assessment of caveability of overlying roof rocks.

The GDK-10A Incline, RG-III Area, SCCL, has been identified as the first panel for the study. All the preliminary data related to the mine has been collected. The necessary instruments are being procured.

The data from already extracted longwall panels was collected from GDK-9 incline, VK-7 Incline and PVK Incline of SCCL.

8.2.3 Feasibility of extraction of pillars by wide stall method at GDK-8A Incline, RG-2 Area, SCCL, Project No. GC0704
(Atul Gandhe, S. Benady, V. Venkateswarlu and S.B. Mishra)

At Godavari Khani 8A Incline, the top seam no. 1 was developed by bord and pillar method and was extracted by conventional splitting and slicing method. So far 33 panels were depillared in this seam by caving method. Later, the DGMS accorded permission for adopting wide stall method using side discharge loaders at this mine. The method was initially adopted in panel no. 47 (WS-1) where there was a clay band at the bottom. The method was also used in the adjacent panels, WS-2 and WS-3 where the clay band was at the top of the seam. Strata monitoring was carried out during working of these panels. Following the successful working of these wide stall panels, SCCL proposed to extract coal from three other similar panels having clay bands.

Panel no. WS-4 in seam no. 1 was studied for its feasibility for widening and deepening by widestall method. This panel has 372 pillars between 28D/7L and 34D/23L with a depth cover ranging from 39 m to 90 m. The smallest size of the developed pillars in this panel is 15.8 m x 16.7 m (solid, corner to corner), and that of the largest pillar is 20.8 m x 40.3 m. The width of the galleries varies from 3 to 5 m.

For designing the panel, estimation of the likely rock loads and support requirements, empirical classification methods, Rock Mass Rating (RMR) etc were calculated. The RMR of 55 classifies the roof strata as Class III-B Fair Roof. The rock load exerted on the immediate roof was estimated. The rock mass quality index, Q, based on NGI classification approach was also determined for the immediate roof.

The strength of the coal pillar was calculated and the safety factors were deduced. Calculations were made for discontinuous subsidence due to the extraction of all the 372 pillars with a shallow depth cover of 39 m to 90 m. On the basis of results obtained, the following recommendations were made:

Depth (m)	No. of pillars	Width of extraction (m)	Final height of extraction (m)
39-70	164	**THE GALLERIES SHALL NOT BE WIDENED OR HEIGHTENED**	
71- 89	193	7	4.8
> 89	15	7	6.0

Based on the above, it was concluded that the galleries of widestall panel WS-4 can be widened to 7 m, and with an acceptable minimum safety factor of 1.86. The total height of extraction could be 4.8 m in the depth range of 71 to 89 m, and 6 m if the depth is more than 89 m.

Similar studies for WS-6 and WS-8 panels at the mine are in progress.

8.2.4 Stability of rhombus shaped pillars at KTK-1, 5 & 8, Bhupalapalli Area, SCCL, Project No. GC0605
(V. Venkateswarlu, Atul Gandhe, S. Benady and S. B. Mishra)

Strata control problems are encountered at KTK-1 and 5 Inclines, particularly due to steep gradients. To negotiate the steep gradients, the 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. Similar problems are expected at KTK-8 Incline where high capacity longwalls are proposed to be deployed.

A scientific study was taken up for understanding the stability of the rhombus shaped pillars. The estimates of the likely roof pressure and the natural support resistance with the included in-square pillars were calculated.

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

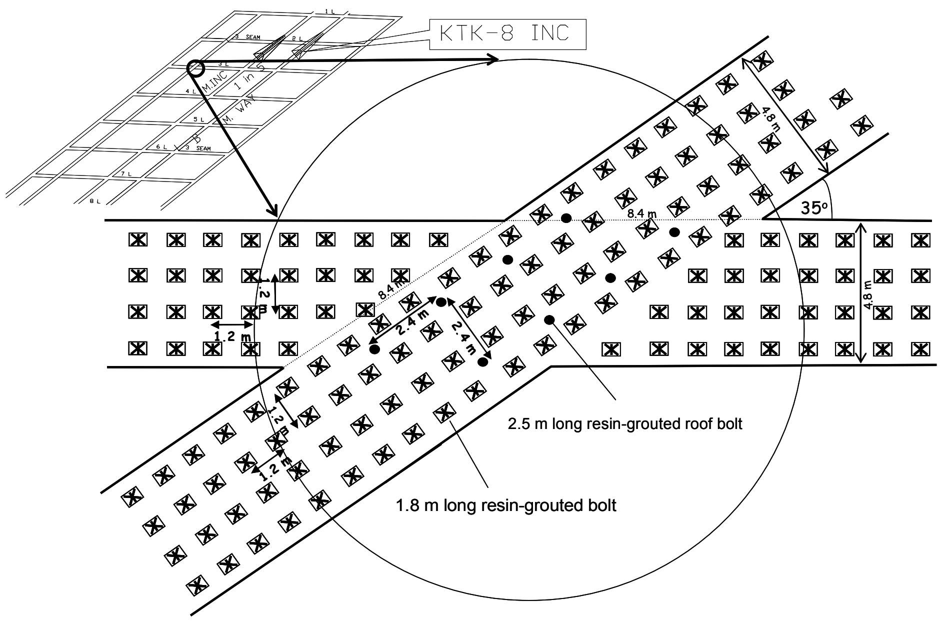


Fig. 8.2 Support design in galleries and junctions with rhombus shaped pillars

The roof in the level and the dip-rise galleries shall be supported by 1.8 m long full-column resin grouted roof bolts at 1.2 m x 1.2 m spacing. The roof strata in the junctions shall be supported by resin-grouted roof bolts. In addition, 2.5 m long resin-grouted roof bolts (eight in number, in 4 x 2 rows) shall be installed at 2.4 m x 2.4 m spacing in between the bolting rows at the centre (Fig. 8.2).

In case the area near the acute-angled corners of the pillars becomes weak due to spalling, additional supports of 0.5 m thick masonry/concrete wall should be provided for 2 m length on either side of the corner.

The ground conditions in 1A seam of KTK-1 and 5 Inclines were also studied. However, 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.

The study in other seams and at other mines is continuing.

8.2.5 Design of supports at KTK-2, 3 and 6 Inclines, Bhupalpalli Area, SCCL, Project No. GC0604
(Atul Gandhe, S. Benady and V. Venkateswarlu)

Roof control problems are being experienced at KTK-2, KTK-3 and KTK-6 inclines of the Bhoopalpalli area of SCCL. Studies were taken up to formulate the systematic support rules for the development workings in all the three seams occurring at these three mines.

The strata at these mines are steeply dipping by 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, and 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.

8.3 Instrumentation and strata monitoring in wide-stall panel at GDK-8A Incline, RG-2 Area, SCCL, Project No. GC0702
(S. Benady, Atul Gandhe and V. Venkateswarlu)

Following the successful working of earlier wide stall panels, panel no. WS-3 was also worked by the wide-stall method. Instrumentation and strata behavior monitoring were carried out in this panel.

No roof movements were recorded in the workings ahead of pillars under extraction, and no bed separation was recorded at the junctions during the monitoring period. The remote monitoring instruments also did not show any deterioration of the roof or the pillar after widening and deepening of the galleries. This confirms the stability of the roof after widening and the efficacy of supports in the galleries and at the junctions.

8.4 Slope stability studies

8.4.1 Design of slopes in iron ore mines, Goa, Project No. SS0701 & SS0702
(Atul Gandhe and V. Venkateswarlu)

Opencast method is used to extract iron ore by M/s Salgaocar Mining Industries Pvt. Ltd., and M/s VS Dempo & Co Pvt Ltd., Goa. The slopes in these iron ore mines consist mainly of soft, soil-like and weathered schistose formations, laterites, and various types of clays. The soft formations are characterized by the presence of tension cracks. This region receives heavy rainfall every year. Water seepage during the rainy season (Fig. 8.3) reduces the shear strength of the slope formations, causing failures and cavities (Fig. 8.4). Due to this problem, studies were initiated to investigate the stability of the pit slopes and to suggest suitable design parameters.

For designing the safe slope angles, it analysis would be carried out based on the limit equilibrium method using GALENA software. Soil samples were collected from the mine and physico-mechanical properties of the soil/rocks were determined. These properties will become the basic input for analysis.

Fig. 8.3 Water seepage within the pit slopes at an iron ore mine in Goa

Fig. 8.4 Cavity formation in a pit slope at an iron ore mine in Goa

9. DIMENSIONAL STONE TECHNOLOGY

Exploitation of dimensional stones in a scientific way requires geological and geotechnical studies to characterize the deposit, testing for various properties and planning of quarry including equipment selection. Controlled blasting/splitting techniques are to be designed for reducing the damage to blocks and for maximising the recovery. During 2007-08, the Department of Dimensional Stone Technology completed one sponsored project and conducted one training program.

9.1 Setting up of a test house (CDOS) at Jaipur, Rajasthan, Project No. GM0202

(A. Rajan Babu and S. Udayakumar)

A test house was commissioned and equipped with state-of-the-art facilities to undertake various tests as per national and international standards such as ASTM and European standards. These tests are listed below:

Physical properties

- Density
- Specific gravity
- Water absorption by weight
- Porosity
- Permeability
- P-wave velocity
- Hardness
- Gloss reflectivity
- Abrasion resistance test

Petrological/Chemical properties

- Physical properties (colour, streak, hardness, lustre, etc)
- Chemical composition (elements)
- Modal composition (minerals)
- Optical properties (under plain and crossed polarised light)

Mechanical properties

- Compressive strength
- Tensile strength
- Flexural strength
- Modulus of rupture
- Static elastic constants (Young's modulus, Poisson's ratio)
- Impact strength
- Point load strength index
- Slip resistance test
- Shear strength
- Dynamic elastic constants
- Slake durability
- Thermal dilation co-efficient
- Swelling test

Weathering

- Freeze resistance
- Temperature and humidity cycling test (freeze and thaw)
- Salt corrosion resistance test
- Weathering and acid rain resistance

9.2 Training on exploration, quarrying techniques and testing of dimensional stones at NIRM, KGF, Project No. GM0604

(A. Rajan Babu)

A contract was signed between NIRM and Commissionerate of Geology and Mining, Government of Gujarat, for conducting training courses for their executives on "Exploration, Quarrying Techniques and Testing of Dimensional Stones." The following topics were covered:

- Introduction to dimensional stone quarrying (special reference to granite and marble)
- Exploration of dimensional stone deposits
- Granite quarrying scenario in Gujarat
- Glossary of scientific and quarry terms
- Dimensional stone granite quarrying
- Blasting in dimensional stone quarries

- Introduction to new developments in quarrying technology
- Development and planning of marble quarries
- Scientific exploitation of dimensional stones
- Case studies
- Risk associated with dimensional stone granite quarrying in Indian conditions
- Rock mass classification system
- Blast design methodology for surface mines
- Testing of dimensional stones
- Application of geophysical techniques for exploitation of dimensional stones
- Detection of hidden flaws and fractures in dimension stones

Fig. 9.1 Black granite quarry, Ongole, A.P.

Field visits were made to black granite quarry at Kanigiri, Ongole, A.P. (Fig. 9.1) and Paradiso colored granite quarry at Krishnagiri, T.N. (Fig. 9.2), where exploration techniques, method of quarrying and controlled blasting procedures were demonstrated.

The training programme was successfully completed at NIRM, KGF from 16 to 30 April 2007.

Fig. 9.2 Paradiso granite quarry, Krishnagiri, T.N.

9.3 Technical guidance and advice related to the dimensional stone quarrying operations for KIOCL, Bangalore

(A. Rajan Babu and V. P. Mishra)

Scope of Work

- To assist in survey and identification of granite deposits having potential for commercial exploitation.
- To conduct tests on rock samples to establish its quality and assess the market potential

MOU is signed; approval is awaited to take up the work.

10. ENVIRONMENTAL GEOTECHNOLOGY

Environmental audit is essential for mining and allied industries. The Environmental Geotechnology Department deals with assessment of air, water and soil qualities, noise survey and measurement of meteorological parameters. During 2007-08, this department completed two in-house projects and one S&T project was in progress.

10.1 Assessment of dust and meteorological parameters at NIRM premises, In-house Project No. IN0601

(Surendra Roy and G. R. Adhikari)

The particulate matter in the atmosphere is mainly divided into two categories (TSP, PM_{10}). Total suspended particulate matter (TSP) is the particulate matter collected with a high volume sampler, which captures particles ranging from 0.1 to about 100 µm in diameter. PM_{10} is the particulate less than 10 µm, which can pass through the nasal tracts and enter the lungs. The extent to which an individual is affected by air pollution usually depends on the duration of exposure and concentration of air pollutants.

The mining and beneficiation of ore at KGF generated a large amount of gold mill tailings, which were dumped at different locations in the mining township. After the closure of the gold mines, feasibility studies for setting up new industries are being conducted. Although the need for other industries is indisputable, local residents are concerned about the air pollution that may be caused by the industries.

A study was carried out to generate basic data on ambient air and meteorology. It dealt with quantification of PM_{10}, TSP in different seasons and assessment with reference to Indian regulations. It also aimed to study the influence of meteorological parameters on the particulate.

Dust sampling was carried out twice a week for a duration of four weeks in each season. In rainy season, no sampling was conducted as the dust concentrations will be low. Twenty four samples were collected in three shifts of eight hours duration in each season. Meteorological data for about one year including the dust monitoring period were generated.

It was concluded that particulate concentrations on some monitoring days exceeded the permissible limits in the area. Therefore suitable mitigative measures must be incorporated in the environmental management plan of the new industries to be set up in the area. Systematic dust sampling must be conducted to ensure that the ambient air is not deteriorated by the industries. PM_{10} was the highest in winter because the wind direction was predominant from the gold mill tailing dumps. The PM_{10} /TSP ratio was found to be the highest in winter. In general, TSP was the highest in spring, probably due to the influence of dust generated from the open and uncovered land nearby the monitoring station. In summer, the dust concentrations were the lowest basically due to the intermittent rain. The correlations of wind speed, temperature, humidity and solar radiation with PM_{10} and TSP were poor, but the correlations improved significantly when multiple regression analysis of data was carried out. It shows that meteorological conditions have influence on dust concentrations.

10.2 Noise produced from diesel and electric surface coal mining machinery and possibility of rock characterisation using noise levels while drilling, Dudhichuwa OCP, In-house Project No. IN0701

(Surendra Roy and G. R. Adhikari)

Various types of machines such as drill machines, draglines, shovels, dumpers and dozers are used in opencast coal mines. These machines are operated either by diesel engines or by electric motors. Some of them are mobile while others like crushers are fixed. These machines create noise pollution problems to the operators and their surroundings.

In order to protect the health and safety of operators and their surroundings, DGMS has defined the maximum allowable daily noise exposure as 90 dB(A) in an eight-hour shift with unprotected ears via their circular no. DG (Tech)/18, 1975. The Government of India has made another standard applicable for environmental noise for coal mines. This standard limits the sound level to 75 dB(A) from 6 AM to 10 PM and 70 dB(A) from 10 PM to 6 AM. Therefore, the noise generated by mining machines needs to be monitored in terms of occupational noise and environmental noise. The objectives of the study were to assess environmental noise and operator noise dose for diesel and electric mine machines and to study application of noise level in rock characterization.

The data were collected at Dudhichuwa opencast coal mine, NCL. The study concluded that the environmental noise levels, projected and measured operator's noise dose for the diesel machines were higher than those for the electric machines. The sound levels on different floors of the crusher, though electrically operated, were higher than the prescribed limits due to poor dissipation of noise inside the crusher house. For some machines also, the environmental noise as well as operator's noise dose was found higher than the prescribed limits. The effect of noise can be minimised in coal mining by replacing diesel machines with electric machines, wherever possible. The measured sound levels while drilling in sandstone could be used to characterise the rock as soft, medium or hard, which can find application in blasting.

10.3 Study on blasting dust management system in an opencast coal mine, S&T Project EE0601

(Surendra Roy and G. R. Adhikari)

Drill cuttings and core samples were collected from different benches of Dudhichua Project, NCL and analysed.

There was no significant difference in the specific gravity of the overburden benches indicating that it would have similar influence upon dust during overburden bench blasting. The density and silt percentage of overburden varies from bench to bench. Low density rock shows higher silt percentage and vice versa. The variation in the specific gravity in coal seams might be due to the presence of shale and other dirt materials. Low density of coal indicates higher silt percentage. Moisture content depends upon the depth and the density of rocks and will also vary from season to season. Hence, it will affect the dust generation during blasting. Further study is in progress.

11. TECHNICAL SERVICES

(C. Srinivasan, A. N. Nagarajan, A. Vijayakumar and S. L. Mary)

Technical Services Department (TSD) provides logistic and infrastructure support to various Departments of the institute by way of project monitoring, project accounting, technology transfer, library and information services, documentation, publicity and public relations. This Department maintains records related to periodic reviews of projects, Department wise earnings and total cash flow of the Institute. It also forwards monthly/quarterly progress reports of various projects to the respective sponsoring agencies and provides secretarial assistance to the Peer Review Committee, Governing Body and General Body of the Institute.

11.1 Project monitoring

TSD provided supports to execute consultancy/sponsored, S&T and in-house projects. Its activities included preparation of plan documents, annual budget, interaction with sponsoring agencies on the subject and expenditure monitoring. The activities for sponsored projects include submission of proposals, ensuring fund flow and evaluation of customer satisfaction levels.

11.2 Liaison services

R&D activities, capabilities and achievements of different departments were collected from time to time. Information on R&D activities of the institute was provided to the Ministry of Mines, other government organisations and also to clients on request.

Custom/excise duty exemption was obtained from the Department of Scientific and Industrial Research, New Delhi. It is valid up to the year 2012.

TSD has applied for recognition of NIRM by the Department of Science and Technology, New Delhi beyond March, 2008.

11.3 Publications

TSD forwarded several reports on completed/on-going projects to various sponsoring agencies. It also facilitated NIRM Scientists in preparing reports and papers. Copies of Annual Report for the year 2006-2007 were circulated to various user industries, academic/ research institutions and to some eminent persons in India and abroad.

11.4 Publicity

Advertisements on Institute's activities and capabilities were released in various journals, souvenirs and newsletters for wide publicity. Individual memberships of various professional societies for Scientists were renewed.

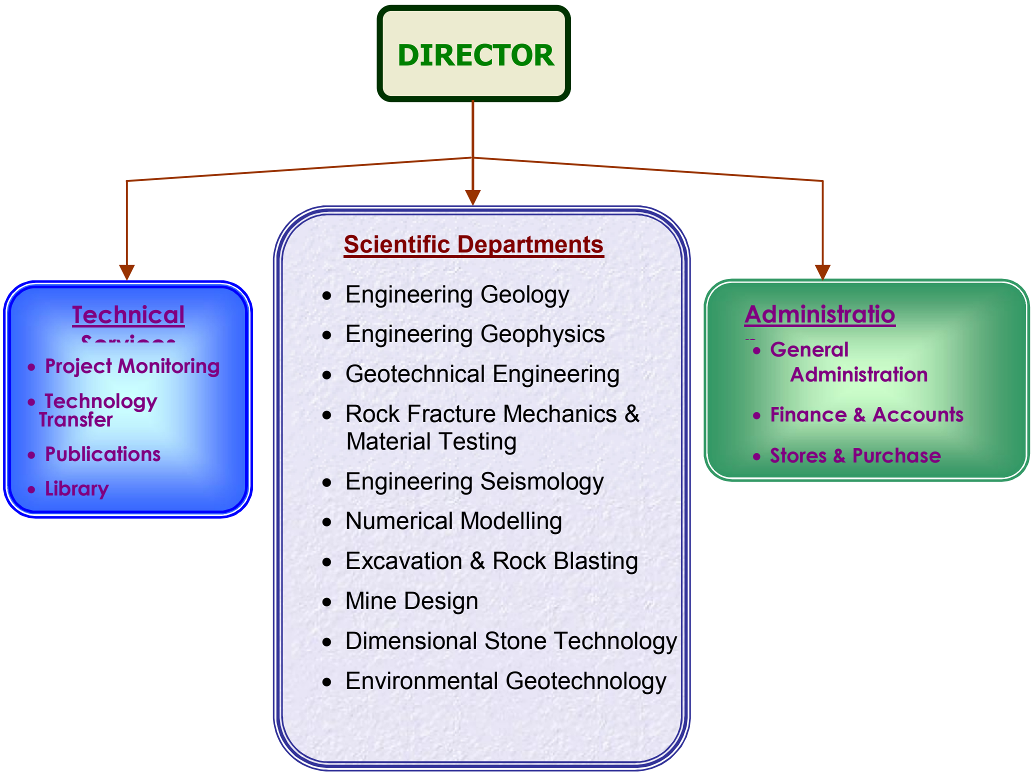
11.5 Library and documentation

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

Annexures

Annexure - 1

ORGANISATIONAL CHART



Annexure - 2

MEMBERS OF THE GENERAL BODY

Chairman

Sri J P Singh, IAS
Secretary to Government of India
Ministry of Mines
3rd Floor, A Wing, Room no. 320
Shastri Bhawan
Dr. Rajendra Prasad Road
NEW DELHI – 110 115

Members

Shri S. Vijay Kumar
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Dr Rajendra Prasad Road
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Jt. Secretary & Financial Advisor
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Geological Survey of India
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K O L K A T A – 700 016
West Bengal.

The Director General of Mines Safety
Diretorate General of Mines Safety
DHANBAD ─ 826 001
Jharkhand

Shri C.P. Ambesh
Controller General
Indian Bureau of Mines
Indira Bhavan, Civil Lines
NAGPUR - 440 001

Shri S.K. Dodeja
Director (Projects)
National Hydro-Power Corpn Ltd
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

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Goverdhan Vilas
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Rajasthan

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WEST BENGAL

Shri K.B. Dubey
Director (Projects)
N T P C Ltd
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Shri A.K. Bhandari
Advisor (TPPC)
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Dr. P. C. Nawani
Director
National Institute of Rock Mechanics
Champion Reefs
KOLAR GOLD FIELDS – 563 117

Secretary (Non-Member)

Mr. A N Nagarajan
Scientist, Technical Services Department
National Institute of Rock Mechanics
Champion Reefs
KOLAR GOLD FIELDS – 563 117

Annexure - 3

MEMBERS OF THE GOVERNING BODY

Chairman

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The Director General of Mines Safety
Directorate General of Mines Safety
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Controller General
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Government of Karnataka
Vikas Soudha
BANGALORE - 560 001.

Dr. P. C. Nawani
Director
National Institute of Rock Mechanics
Champion Reefs
KOLAR GOLD FIELDS - 563 117

Secretary (Non-Member)

Mr. A N Nagarajan
Scientist, Technical Services Department
National Institute of Rock Mechanics
Champion Reefs
KOLAR GOLD FIELDS – 563 117.

Annexure - 4

MEMBERS OF THE PEER REVIEW COMMITTEE

Chairman

Sri Ravi Shanker
Director General (Retd.)
Geological Survey of India
B-5, Sector K, Aligunj
LUCKNOW – 226 020

Members

Prof. A. K. Ghose
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West Bengal.

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Member (D&R)
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Dr. P. C. Nawani
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Member-Secretary

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Annexure - 5

SUPPORTING ORGANISATIONS/ CLIENTELE

Central Government Ministries & Departments

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

State Government / Public Sector Organisations

Bharat Earth Movers Limited (BEML)
Centre for Development of Stones (CDOS)
Central Mine Planning & Design Institute Limited (CMPDI)
Commissionerate of Geology & Mining, Gujarat (CGM)
Hindustan Zinc Limited (HZL)
Hutti Gold Mines Limited (HGML)
Kudremukh Iron Ore Company Limited (KIOCL)
Manganese Ore India Limited (MOIL)
National Hydro Power Corporation Limited (NHPC)
National Thermal Power Corporation (NTPC)
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)

Private Companies

Advance Mining Technology (AMT)
Alliance Mineral Private Limited (AMPL)
Bangalore Elevated Tollway Limited (BETL)
Constell Consultants Private Limited (CCPL)
Delta Construction Systems (DCS)
Energy Infratech Private Limited (EIPL)
Erudite Engineers Private Limited (EEPL)
Faiveley India Transport Limited (FITL)
Ferro-Alloys Corporation (FACOR)
Forbes Gokak Limited (FGL)
G. Venkat Reddy & Company (GVR)
India Cements Limited (ICL)
Larsen-Toubro Limited (L&T)

Salgaocar Mining Industries Private Limited (SMIPL)
V. S. Dempo & Co. Private Limited (Dempo)
Visaka Cement Industry Limited (VCIL)
Zoom Mineral Development Private Limited (ZMDPL)

International Organisations

Tala Hydro Power Authority (THPA), Bhutan

Annexure - 6

LIST OF PROJECTS

SCIENCE & TECHNOLOGY PROJECTS

Serial No.	Title of the Project	Funding Agency	Status
1	Optimisation of pillar parameters for development and final extraction of highly inclined seams at SCCL mines	Ministry of Coal, Govt. of India	Completed
2	Investigation of caveability of overlying strata, and development of guidelines for estimation of support capacity for longwall faces (in collaboration with CMRI and ISM)	Ministry of Coal, Govt. of India	On-going
3	Study on blasting dust management system in an opencast coal mine.	Ministry of Coal, Govt. of India	On-going
4	Establishment of Broad Band seismic station	Dept. of Science & Technology	On-going

IN-HOUSE PROJECTS

Serial No.	Title of the Project	Status
1	Prediction and control of ground vibration and air overpressure from construction blasting	Completed
2	Experiments on air overpressure	Completed
3	Assessment of dust and meteorological parameters at NIRM premises	Completed
4	Noise produced from diesel and electric surface coal mining machinery and possibility of rock characterisation using noise levels while drilling	Completed
5	Influence of stress ratio of two principal horizontal stresses on the preferred direction of hydrofrac under polyaxial stress condition for different anisotropic rocks	On-going
6	Extraction of rectangular pillars in a highly inclined seam at KTK-5 Incline, SCCL	Completed
7	Microseismic investigations for coal mines	On-going
8	Data bank of physico-mechanical properties of rocks	Completed
9	Laboratory rock mechanics investigations on basalt	On-going

SPONSORED MINING PROJECTS

Serial No.	Title of the project	Sponsorer	Status
1	Study on ground vibration, air overpressure, flyrock & optimum charge and blasting pattern for controlled blasting, Sankari Works, T.N.	ICL	Completed
2	Monitoring of ground vibration due to quarry blasting at Visaka Cement Quarry, Tandur, A.P.	VCIL	Completed
3	Vertical electric sounding for evaluation of subsurface strata conditions at a quarry site, A.P.	ZMPL	Completed
4	Geotechnical studies for pit slope stability in Odamola, Devachi Raim - Tatodi, Santonachi Upri, Purmare Parvedat Pale and Quella iron ore mines, Goa	SMIPL	On-going
5	Geotechnical studies for pit slope stability in Surla iron ore mine, Goa	DEMPO	On-going
6	Investigation into in-situ strength of coal at GDK-10A Incline and GDK-10 Incline	SCCL	Completed
7	Design of widestall panels (WS-4, WS-5 & WS-6) in No.1 seam of GDK-8A Incline	SCCL	On-going
8	Scientific study to estimate the stability of rhombus shaped pillars and for systematic support rules, in the development workings of no. 1, 2 and 3 seams, at KTK-1, KTK-5 and KTK-8 Inclines	SCCL	On-going
9	Scientific study for suggesting systematic support rules in development workings of no. 1, 2 and 3 seams, at KTK-2, KTK-3 and KTK-6 Inclines	SCCL	On-going
10	Strata control investigations in panel no. WS-3 during extraction by wide stall method at GDK no. 8A incline	SCCL	On-going
11	Training to the Officers of Commissionerate of Geology & Mining, Gujarat, on “Exploration, Quarrying Techniques and Testing of Dimensional Stones” at NIRM, KGF	CGM, Gujarat	Completed
12	Technical guidance and advice related to the dimensional stone quarrying operations for KIOCL, Bangalore	KIOCL	on-going
13	Laboratory geotechnical investigations of dimension stones of Gujarat	CGM, Gujarat	On-going
14	Testing of rocks and dimension stones	AMT, AMPL	On-going
15	Materials testing	HGML, HZL	On-going
16	Setting up of a Test House at Jaipur	CDOS	Completed
17	Determination of in-situ stress and stress gradient between 184 ML to 0ML at Kolihan Copper Mines	HCL	On-going

SPONSORED NON-MINING PROJECTS

Serial No.	Title of the project	Sponsorer	Status
1	Effects of ground vibration due to blasting in the nearby villages at Loharinag-Pala HEP, Uttarakhand	NTPC	Completed
2	Controlled blasting at Gokak small hydel project, Gokak	FGL	On-going
3	Seismic refraction survey for mapping subsurface stratigraphy at Naitwar Mori HEP, Uttarakhand	SJVNL	Completed
4	Seismic refraction survey for mapping subsurface stratigraphy at the proposed thermal power plants in West Bengal and Jharkhand	CCPL	Completed
5	Seismic refraction survey for mapping subsurface stratigraphy at Demwe HEP, Arunachal Pradesh	EIPL	On-going
6	Geological/geotechnical mapping at Tapovan-Vishnugad HEP, Joshimath, Uttarakhand	L&T	On-going
7	Three dimensional numerical modeling of underground caverns of Loharinag Pala HEP	NTPC	On-going
8	Instrumentation, monitoring and data analysis of underground powerhouse complex, desilting chambers of Tala HEP, Bhutan	THPA, Bhutan	Completed
9	Analysis of instrumentation data of dam at Tala HEP, Bhutan	THPA, Bhutan	Completed
10	Deformation monitoring of underground powerhouse cavern of Sardar Sarovar Project, Gujarat	SSNNL	On-going
11	Analysis of instrumentation data of machine hall and desilting complex of Nathpa Jhakri HEP	SJVNL	On-going
12	Three dimensional stability analysis (discontinuum) of the right bank cut slopes of Koteshwar HEP, Rishikesh	THDC	On-going
13	Laboratory geotechnical investigations - Mangdechhu HEP	NHPC	Completed
14	Determination of in-situ stress and deformability parameters (with rock cover of 100 m) at the proposed powerhouse chamber from the exploratory drift at Malana HEP-II, H.P.	EEPL	Completed
15	Determination of in-situ stress parameters by Hydrofrac method at the proposed powerhouse chamber from the construction adit between tail race tunnel and pressure shaft, Malana HEP-II, H.P.	EIPL	Completed
16	Determination of in-situ deformability and in-situ shear parameters of rock mass of dam foundation for the design of the proposed concrete gravity dam, Mangdechhu HEP, Bhutan	NHPC	Completed
17	Cross-hole seismic tomography for evaluation of foundation at pier locations of elevated tollway in Bangalore, Bangalore Elevated Tollway Ltd.	BETL	Completed
18	Geotechnical studies and design of permanent support system for the Gandikota tunnel of the GNSS flood flow canal works, Kadapa District, A.P.	GVR	On-going
19	Laboratory Investigation of rock core samples for LPG Underground Cavern Project	RITES	On-going
20	Support design for tunnel at Nettempadu lift irrigation scheme, Stage – II, A.P.	DCS	On-going
21	Determination of in-situ Deformability Parameters by Goodman Jack at Teesta Stage-II H.E. Project, Sikkim	EEPL	On-going

Annexure – 7

LIST OF PUBLICATIONS

1. Adhikari, G. R. (2007) Examining blast design in India, *Tunnels & Tunnelling International*, November, pp. 25-28.
2. Adhikari, G. R. (2007) Ground vibration and structure response due to rock bursts at Kolar Gold Fields, India, *Journal of Mines, Metals and Fuels,* May, pp. 145-152.
3. Adhikari, G. R., Venkatesh, H. S., Theresraj, A. I. and Balachander, R. (2007) Ground vibrations from blasting in coal mines: The Indian scenario, *MineTech*, April-September, pp. 3-11.
4. Adhikari, G. R., Venkatesh, H. S., Theresraj, A.I. and Balachander, R. (2007) Safe distance from blasting in stone quarries, *Mining Engineers Journal,* Vol. 8, No. 9, April, pp. 9-15.
5. Adhikari, G. R., Venkatesh, H. S., Theresraj, A. I. and Balachander, R. (2007) Measurement and analysis of air overpressure from blasting in surface mines, *Journal of Visfotak – Explosives Safety & Technology Safety*, Vol.1, No. 2, October, pp. 21-26.
6. Balachander, R. and Theresraj, A. I. (2007) Ground vibration and air overpressure studies at two hydel projects in hilly terrain, *Indian Mining Engineering Journal,* September, pp. 47- 51.
7. Gandhe Atul and Venkateswarlu, V. (2007) Estimation of the extent of abutment loads in a stowing panel using FLAC3D, *National Workshop on Application of Numerical Modelling in Strata Control for Coal Mines,* 29-30 October, Dhanbad, pp. 89 – 99.
8. Gandhe Atul and Venkateswarlu, V. (2008) Slope stability study in iron ore mines of Sandur – a case study, *National Seminar on Iron Ore Mining Industry in India*, Bangalore, 11-12 January.
9. Ghose, M. K. and Roy. S. (2007) Contribution of small-scale mining to employment, development and sustainability - An Indian scenario, *Journal of Environment, Development and Sustainability,* Vol. 9, No. 3, pp. 283-303.
10. Mishra, S.B., Nagaraj, C., Venkateswarlu, V. and Adhikari, G. R. (2008) Measurement and analysis of pore water pressure in large caverns and shafts in a hydro-electric project, *Geotechnical and Geological Engineering*, Vol. 16, pp. 367-374.
11. Rajan Babu, A. (2007) Role of joints in dimensional stone extraction by splitting technique, StoneMart2007- 4th International Stone Fair and Conference, February, Jaipur.
12. Rajan Babu, A. (2007) Significance of eco-friendly dimensional stone quarrying, International Conference on Global Stone Technology Forum, November, Jaipur.
13. Rajan Babu, A. and Mishra, V. P. (2007) Empirical relations for block spitting in dimensional stone quarries, Indian Mining Congress on Emerging Trends in Mineral Industry, Udaipur, July 13 -15.
14. Rao, G. M. N. and Jayanthu, S. (2007) Laboratory geotechnical investigations of a Himalayan Rock- A case study, *National Seminar on Mining Technology –Present & Furture*, Bhubaneswar, 21-22 Sept. 07, pp. 143-145.

15. Rao, G. M. N. and Jayanthu, S. (2008) Non-destructive evaluation of man riding ropes and other vital components of mining machinery, *Conference on Emerging Trends in Mining & Allied Industries*, NIT-Rourkela, Feb. 2-3, 2008, pp. 93-99.
16. Roy, S. and Adhikari, G. R. (2007) Worker noise exposures from diesel and electric surface coal mining machinery, *Noise Control Engineering Journal*, Vol. 55, No. 5, September-October, pp. 434-437.
17. Roy, S., Adhikari, G. R. and Gupta, R. N. (2007) Use of gold mill tailings in making bricks – feasibility study, *Journal of Waste Management & Research,* UK, Vol. 25 (5), pp. 475-482.
18. Sengupta, S. (2007) *Hydraulic fracture method to determine in-situ stresses,* chapter in a book on *Engineering in Rocks for Slopes, Foundations and Tunnels* (Edited by T. Ramamurthy), Prentice Hall, pp. 265-283.
19. Sengupta, S. (2007) Measurement of ground stress and its use in rock engineering. *Proceedings on Rock Mechanics and Tunnelling Techniques*, 10-12 October, Gangtok, Sikkim.
20. Sengupta, S., Subrahmanyam, D.S., Joseph, D. and Sinha, R.K. (2007) The role of National Institute of Rock Mechanics in in-situ geotechnical investigations (1997 to 2002) at Tala hydroelectric project, Bhutan. *International Workshop on Experiences Gained in Design and Construction of Tala Hydroelectric Project, Bhutan,* 14-15 June, New Delhi, pp. 150-172.
21. Sinha, R. K., Sengupta, S., Subrahmanyam, D. S. and Joseph, D. J. (2007) Review of computational softwares used for design of structures in rock. *Indian Mining Congress on Emerging Trends in Mineral Industry*, 13-15 July, Udaipur.
22. Sinha, R. K., Sengupta, S., Subrahmanyam, D. S. and Joseph, D. J. (2007) Verification of stress concentration and displacement around a circular tunnel using 3D Boundary Element Programme Examaine^{3D}. *National Seminar on Mining Technology- Present and Future, MineTech07*, 22-27 September, Bhubaneswar.
23. Srinivasan, C., Sivakumar and Ghose, G. K. (2007) Microseismic and b-value study in a shallow subsurface coal mine in India, *Indian Geophysical Union Conference,* Khrukshetra University, November.
24. Sripad, Singh, R., Sudhakar. K., Khazanchi, R. N. and Raju G. D. (2007) Instrumentation of underground excavations at Tala Hydroelectric project in Bhutan. *International Workshop on Experiences Gained in Design and Construction of Tala Hydroelectric Project, Bhutan*, 14-15 June, New Delhi.
25. Sripad (2007) A subsidence prediction model for Godavari Valley Coal Fields using UDEC. *National workshop on Application of Numerical Modelling in Strata Control for Coal Mines,* 29-30 October, Dhanbad.
26. Venkatesh, H. S. and Balachander, R. (2007) Blast design for accelerated excavation of power house cavern at Tala Hydroelectric Project, Bhutan, *International Workshop on Experiences Gained in Design & Construction of Tala Hydroelectric Project, Bhutan*, 14 – 15 June, New Delhi.
27. Venkatesh, H.S., Balachander, R. and Gupta, R. N. (2008) Handling the blockades while excavating the surge shaft at Tala hydroelectric project, *Tunnelling and Underground Space Technology,* Vol. 23, No. 2, March, pp. 145-150.
28. Venkateswarlu, V. and Gandhe, Atul (2007) Rock mechanics aspects of slope stability in Goan iron ore mine, *Workshop on Slope Stability in Iron Ore Mines of Goa,* 29 September.

Annexure - 8

NEWS LETTER

Dr. C. Srinivasan attended the International Workshop on “Experiences Gained in Design and Construction of Tala Hydroelectric Project, Bhutan,” New Delhi, 14-15 June 2007.

Dr. C. Srinivasan attended the National Conference on “In-house R&D in Industry conducted by the Department of Scientific and Industrial Research,” New Delhi, 14-15 November 2007.

Dr. C. Srinivasan guided three lecturers from Allagappa University, Tamilnadu for their M. Phil dissertations on different aspects of rockburst at KGF.

Dr. G. R. Adhikari was nominated as a member of Editorial Board of Visfotak Journal.

Dr. H. S. Venkatesh delivered five lectures on various aspects of blasting at Engineering Staff College of India, Hyderabad, 21-22 August 2007.

Dr. P. C. Jha delivered three guest lectures on site characterisation at a training course for professional engineers on “Geotechnical Investigations for Infrastructure Projects,” College of Engineering, Trivandrum, 13-15 June 2007.

Mr. R.K. Sinha guided one B. Tech Project on a topic related to productivity improvement in surface mines, Mining Engineering Department, GVIT.

Dr. S. Sengupta delivered a key note address on “Measurement of ground stress and its use in Rock Engineering,” at International Workshop on Rock Mechanics and Tunneling Techniques, Gangtok, Sikkim, 10-12 October 2007.

Dr. S. Sengupta was invited for guest lecture at a training course for professional engineers on “Geotechnical Investigations for Infrastructure Projects,” College of Engineering, Trivandrum, 13-15 June 2007.

Dr. V. Venkateswarlu and Atul Gandhe presented a technical paper at the Workshop on Slope Stability in Iron Ore Mines of Goa, 29 September, 2007.

Dr. V. Venkateswarlu, Dr. G. R. Adhikari, Dr. H. S. Venkatesh and Mr. Atul Gandhe attended the National Seminar on Iron Ore Mining Industry in India in Bangalore and presented technical papers, 11 January 2008.

Mr. A. Rajan Babu participated in the Eighth International Granite and Stone Fair in Bangalore, February 2008.

Mr. A. Rajan Babu was invited as Guest speaker at the International Conference on Global Stone Technology Forum, Jaipur, Rajasthan, 14-15 November 2007.

Mr. Atul Gandhe guided one B. Tech project on a topic related to slope stability, Mining Engineering Department, GVIT.

Mr. C. Sivakumar delivered a talk on “Hydroelectric projects monitoring instrumentation review,” at a technical session on “Application of micro-seismic technique to study the stability of river valley slopes near hydroelectric projects,” CSMRS, New Delhi, 25 February 2008.

Mr. Sripad attended the International Workshop on 'Experiences gained in Design and Construction of Tala Hydroelectric Project, Bhutan' and presented a paper on "Instrumentation of underground excavations at Tala H.E. Project in Bhutan." 14-15 June 2007, New Delhi.

Mr. Sripad delivered a lecture on "Subsidence prediction model for Godavari Valley Coal fields, using UDEC", National Workshop on "Application of Numerical modeling in strata control for coal mines," ISMU, Dhanbad, 29-30 October 2007.

Annexure – 9

STAFF LIST

Director

Dr. V. P. Mishra (Current Charge till June 30, 2007)
Dr. P. C. Nawani (from February 20, 2008)

Mine Design

Dr. V. Venkateswarlu
Mr. S. K. Mohanty
Mr. Atul Gandhe
Mr. C. Nagaraj
Mr. Sagaya Benady
Mr. N. Selvaraj

Rock Blasting & Excavation

Dr. G. R. Adhikari
Dr. H.S. Venkatesh
Mr. A. I. Theresraj
Mr. R. Balachander

Rock Engineering

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

Rock Fracture & Materials Testing

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

Engineering Geophysics

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

Numerical Modelling

Mr. Sripad
Mr. G. D. Raju
Mr. K. Sudhakar
Mr. P. S. Varma

Dimensional Stone Technology

Mr. A. Rajan Babu

Seismology

Dr. C. Srinivasan
Mr. C. Sivakumar
Mr. Y. Ahnoch Willy

Environmental Geotechnology

Mr. Surendra Roy
Mr. M. Lakshmipathy

Technical Services

Dr. C. Srinivasan (Addl. charge)
Mr. A. N. Nagarajan
Mr. A. Vijaya Kumar
Mr. N. Sounderrajan

Director's Secretariat

Mr. G. S. Govinda Setty
Mr. A. Narayanaswamy

Library

Mrs. S Lourdu Mary

Accounts & Administration

Dr. P.C. Jha (Addl. charge)
Mr. M. R. Muralidharan (U/S)
Mr. Y. L. Visweswaraiah
Mr. J. V. Sastry
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Mr. S. B. Mishra

Persons who resigned

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NATIONAL INSTITUTE OF R0CK MECHANICS
राष्ट्रिय शिला यांत्रिकी संस्थान

(under Ministry of Mines, Govt. of India)

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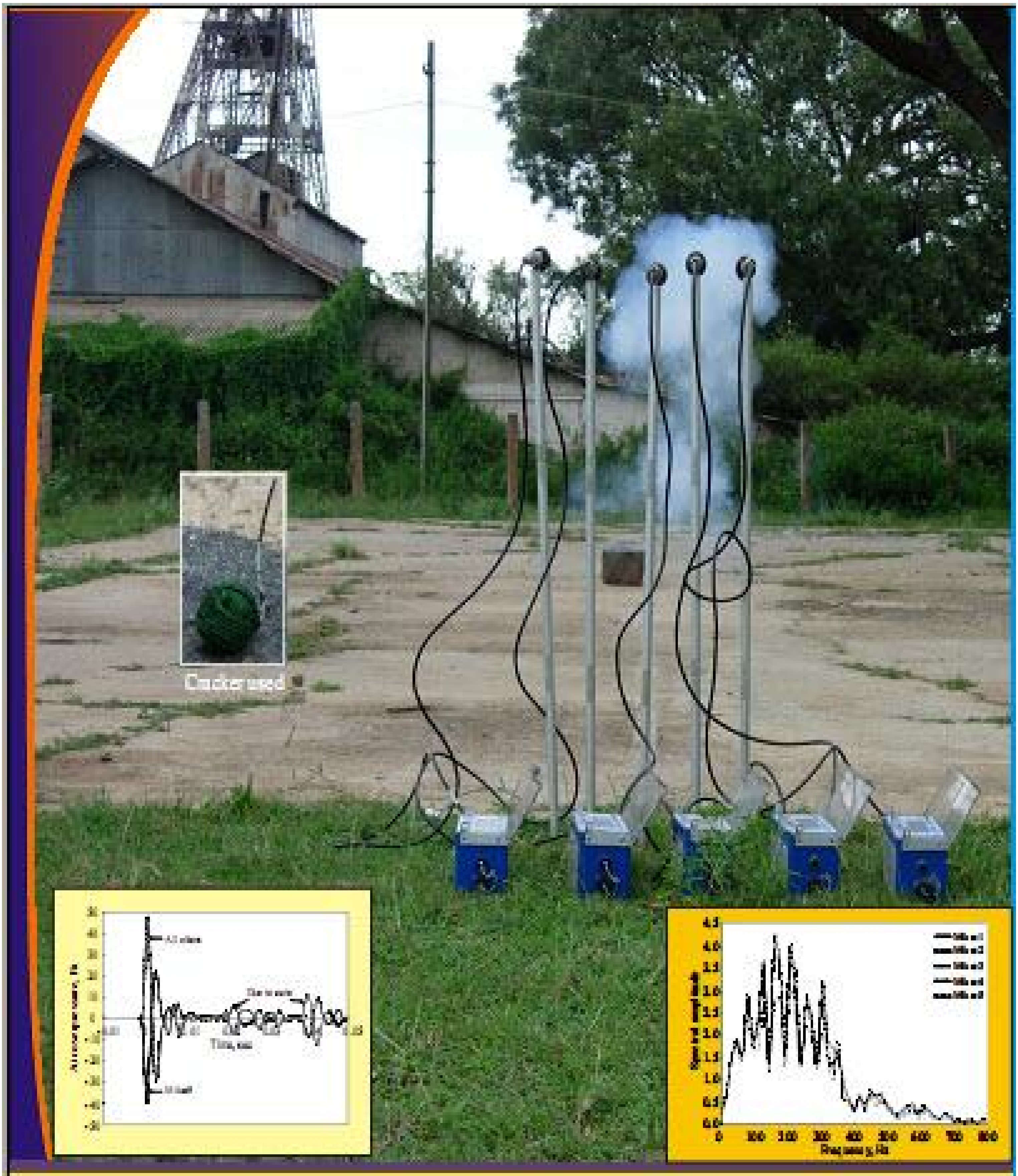

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