वार्षिक प्रतिवेदन
ANNUAL REPORT
2015-16

राष्ट्रीय शिला यांत्रिकी संस्थान
National Institute of Rock Mechanics

(Ministry of Mines, Government of India)
Outer Ring Road, Eshwar Nagar
BSK 2nd Stage, Bengaluru – 560 070
Karnataka, India

Border Roads Organization (BRO) Engineers during a training course on controlled blasting & excavation engineering Organized by NIRM at KGF from 26-31 October 2015

Indian Railways Executives during a training course on Tunnelling Technology Organized by NIRM & NGI, Norway during 16-24 October 2015 and 5-14 January 2016

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Front Cover: Rajasthan Atomic Power Project site, Rawatbhata, Rajasthan

Back Cover: 1. 3D model of Mangdechhu powerhouse complex
2. A 100 m long, 29 m wide 26 m deep trench, one of the largest trenches in the world, dug for active fault studies around Jaithapur, Maharashtra

Edited by

Dr AK Naithani

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CONTENTS

Director's Report

I have pleasure in presenting the Annual Report of this Institute for the year 2015-16. During this year, NIRM has made big strides in its key areas of applied research and industry sponsored projects, in the following areas :

- Hard rock & metal mines
- Coal mines
- Hydroelectric & tunnelling projects
- Infrastructure development

The contributions made by the Institute and the credibility gained by the Institute are reflected in the variety of projects completed successfully, the number of projects and the number of re-visiting clients. Some of the main R&D activities during this year are .

Non-Coal Mines

NIRM has expertise in the areas of numerical modelling, geophysical mapping and ground control investigations to address a variety of problems in hard rock mining projects. The major areas of research include :

- Optimum design of mining operations, and
- Monitoring and evaluation of stability of excavations for improving safety, conservation and productivity.

During the period under review, NIRM carried out investigations at the mines of Hutti Gold Mines Ltd, for evaluation of the stability in the deeper levels of the four reefs of Hutti mine, and for design of stopes at Uti and Hirabuddinni mines. NIRM continued its association with the UCIL mine at Tummalapalli, and guided the mine authorities in proper method of work and support design for both footwall and hangwall lodes of the mine below 100 m depth. NIRM Scientists designed the stoping parameters for Munsar mine of MOIL, and are continuing the investigations at Chikla mine. Slope stability investigations were carried out at Pallava Granites (AP) and Copila Gaichem Paul iron mines (Goa) for safe working of the mines; similar studies are underway at A Narrain Iron Ore Mines (Karnataka) of Vedanta Group. At Rajpura-Dariba mine of HZL, GPR survey is proposed to be conducted to identify some hidden weak zones.

Coal Mines

NIRM has made significant contribution to the development of safe and economic practices in several coal mines under difficult geomining conditions. The major areas of work include :

- Formulation of method of work and strata control investigations under difficult ground conditions like fire & high stresses
- Feasibility of extraction under surface structures, water ways and subsidence

- Mapping of old workings, and barriers around old workings from underground
- Study of cavability of roof strata and design of pillars
- Subsidence predictions and strata behaviour studies for longwall panels
- Design of methods for speedy extraction of standing pillars
- Design of support system based on RMR and in-situ stress measurements
- Study on ground vibrations, assessment and control
- Geophysical survey for mapping for hard rock patches and lignite deposits.

During the period, the Institute undertook studies mostly in the mines of SECL. The Churcha group of mines in this area is characterized by hard, difficult-to-cave roof. NIRM designed proper support system and continued monitoring for the strata behavior in several panels, thus contributing to safe extraction of coal in these mines. Non-destructive testing of vital components of the mining machinery was conducted in a number of mines of SCCL, SECL, WCL and GMDC.

Hydro-electric & Tunnelling Projects

NIRM has made significant contribution to the construction of almost all the hydro-electric projects in India. Main areas of rock engineering investigations carried out by NIRM in this field are :

- Geotechnical and geophysical investigations
- Measurements of in-situ stress and dynamic parameters
- Instrumentation and monitoring
- Numerical modelling for stress analysis and design of support systems
- Controlled blasting

As part of these studies, investigations were carried out for determination of in-situ safe bearing capacity of the overburden material at Teesta Lower Dam – III Power Station (Sikkim) and 3-dimensional numerical modelling of the power house complex at Tehri Pumped Storage Project (Uttarakhand). Instrumentation and strata monitoring studies at Tala hydroelectric Project (Bhutan), Nathpa Jhakri Power Project (HP) and Sardar Sarovar Project (Gujarat) have been continuing for over a decade.

Industries related to Infrastructure Development

NIRM has involved in the design / construction of several infrastructure development projects such as larges underground storage caverns, metro rail projects and the railway tunnels under difficult geological conditions. Main areas of rock engineering investigations carried out by NIRM in this field are :

- Geotechnical and geophysical investigations
- Numerical modelling for stress analysis and design of support systems
- Controlled blasting

Among the developments made in this area by the Institute is the innovative technique of controlled blasting in hard rocks for speedy construction of Railway Under Bridges. Efforts are on to popularize this system in consultation with the Railway authorities. Controlled blasting design was also given and successfully implemented near several operating units of the Rawatbhata nuclear plant (Rajasthan). Several rock mechanics, engineering geological and seismo-tectonics studies have been carried out for Kudankulam Nuclear Power Project (Tamil Nadu) for ascertaining its safety, and the project could be commissioned after allaying all geology-related fears. Testing of rocks for the atomic research centre at Kalpakkam are continuing. The geophysical technique of seismic refraction survey was used at one of the construction sites in Bengaluru for identifying the depth of bed rock for foundation design. Similar studies coupled with extensive engineering geological investigations have been carried out for safe construction of the proposed 350-bed hospital complex of Jayadeva Institute of Cardio-vascular Sciences & Research in Mysore.

Performance Evaluation

During the year 2015-16, NIRM has completed 35 sponsored and 2 S&T projects, and work on about 50 other projects has been continuing. This year, our scientists have published 31 technical papers in international journals / national journals / conferences. NIRM received from the Ministry of Mines, Rs. 500 lakhs as Non-Plan Grant-in Aid, and Rs. 235 lakhs as Special Plan Grant towards equipment. The internal revenue generation from projects etc. was Rs. 450 lakhs.

Acknowledgement

I wish to place on record the sincere appreciation to various agencies and industries who have reposed faith in our research initiatives through sponsored projects and assignments.

I thank the Chairman and Members of the Governing Body and General Body of the Institute for facilitating support from the Ministry of Mines, Government of India. The guidance and support received from the Members of Peer Review Committee of the Institute is also gratefully acknowledged.

Thanks are also due to the scientists and staff of NIRM who have made a dedicated effort towards the progress of the Institute.

We will maintain our interaction with the user industries and agencies, and continue to meet the requirements of the industry to achieve our mission goal to become a global R&D entity in the field of rock engineering.

PROJECTS EXECUTED

1. ENGINEERING GEOLOGICAL INVESTIGATIONS

Engineering geological investigations provide comprehensive geological and geotechnical information for different civil engineering structures during pre-construction, construction and post-construction stages. The inputs of geological and geotechnical data are pre-requisite for economic and safe designing of construction projects related to power sector (hydro, thermal, nuclear), communication sector (metros, rails, tunnels, roads, bridges), mining sector, crude oil storage caverns, lift irrigation sector, and also for geohazard assessment and mitigation. During 2015-16, the department has undertaken works related to detailed geological investigations in various stages of the project developments and completed five projects, and three projects are in progress.

- The Package - 12 of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (PCSSLIS) was constructed for drawal and lifting of 77.914 TMC of water from New Reservoir at Imamabad to New Reservoir at Tadakapally Village, Siddipet (M), Medak District by water conveyor system involving a 9.0 m dia., 9.18 km long tunnel, surge pool and pump house complex with all associated components to irrigate an Ayacut of 1,25,000 acres. Earlier open pump house and surge pool pits were proposed. Instead an alternative underground 'Pump House Complex' was proposed by National Institute of Rock Mechanics after the site visit. Then detailed engineering geological and geotechnical investigations were carried out for the underground surge pool and pump house (Fig. 1.1). The detailed investigation includes large scale geological mapping on 1:500 scale, geological logging of drill holes, in-situ stress measurements, laboratory testing on rock samples for geomechnical parameters and to conduct stress analysis of the surge pool and pump house complex using 3D modelling for a given excavation sequence, and to suggest suitable support system for roof and walls. The dimension of surge pool finalized was 350 m (L) x 15 m (W) x 44.33 m (H) and for pump house 150 m (L) x 19 m (W) x 40.5 m (H). Cavities were excavated as per the recommendations of NIRM.

- At Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (PCSSLIS), Package-6, Karimnagar District of Telangana State, geological mapping (3-D and face mapping), rock mass assessment and support system of twin tunnels (RMT & LMT), underground pump house, transformer cavern and surge pool are being carried out by NIRM since July 2013. The scope of the work includes rock matrix description; rock discontinuity orientation & description, ground water condition, rock mass quality assessment and permanent support recommendations based on rock support categories as mentioned in Basic Engineering Design after every drill & blast-mucking-scaling cycle (Fig. 1.2 to 1.5). This scheme comprises of 2.4 km long approach channel, 0.948 km gravity canal, 9.475 km long & 10 m diameter, D-shaped twin tunnels up to chainage 10.675 km and an underground pump house complex from chainage 10.675 to 10.785 km. Excavation of surge pool (25 W x 375 L x 67.8 D m), transformer cavern (16 W x 203.4 L x 27.5 D m) and pump house (25 W x 210.6 L x 49 D m) is being done from access tunnels, which are joining the caverns from left side. As per the agreement Phase-III (up to March 2016) is successfully completed and now the project is extended up to March 2017.

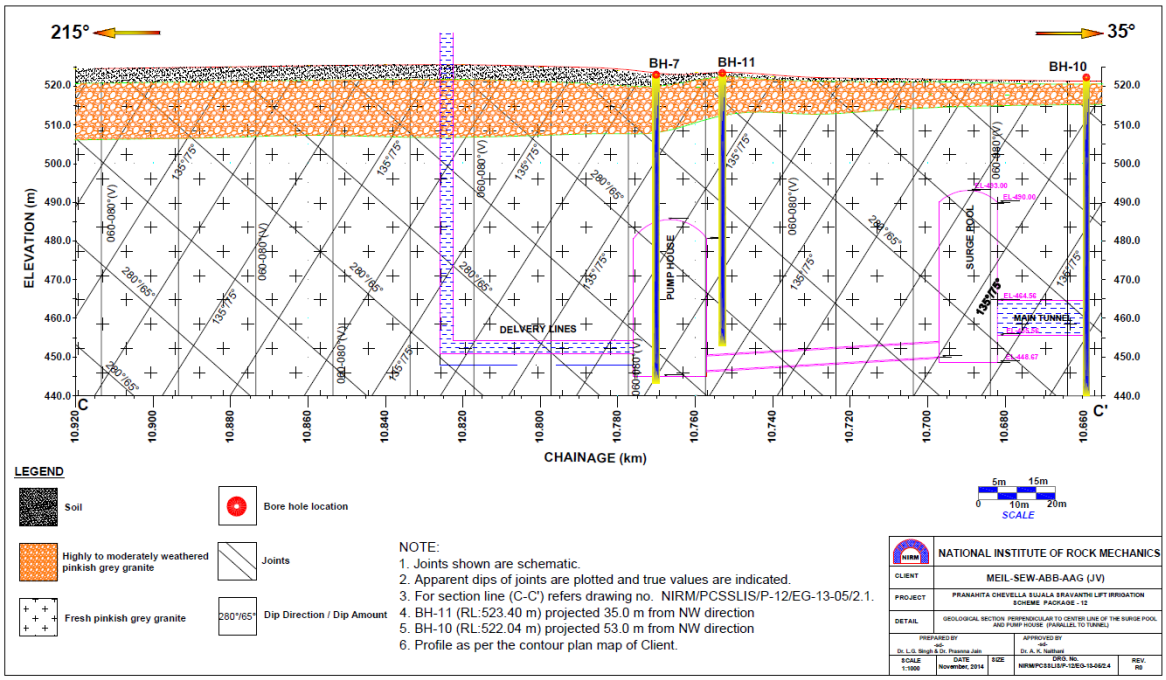

Fig. 1.1 Geological section perpendicular to the centre line of surge pool and pump house – PCSSLIS P12 **/

Fig. 1.2: Rib erection work under progress at chainage 3023 m in RMT upstream

Fig. 1.3: End wall of pump house at chainage 210.6 m

Fig. 1.4: Bench excavation under progress in the transformer cavern

Fig. 1.5: View of excavated escape tunnel from Medaram side

- Engineering geological investigations were carried out for the tail race pool and tail race channel area of Pulichintala hydro electric scheme (4 x 30 MW) (PCHES), Guntur District of Telangana State. Investigations include large scale engineering geological mapping on 1:200 scale of foundation strata at foundation levels of TRP and TRC and inclined/vertical surfaces i.e. excavated inclined/vertical walls; identification of geological defects and recommendations of suitable engineering measures. The Pulichintala HES Project is a balancing reservoir to store about 45.77 TMC to facilitate supply of water in a regular manner to ensure timely nursery and transplantation operations during June and July in Krishna Delta and to install four units to produce 120 MW electricity by utilizing water from Pulichintala Reservoir. The TRP and TRC area is occupied by foliated phyllite and quartzite belonging to Cumbum Formation of Nallamalai Group of Cuddapah Supergroup. The assessment of RMR for phyllitic rock masses, based on the rock joints and their nature, drill holes and laboratory test data has been done. For the assessment of the stability of rock slopes, Slope Mass Rating (SMR) approach was adopted. The approach is based on modification of RMR system using adjustment factors related to discontinuity orientation with reference to slope as well as failure mode and slope excavation methods. The determination of failure modes in rock slopes were done on the basis of the geological discontinuities observed on the slope.

- Construction stage engineering geological mapping of Natural Draft Cooling Towers (NDCT) of Rajasthan Atomic Power Project (RAPP) Units 7&8 were carried out for Gammon India Limited. The investigations include large scale engineering geological mapping on 1:100 scale of foundation strata at foundation levels of NDCT 7A, 7B, 8A and 8B, identification of geological defects and recommendations of suitable engineering measures. The floors were examined on a grid to grid basis; the size of grid was 1 m x 1 m. All the lithological and structural features were observed and mapped using Total Station Surveying equipment (Fig. 1.6). Classification of rock mass using Rock Mass Rating was done and based on investigations recommendations for the treatment of foundations were given (Fig. 1.7). Four reports pertains to NDCT 7A, 7B, 8A and 8B were submitted to the NPCIL/GIL.

Fig. 1.6: Collection of data using TS surveying equipment from tower foundation of NDCT 8B

Fig. 1.7: Purplish/yellowish brown quartzitic sandstone exposed at tower foundation level

- Engineering geological investigation of the Over Head Tank (OHT) foundation was carried out for SNC-LAVALIN. SNC-LAVALIN designed 1.5 million litres per day (MLD) OHT on 18 m staging for Bellary water supply project in Karnataka State. The objectives of this study were to collect the foundation engineering geological parameters and recommendations of suitable engineering measures for the improvement of the foundation. The proposed site is an isolated hillock made of grayish-white, coarse grained equigranular leucocratic granite of Late Archaean (2900 – 2600 Ma) age. The hillock is spread with massive boulders of granite rock at surface. These huge massive boulders are found disconnected from the in-situ rock mass. Granite boulders are massive and fresh. Towards the northern side of this hillock, at the bottom of big boulder near the water pond and behind Devi statue, big cave is there. Based on this feature the foundation of heavy structure was shifted towards southern side during the earlier investigations. The foundation of OHT will be resting as per design on a raft of 1.5 m thick at about 2.65 m below the existing ground level for functional requirement.

- Construction stage engineering geological mapping of pond floors and pump houses of Natural Draft Cooling Towers (NDCT) of Rajasthan Atomic Power Project (RAPP) Units 7&8 are being carried out for Gammon India Limited. The investigations include large scale engineering geological mapping on 1:100 scale of foundation strata at foundation levels of NDCT 7A, 7B, 8A and 8B pond floor and pump houses of 7 and 8, identification of geological defects and recommendations of suitable engineering measures. The floors are being examined on a grid to grid basis; the size of grid is 1 m x 1 m. All the lithological and structural features are being observed and mapped using Total Station Surveying equipment (Fig. 1.8 & 1.9). Classification of rock mass using Rock Mass Rating is being done and based on investigations recommendations for the treatment of foundations are being given.

Fig. 1.8: Collection of data after cleaning of the CWPH-7 foundation

Fig. 1.9: Purplish - yellowish brown quartzitic sandstones exposed at CWPH-7 foundation level

- The Package - 12 of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (PCSSLIS) is being constructed at Medak District of Telangana State. After reengineering the locations of surge pool, transformer cavern and pump house are changed. The Package - 12 of PCSSLI scheme comprises detailed investigations, designs and execution of lift irrigation scheme for drawl and lifting of 77.914 TMC of

water from New Reservoir at Imamabad to Sri Komaravelli Mallanna Sagar by water conveyor system involving a D-shape 9.0 m dia., 16.18 km long tunnel, surge pool and pump house complex with all associated components to irrigate an Ayacut of 1,25,000 acres. The capacity of new Sri Komaravelli Mallanna Sagar reservoir will be 50 TMC. For better rock mass classification and structural design of supporting system at new site, preconstruction stage engineering geological and geotechnical investigations are being carried out for the proposed underground pump house complex. The detailed investigation includes large scale geological mapping on 1:500 scale, logging of drill holes, in-situ stress measurements, laboratory testing on rock samples for geomechnical parameters and support design studies. The basic purpose of these investigations are to identify/map different rocks and structures like joints, shear zones, faults, fracture zones etc. and to determine engineering properties of rocks and rock masses by lab testing and in-situ testing and to conduct stress analysis of the pump house complex using 3D modelling for a given excavation sequence and to suggest suitable support system for roof and walls.

- Engineering geological investigations of the cave area of Shri Mata Vaisno Deviji of Jammu and Kashmir are being carried out. This project is sponsored by Shri Mata Vaishno Devi Shrine Board (SMVDSB). The objectives of his study are to identify the geological defects in the cave area and recommendations of the protective measures. Review of the executed slope stabilization work with respect to achieving the objectives and further replication of the same on new locations is also being done. The Holy Shrine of Shri Mata Vaishno Deviji is one of the most popular pilgrimages in the Country. The Shrine is located at an altitude of 1765 m in the Reasi District of Jammu and Kashmir State (Fig. 1.10). The pilgrimage to the holy Shrine involves trekking of about 13.5 kms from Katra through hilly terrain. Some portions of this track experiences landslides and also falling shooting stones originating from uphill slopes injuring the Yatris.

Fig. 1.10: View of Shri Mata Vaishno Deviji

Seismotectonic Investigations

Seismotectonic studies evaluate the criticality of Geological structures in an area which is very essential for designing mega critical civil engineering structure including nuclear establishments. The study includes evaluation of the existing geologic structural as well as seismological information and delineation of lineaments through analysis of high resolution satellite images. Site specific geological investigations are integral part of these studies to identify and evaluate active fault of any terrain. Over the years NIRM carried out seismotectonic/active fault at several locations, as per IAEA and AERB guidelines. Following are the details of the projects carried out during 2015-16.

- Seismotectonic evaluation in 30-50 km radius of Kudankulam Nuclear Power Plant (KKNPP), Tamil Nadu was completed during this period. It is identified L4 and N2 as active faults which are significant to the design of KKNPP. The L4 represent NW-SE trending Thenmalai fault and N2 another fault parallel to it. These two faults are having regional affinity to Achankovil shear system. The study prepared final Seismotectonic Map for site evaluation (Fig. 1.11) and the lineaments were categorized into different groups. Based on the paleoseismological evidence in different cratonic region around the world and maximum magnitude earthquake observed with in 300 km, the study proposed a maximum magnitude of M= 6.0 to surface rupturing faults L4 and N2 which have also been associated with microseismicity. It was also proposed that the sympathetic lineaments which are associated with microseismic activity but with no surface rupture may be considered having lesser magnitude (M= 5.5). Major other regional lineaments which are spatially associated with M=6 events are also assigned a magnitude M=6. The estimation of Maximum magnitude for different lineaments proposed by the study, based on the AERB guidelines, was agreed by the members expert committee of AERB.

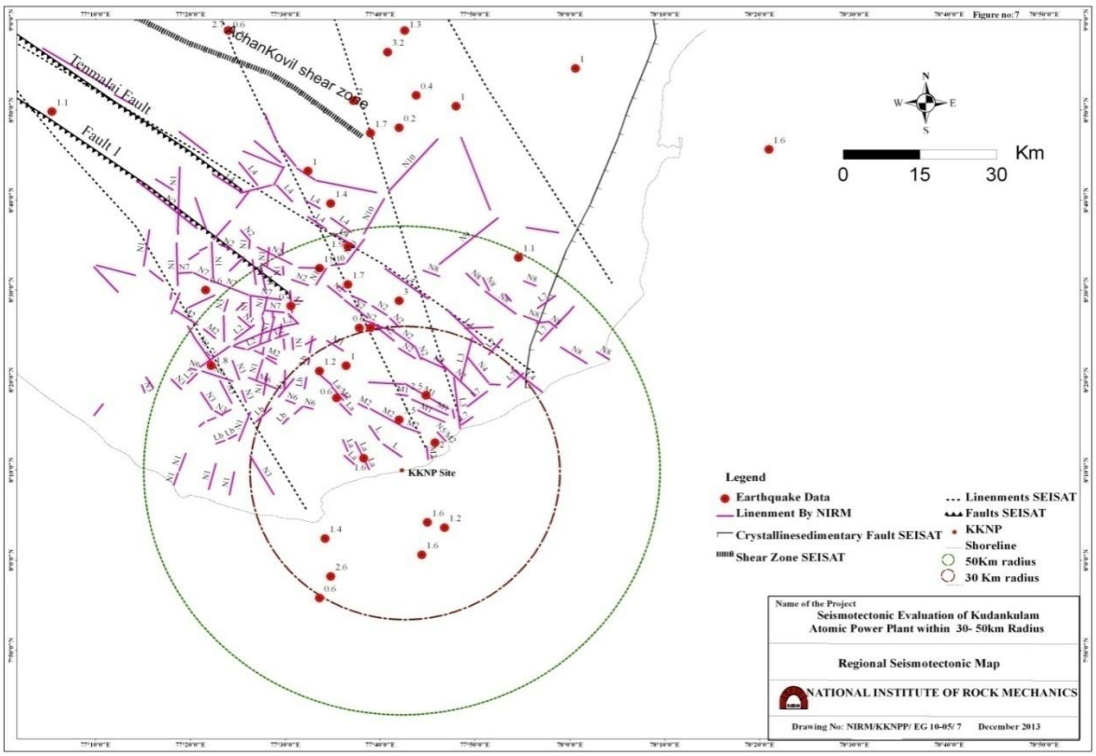

Fig. 1.11 Final seismotectonic map prepared for KKNPP

- NIRM identified many lineaments during the seismotectonic evaluvation of the KKNPP site. However, there is no surface signatures identified for 'L2' lineament, which is marked in SEISAT. For further confirmation status of the L2, Multichannel Analysis of Surface Wave (MASW) followed by trench investigations was carried out to observe subsurface signatures, if any, at different places across the lineament. The MASW survey was conducted in collaboration with Earth Science Department of The Indian institute of science (IISc), Bengaluru. For identifying the survey lines the lineament was marked on the ground, based on the coordinates from SEISAT map using GPS (Fig. 8.36). For better understanding of MASW signal associated with the faults, the survey was carried out for L4 and N2 lineaments at three locations where faults are exposed (R1, R2 & R3). The observation from MASW signal from these locations suggests that the subsurface continuity of fault traces can be detected through this survey by identifying density contrast of the material across it. Subsequently the survey was conducted along the L2 lineament at three locations namely E1, E2 & E3 (Fig. 1.12). Across L2 at Radhapuram undisturbed low velocity layers are identified (Fig. 1.13). Trench studies at Udaiyattur identified that this low velocity layers are (Vs ≈ 400m/s) soft sediments (Fig. 1.14). In another profile near Sillatikulam too no abrupt velocity contrast observed. The low velocity layers (Vs=700-800 m/s) at this location is verified through trenching and it is identified as semiconsolidated laterite. The study concluded that there is no subsurface trace of any fault related structures corresponding to L2 lineament observed in these locations.

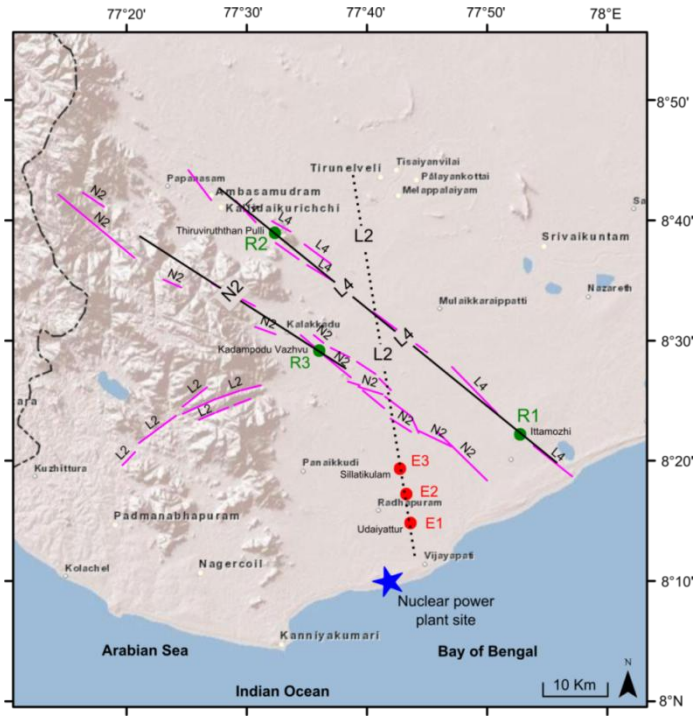

Fig. 1.12 The lineaments studied for fault identification

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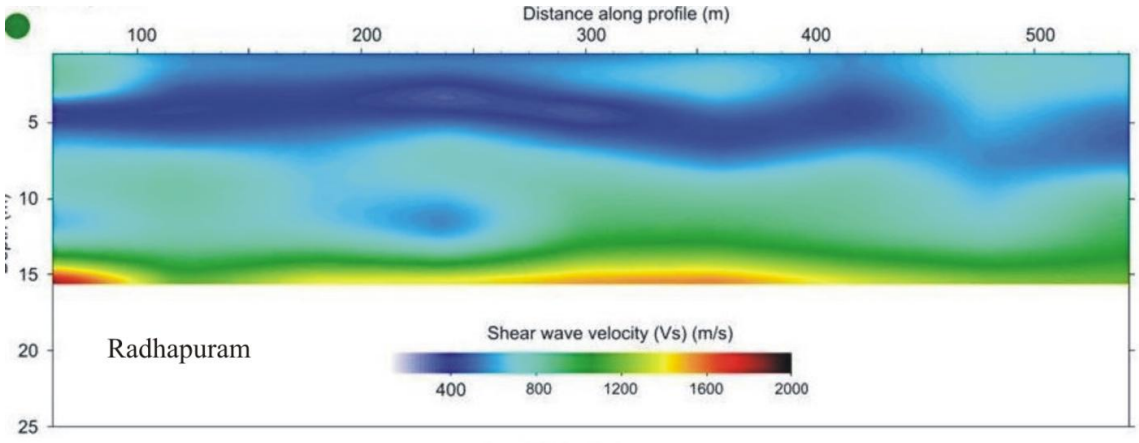

Fig. 1.13 2D shear wave velocity profiles across the lineament L2 near Radhapuram

Fig. 1.14 Very soft sediment exposed in the velocity zone 400 m/s at Udaiyattur

- A lineament was identified within 5 km of the proposed Nuclear power plant at Jaitapur (Fig. 1.15), during site evaluation studies carried out by GSI. Subsequently, the experts who reviewed the studies recommended that this lineament need to be evaluated through trench studies. This is one of the largest trenches made in the world for paleoseismological studies and is designed by NIRM (Fig. 1.16), to be excavated in depth interval of 2-3 m in 10 (0-9) stages. The excavations were started in December 31st, 2014 and completed in June 2015. To obtain maximum information from the trench area, three parallel trenches were made till stage 7 (Fig. 1.16) and mapping was done in 1:20 scale. Based on the observations, the trench was shifted towards north by 5 m in stage 0 and the western trench shifted by another 5 m in stage 1. The trench exposed 7-8 m thick laterite cap followed by laminated clay.

- At the northern end at stage 3 the laterite appears to have crushed with a dislocated goethite layer (Fig. 1.17). A fracture originated from this location continued up to the top. In the central part of the trench the clay layers below the laterite show anticlinal folding (Fig. 1.18) in the central and eastern trenches. Below the clay layers within the altered basaltic layers a dike is observed in the central part of the trench (Fig. 1.19). Minor young displacement is observed in the dyke (Fig. 1.20). The other structural features mapped include Liesegang formation and small scale folds. The depth of the trenching was initially proposed to be about 10-20 m however it reached up to the sea level (26 m) because of the absence of bed rock. At 1 m MSL a red bole layer is observed (Fig. 1.21). To see any offset in the basalt layers/flows this redbole is traced and found gradually dipping towards south. The trench was visited by many national experts invited by NPCIL and NIRM scientists interacted with them regarding the observations (Fig. 1.22).

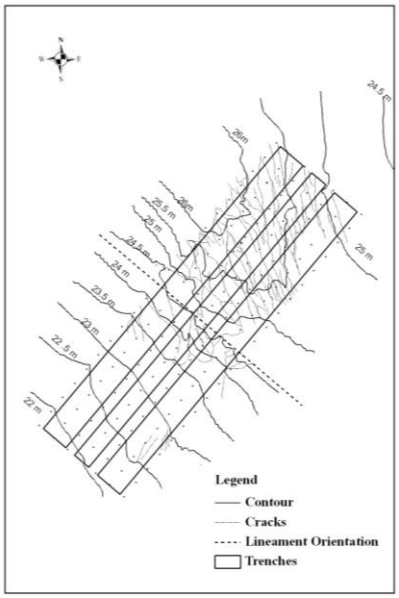

Fig. 1.15 The location of lineament and trenching area (100 x 30 m)

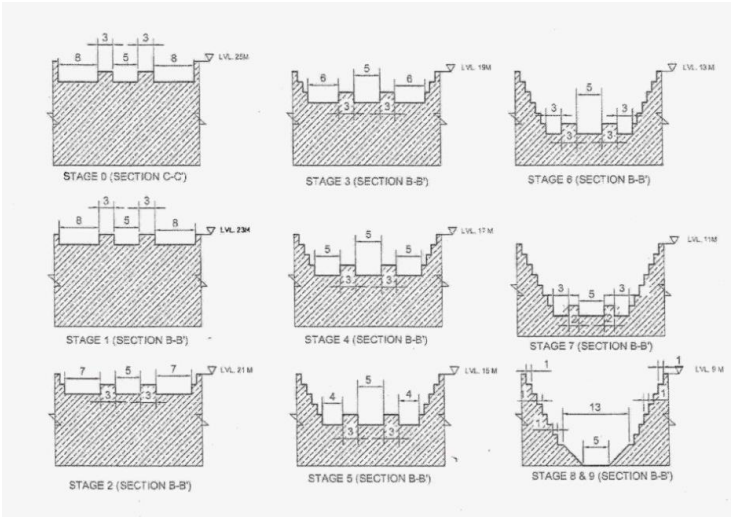

Fig. 1.16 Design of the trench at different stages in sectional view

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Fig. 1.17 Hard laterite sitting over crushed laterite. The arrows indicate the dislocated layer of iron formation

Fig. 1.18 Anticlinal structure observed in the trench face formation

Fig. 1.19 The dike observed in the central part of the trench & small scale reverse fault observed

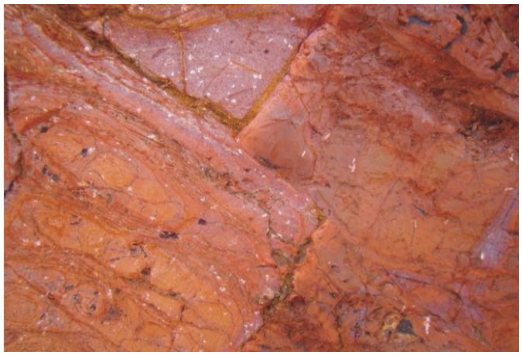

Fig. 1.20 Reverse fault showing cross cutting relations

Fig. 1.21 Red bole observed at the bottom of the trench

Fig. 1.22 The National experts visited the trench on 02.06.15

- The potential threat of great earthquakes from the Himalayan sources is a major scientific and societal concern. The study proposed to conduct paleoseismological studies in the selected locations within the central Himalaya and Bhutan frontal thrusts to determine ages, sizes and the extent of the earthquake ruptures. During this period we carried out detailed field investigations at Chorgaliya, in the frontal belt of Himalaya. A 35-meter long with a depth of 3 to 4 m and 2-m- wide trench was excavated at the foot of the frontal Himalayan thrust (Fig. 1.23). The trench exposed three major sedimentary units: a lower sandy facies, middle bed of boulders, cobbles, gravels and pebbles with some sand and an upper sandy-silty unit. The top of the upper sand-silt unit is marked by a depositional unconformity and then continued by landslide debris. The scarp was formed by a 30- to 60-m-high strath terrace capped by middle- to late-Holocene fluvial gravels, probably associated with a tributary channel. The scarp represented uplifted inset terraces, associated with a tributary channel that drains the high terrace, across the MFT. Further work is going on.

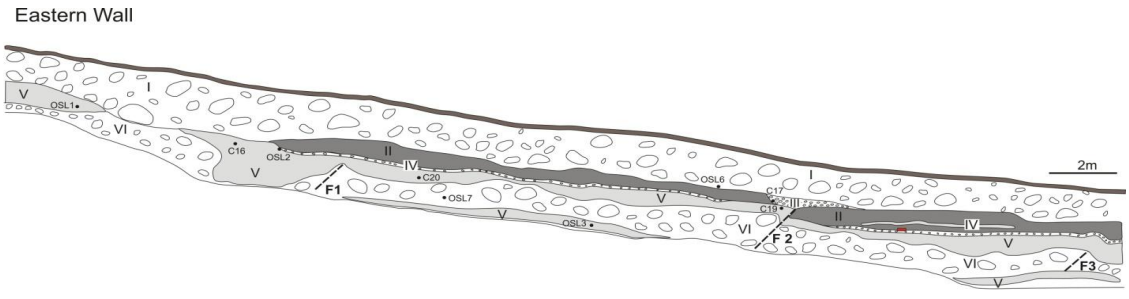

Fig. 1.23 A 35 m long Trench exposed near Chorgaliya

2. ENGINEERING GEOPHYSICAL EXPLORATION

Engineering geophysical investigations are essential tools for any civil engineering projects. They provide detailed subsurface information in a non-invasive manner. These form an essential element as design inputs in decision making exercise, in design alteration as well as in various trouble-shooting operations. The Institute carries out geophysical investigations for mapping of subsurface strata as part of site characterization studies. Investigations are carried out from surface, underground or across boreholes, using seismic, electrical or GPR tools. During this period 6 sponsored projects are executed. For two projects final reports are submitted and for two projects draft reports were sent to THDC for VPHEP, Uttrakhand and KRCL Jammu. In addition, enquiries have been received for four prospective projects. During this period significant progress is made in the on-going S & T project. Details of the work done in these projects are discussed in the following section.

- Karnataka Urban Water Supply & Drainage Board (KUWS&DB) has proposed construction of composite dam across Markandeya River to provide drinking water to Kolar city, Bangarpet, Malur and 45 other villages en-route. The proposed dam site is situated in Bangarpet Taluk near Yargol village which is 24.15 km South of Bangarpet town. In order to investigate the rock mass conditions along cut off trench of saddle dam embankment, geophysical survey using seismic refraction method was carried out, the scope of survey being to provide information on the nature and profile of overburden, weathered rock and bed rock in the subsurface. The seismic section up to 30 m depth along the saddle dam is shown in Fig. 2.1. Considering the role of the saddle dam it was recommended that – a). the soft rock mass represented by seismic velocity Vp<1500 m/s which was mainly compact soil / soft rock should be extracted, b). rock mass represented by seismic velocity 1500 m/s<Vp<2500 m/s should be properly grouted. This layer is mainly weathered rock which is highly permeable. The purpose of grouting was to achieve the permissible permeable limit of 3 Lugeons and c). once the grouting of bottom layer is done, the top should be filled with black cotton soil. Rocks representing the jointed rock mass layer with seismic velocity between 2500-3500 m/sec need not require grouting. Thus by excavating the top soft rock layer and grouting the weathered rock mass layer, the saddle dam foundation can be safely laid as per engineering considerations. Therefore, it was recommended to go ahead with the grout plan (staggered grouting).

  The above recommendations were implemented immediately at the site and the mapped seismic velocity layers are exactly matched with the excavation. For the understanding photographs of excavated area are shown in Fig. 2.2. These photographs representing the exact nature of undulating nature of subsurface layers which were mapped from the seismic refraction study. The entire exercise highlighted the usefulness of geophysical investigations for understanding the rock mass before construction.

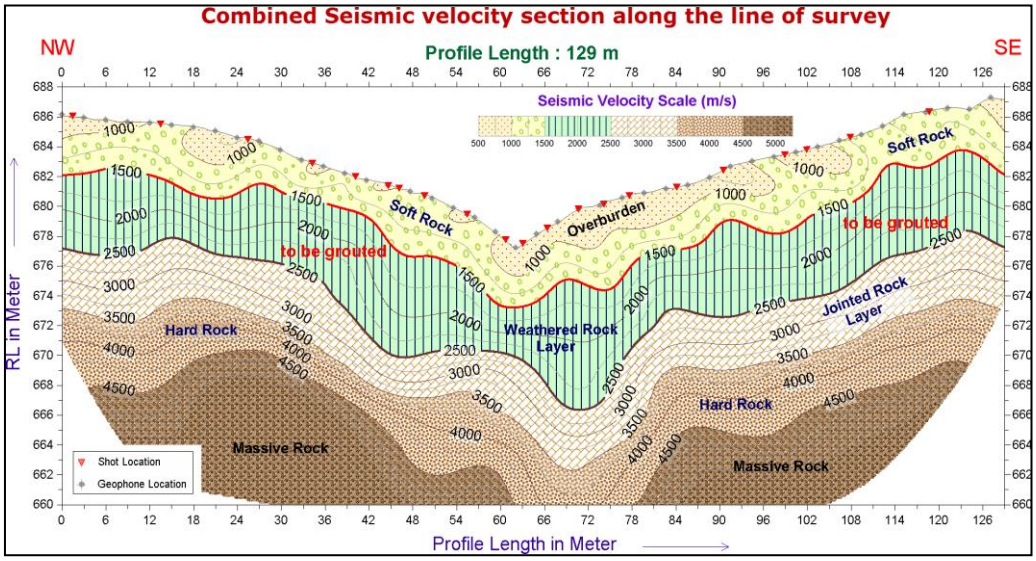

Fig. 2.1 Seismic velocity section along the trench of saddle dam embankment showing different velocity layers up to the depth of 30 m

Fig. 2.2 Photograph showing different soil layers clearly and the zoomed area showing the watered layer deeper in the middle of the trench.

- THDC India Limited is implementing the Vishnugad-Pipalkoti Hydroelectric Project across the Alakananda River in the state of Uttarakhand. The project envisages to generate 444 MW power by utilising a gross head of 237 m. Various constituents of projects broadly include 425 m long diversion tunnel of 10 m diameter, concrete gravity dam of 65 m height, 13.4 km long HRT of 8.8 m diameter, an underground powerhouse and 3.07 km long TRT. As part of project site investigations, the project authorities have requisitioned site investigations by geophysical methods at locations of various appurtenant structures coming under the project area. Accordingly

geophysical survey using seismic refraction method was carried out at four different sites – (a) around the TBM entry adit, (b) around the MAT & CT/VT, (c) along the TRT and (4) at the inlet of the diversion tunnel. Five lines each measuring 230 m in length were surveyed at the site of TBM entry adit, three each of 230 m length at the MAT & CT/VT site, one 230 m line along the TRT and one line of 69 m length at the inlet area of the diversion tunnel. Additionally, S-wave survey was done along a single profile line of 115 m length at TBM entry adit. The layout of survey lines around the diversion tunnel is shown in Fig. 2.3 and a typical seismic section at the TBM site is shown in Fig. 2.4. The survey results did not indicate presence of any geological anomaly or pitfall at any of the four locations. Final report with classified interpretation of seismic sections along different survey lines was submitted in December 2015.

Fig. 2.3 Photograph from diversion tunnel inlet area showing survey lines (L10)

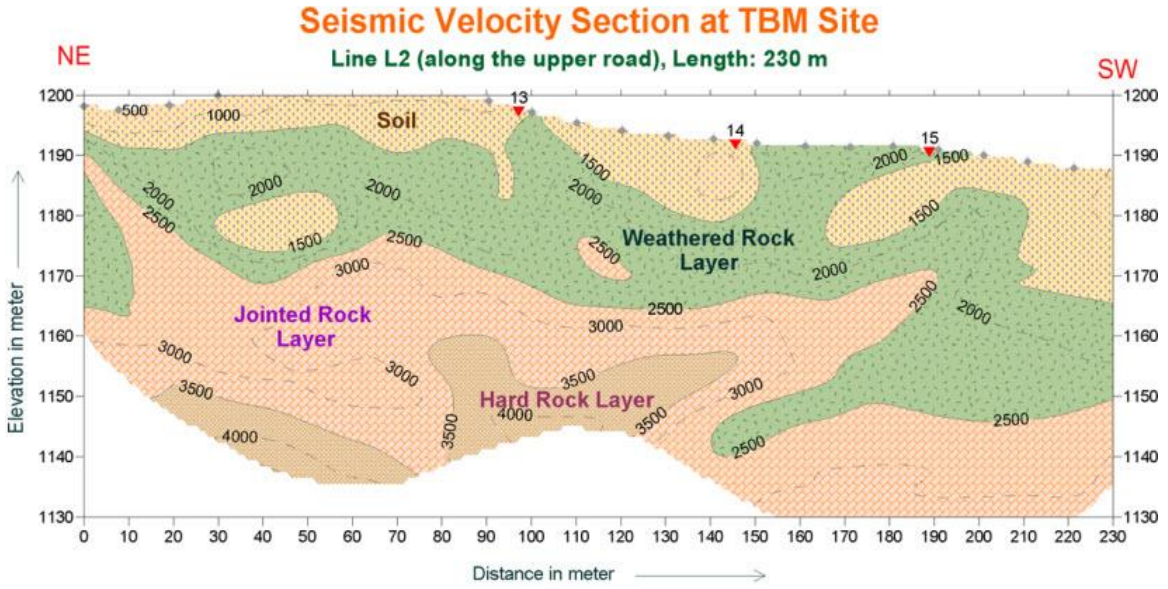

Fig. 2.4 Typical seismic velocity section at the TBM site

- M/s Prestige Estates Projects Limited, Bengaluru proposes to build a residential apartment within 90 m x 90 m plot next to Leela Palace Hotel in the CBD, Bengaluru. A ten-storey apartment with four levels of subsurface basement for car parking is

planned under this construction. For this purpose, excavation of basement level is planned upto 24 m depth. Before excavating the central portion, it was proposed to construct a 315 m long diaphragm wall around the periphery of the excavation. While excavation for laying the diaphragm wall was being done by using a CSM machine, severe vibrations were reported from nearby residences even though the measured vibration level were well within the prescribed limit. In order to overcome this problem, the client requested to suggest a safe excavation depth. For this purpose, seismic refraction survey was carried out at 3 m geophone interval along the available stretches of the d-wall (it was partly covered under concrete and office space). With this set-up, the accuracy of seismic survey is ensured upto 0.3 m. The survey was done upto the planned excavation depth of 25 m using the sledgehammer. In order to arrive at the safe excavation depth, use is made of engineering classification for excavation of rock mass based on seismic velocity, hardness and strength as prescribed by Bell (1992). Accordingly, the subsurface strata is sub-divided into five category as (a) Top Soil, (b) Hard Soil, (c) Soft Rock (d) Hard to Rip Layer, (e) Hard Rock requiring blasting.

A sample seismic section generated along the northern boundary is shown in Fig. 2.5. Going by the plan of the survey lines and overall disposition of various subsurface layers, it is felt that the subsurface layer with P-wave velocity of over 1800 m/s is the ultimate layer up to which ripper (CSM of 150 HP capacity) may be used in the urban settlement area. This is shown by thick red-coloured line which is the layer depth for excavation without blasting. Once the excavation reaches this depth, controlled blasting may be used for further excavation. Further, while recording the seismic data during operation of CSM machine, it was found that most of the vibrations were shear waves (having much lower velocity of arrival). Because of steady-state vibrations dominated by surface waves, damages due to ripping below the prescribe red-line level may be seen at a much lower PPV level than the one prescribed using blasting source.

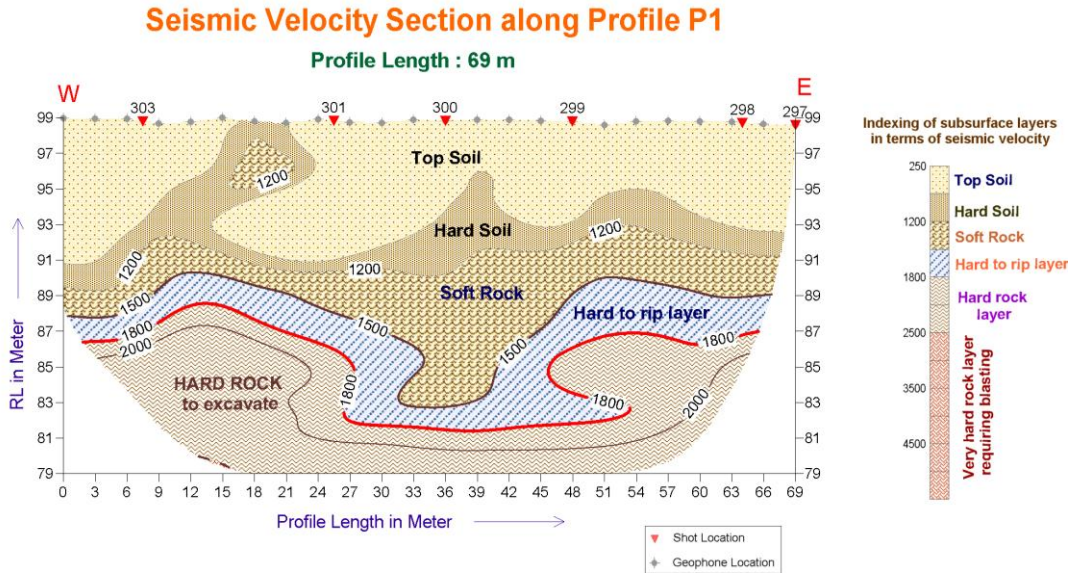

Fig. 2.5 Sampling seismic section along northern boundary

- S&T project on development of a viable technique for assessment of reclaimed land and for safety of structures under settling environment sponsored by MOM is continuing since April 2012. As per the proposal, the listed objectives of the project includes: a) in-situ geophysical measurements of P and S wave velocity for evaluating soil stiffness and other relevant parameters for assessing settlement potential, b) non-destructive testing of ground and structures based on integrated geophysical techniques, c) laboratory measurements on rock samples, d) qualitative and quantitative analysis of geophysical results, e) derive site-specific relationship between rock mass properties and measured parameters and f) formulation of a viable geophysical methodology for evaluating integrity of structure and stability of subsurface (ground, foundation etc.). During this period, cross-hole survey in the Kajora area of IOCL pipeline was carried out to analyse the subsidence risk of the ground below the pipeline. This was done in addition to ERI and seismic refraction survey sponsored by the IOCL. The cross-hole survey was carried out close to the likely subsidence area to assess the dynamic parameter of the subsurface conditions so that the future risk can be understood in a better manner. For this we got drilled two boreholes up to 20 m with a separation of 20 m. Both P and S wave survey was carried out between the pair of boreholes with an interval of 0.5 m and 1 m respectively. To carry out P-wave survey, borehole sparker source was used. For generation of shear waves, similar probe with pneumatic clamping system was used. This Probe can be rotated using a pipe string towards the direction of the receiver and perpendicular to the receiver. The data was collected with equal depth interval of 0.5 m. 12channel hydrophone with a spacing of 2 m was used for receiving the signal. Crosshole p-wave velocity between a pair of holes showing in Fig. 2.6. Both P- and S-wave velocities were plotted in the vertical section (Fig. 2.7). The survey result showed some interesting pattern. While P and S wave velocities in general increase with depth, it was not so in this case. Results indicated a peculiar depth range between 10-16 m where S-wave velocity decreased while P-wave velocity kept increasing as usual. This type of phenomena is observed under post failure condition of rock mass and is reported as ‘Dilatation’ phase which is an established precursor for impending failure. So far this dilatation was observed only under controlled experimentation in the laboratory. This was the first time that evidence of a dilatation phase was noticed in a field condition suggesting an impending subsidence like failure in the near future. Based on this confirmatory inference from the cross-hole survey, entire area is now monitored by subsidence pillars to detect any abnormal trace of movement. Thus this survey established another marker of settling environment in the form of “dilation zone”. Further work is being planned and procurement plan for surface survey equipment is underway.

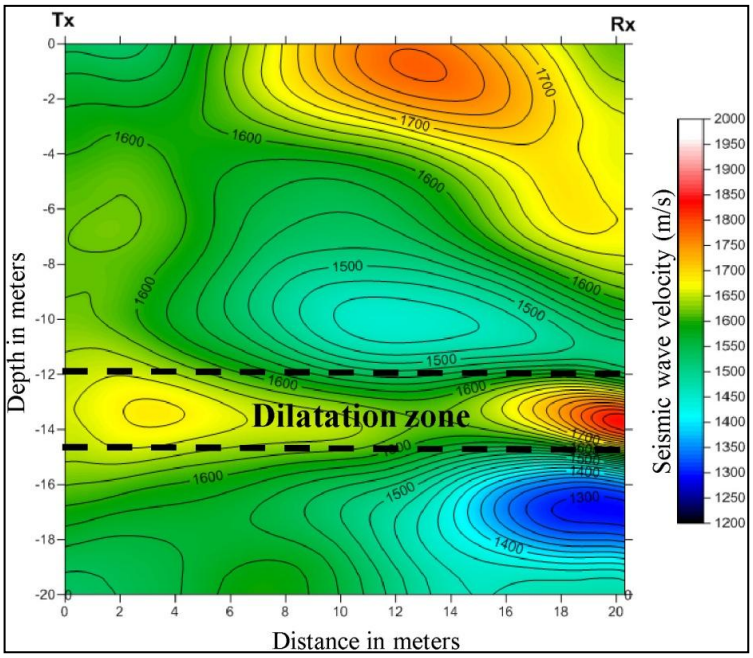

Fig. 2.6 Variation of seismic wave velocity between the pair of holes mapped the presence of high velocity layer between 12-15 m depth

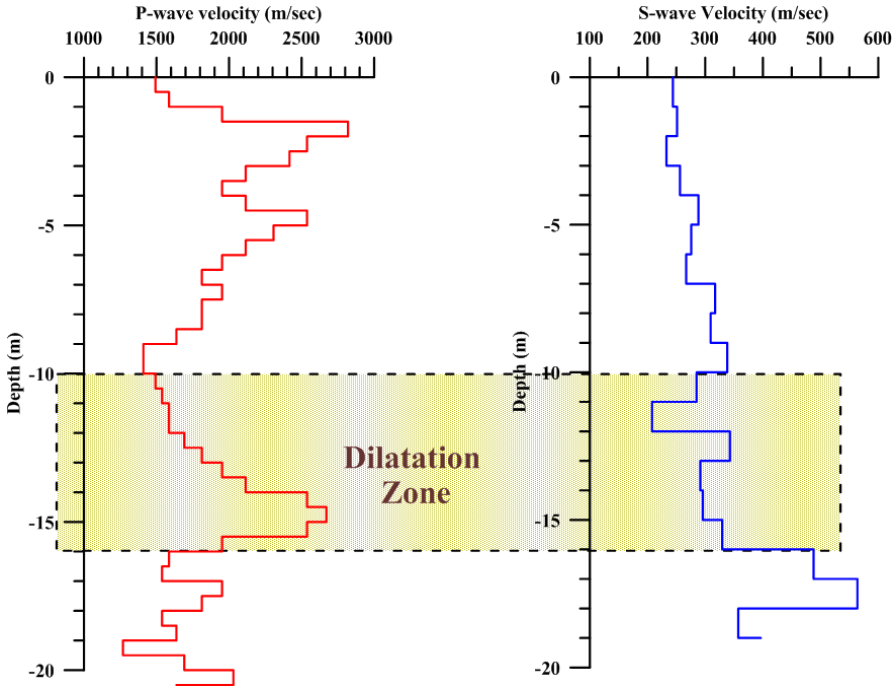

Fig. 2.7 Variation of seismic (P and S) wave velocity with depth showing plastic zone

- M/s Konkan Railway Corporation Ltd. (KRCL) constructing a special bridge across river Chenab at village Kauri, District Reasi in the state of Jammu and Kashmir. This bridge is part of several bridges and tunnels which make the Katra - Laole section of Udhampur-Srinagar-Baramullaa Rail Link (USBRL) project, around 125 Km from Jammu. Once it is completed, it will be the highest rail bridge of its kind in the world. The proposed length of this bridge is 1315 m between chainage 50/400 to 51/715 and

at a height of 359 m (around 855 m above MSL) from the river bed. The total length of this bridge is covered with 18 pillars numbering from S10 to S180, out of which pillars S10 to S40 are on the left bank (Bakkal side) and S50 to S180 are on the right bank (Kauri side). The central span of steel arch covering a length of 480 m between pillar S40 and S50. This arch is designed as a two-fold ribbed arch comprising steel girders with scaffolding braces produced on the spot. The highest pillar S50 is on the Kauri side with a high of 129 m. The bridge structure has been designed to withstand wind speeds up to 264 km/h and resist temperatures down to -20°c. In order to set up the strong foundations for the bridge, large scale rock anchoring, drilling and grouting activity has been done on both sides of the river valley. During excavation in the foundation of S60 pillar, two sets of wide open joints apparently forming a wedge type feature were noticed. M/S KRCL officials requested to carry out seismic tomography investigations at the pier of S60 to know the depth and extension of these openings and presence of cavities. After a site visit by NIRM officials, it was suggested to drill five holes to carry out five sets of cross-hole seismic tomography up to the depth of 60 m. The location of boreholes was marked on the site plan as shown in Fig. 2.8.

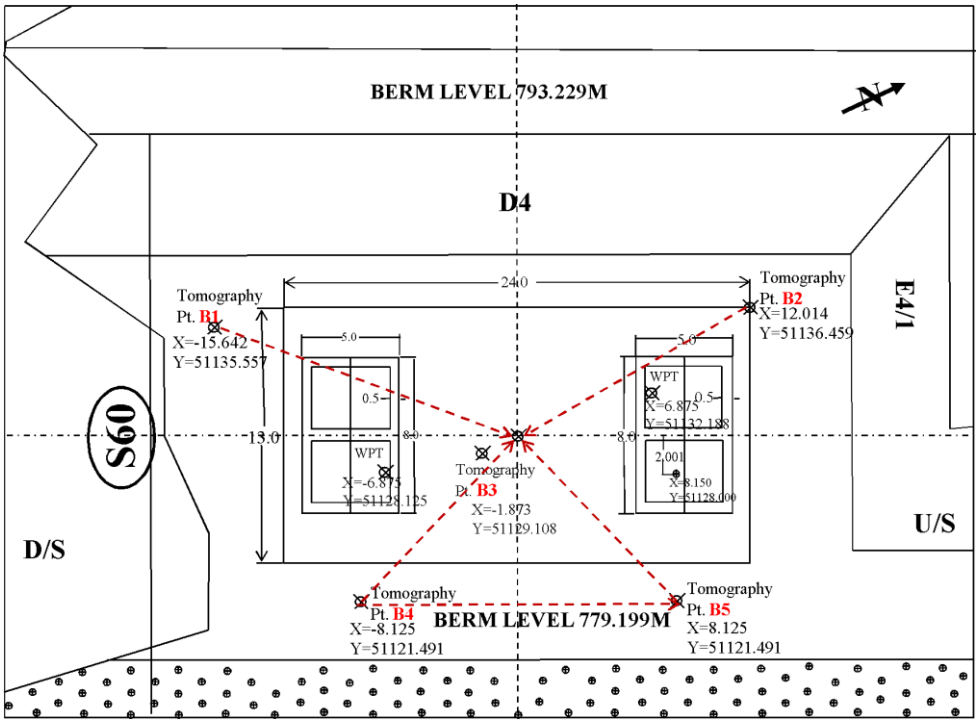

Fig. 2.8 Foundation location of S60 pier with marked boreholes (B1 to B5) used for seismic tomography study.

Accordingly tomography survey between B1-B3, B2-B3, B4-B3, B5-B3 and B4-B5 was carried out. Borehole sparkar used as source and 12 channel hydrophone chain with 1 m spacing as receiver. Data was acquired with an interval of 1 m shot spacing along the borehole and the entire borehole length was made two parts. Bottom tomogram from -60 m to -19 m and the top tomogram -24 m to surface with an overlap of six positions. During the processing these two parts were joined together and made a single tomogram up to the depth of 60 m. In addition we joined the two diagonal tomograms i.e. B1-B3-B5 and B4-B3-B2 for the better visualisation of the subsurface conditions. One such typical diagonal velocity tomogram section was presented here

as Fig. 2.9. Final interpretation we infer following details, the geological setting of this area was primarily weak rock mass with some open joints. Seismic velocity of 4000 m/s and above, which is indicative of a good quality hard rock for foundation but intensive grouting of the subsurface from the top and front face has drastically changed the subsurface which appears as two separate blocks. Top 25 m was grouted wherein we get a consistent seismic velocity in the range of 4000-6000 m/s and the bottom 30 m section has still left over pockets of weak zone appearing as cavities or untreated joint plane. The river-end face appears to be quite firm with seismic velocity appearing above 4000 m/s till the bottom but its effect is not seen beyond 15 m from face. Since the weak zone has more thickness towards river-end, there are chances of uneven settlement if the load transfer in the foundation exceeds 50 m depth. Hence, we recommended for the bottom portion according to the load dissipation with depth.

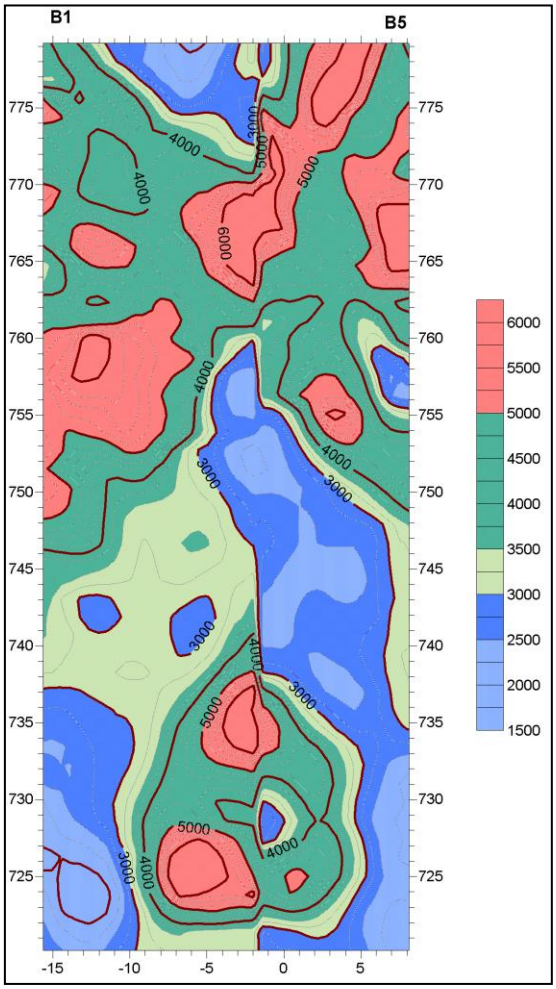

Fig. 2.9 Seismic velocity tomogram between B1-B3-B5 diagonal showing weak zones up the depth of 60 m

- Rajpura Dariba Mine of Hindustan Zinc Limited (HZL) is located at the southern extremity of Rajpura Dariba Bethumni metallogenic belt in Rajsamand district of Rajasthan. It is premier zinc producing mine, ore extraction is done by Vertical Crater Retreat and Blast Hole Stoping methods. Two important lodes are the Main lode and the East lode which are separated by 300 m. Pb-Zn deposits found at shallow levels to a depth of 600 m and therefore exploitation continued ever since the ancient past.

Several older workings in the form of irregular pits, trenches and small diameter shafts are seen around the area; however, some of the abandoned workings are in the form of unlined/ lined shafts showing signatures of past dewatering. At present, mining in the East load is being done below 100 mRL and the possibility of safe mining up to 200 mRL is being explored. At 200 mRL, there is a drive/ tunnel which is safely approachable with provision of ventilation and lighting. Several boreholes were drilled along this drive and one such borehole was punctured some old working and caused excessive water inflow into the 200 mRL drive. It was therefore necessary for HZL to assertain the presence of old water logged workings around the 200 mRL gallery. Crosshole GPR surveys suggested for mapping of these old workings by study and analysing of radar wave attenuation using a series of horizontal boreholes along the 200 mRL drive. Accordingly crosshole radar survey for eight pairs of holes with transmitter and receiver movement of 0.5 m along the boreholes was carried out and generated 2D map of radar wave attenuation in the study area as shown in Fig. 2.10. Crosshole GPR study revealed the presence of waterlogged area along the 200 mRL drive between BH 43 - BH 44 and BH 47- BH 48. Attenuation results were correlated with the geological strata and suggested the presence of high conductive disseminated ore body with high water content. Crosshole GPR study using radar wave attenuation delineated the presence of old working in the study area.

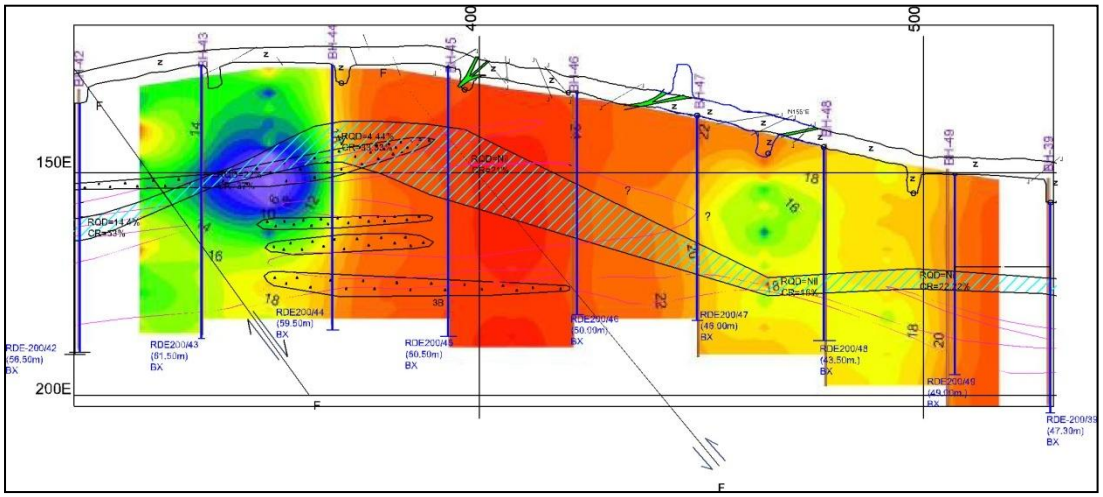

Fig. 2.10 2D map of radar wave attenuation was superposed with the geological strata along the 200 mRL drive

Environmental Geophysical Investigations

NIRM has created a new team for carrying out environmental and exploration geophysics related investigations, with an objective of research and application of near surface geophysical imaging and monitoring techniques to address various geo-environmental problems in the surrounding environment. Typical problems are like evaluation of urban planning and construction, structural monitoring, imaging for subsurface utilities, environmental impact assessment and investigations on vulnerability of major structures to natural hazards like earthquake and landslide.

- A science and technology project for estimation of seismic hazard to monitor seismic activities in and around the mined out areas of Kolar Gold Fields and identify potential zones of hazards due the mine induced seismicity is in progress. So far locations for installation of sensors on surface and monitoring station have been identified. Equipment procurement is in progress and as the job is on top priority the installation of seismic monitoring network will be completed by end of 2016.

3. IN-SITU GEOTECHNICAL INVESTIGATIONS

Geotechnical investigations are an essential and integral part of any civil and mining engineering project. All the major projects where rock excavation is involved require *in situ* geotechnical investigations prior to design. In the design of underground and surface structures the decisions for geometry, shape, excavation sequence, orientation of the structure, support system, the acceptable water pressure for the conduits are dependent upon the results of different geotechnical investigations generated during the initial stage to construction stages of any project. In coal and metal mining, the mine layout, pillar design, stope design and sequence of mining are dictated by geotechnical investigation results for safe and economical extraction of the mineral. The department with its experienced manpower and state of the art equipment is actively involved in different geotechnical investigations of numerous projects in India and abroad. During the period 2015-16, the department completed three sponsored projects. Furthermore, there are three ongoing sponsored projects and one S&T project.

- Teesta Low Dam – III power station is located in Darjeeling district of West Bengal. The project was commissioned in 2013 with installed capacity of 132 MW (4x33 MW). It is proposed to store one complete set of spillway stop log units on left bank of barrage made up of overburden/backfill material. Stop logs are used in floodgates to adjust the water level or flow rate in a river, canal, or reservoir. The safe bearing capacity and modulus of sub-grade reaction parameters are essential for the design of foundation. The safe bearing capacity test was carried out in three locations and the results are 40.02, 50.03, 50.05 T/m^2 (Fig. 3.1). The modulus of sub-grade (K) for surrounding soils of backfilling or overburden material ranges from 25.6 to 33.6 kg/cm^3.

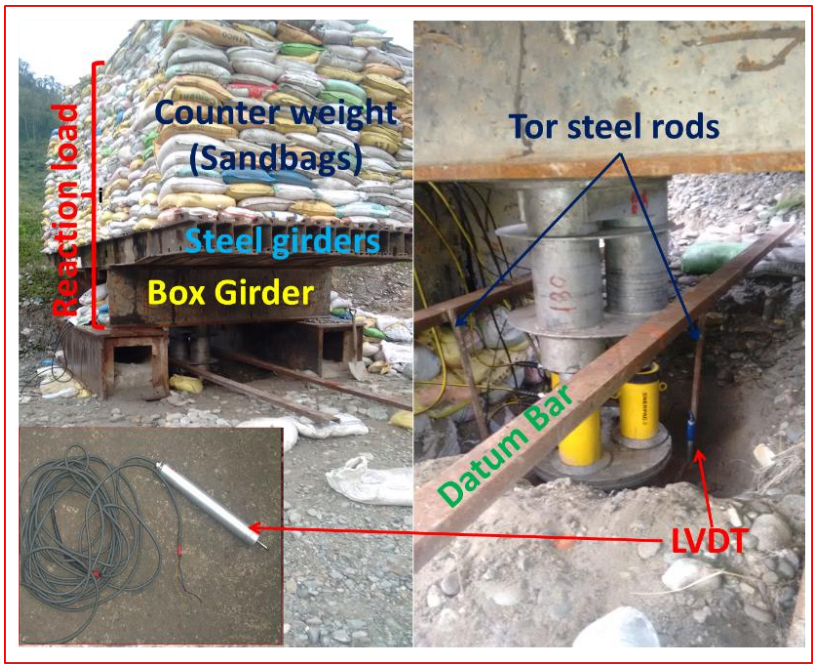

Fig. 3.1 Complete setup of plate load test equipment

- Dr. B. R. Ambedkar Pranahita Chevella Sujala Sravanthi scheme envisages diversion of 160 TMC of water from river Pranahita, a major tributary to river Godavari to irrigate an ayacut of 16,40,000 Acres in Adilabad, Nizamabad, Karimnagar, Medak, Warangal, Rangareddy and Nalgonda districts of Telangana. Besides irrigation, the project also provides provisions for drinking and industrial water supply. For the design of underground pump house the i*n situ* stress parameter is of utmost importance. The stability of any underground cavern gets enhanced if the long axis of the cavern is oriented along or sub-parallel to that of maximum principal stress direction. Hence, the scope of the work was to determine the i*n situ* stress parameters at the vicinity of underground pumphouse for its best orientation. The *in situ* stress measurments were conducted in four zones from 10 to 50 m depth of the bore hole (Fig. 3.2). The shut-in pressure derived from the stress plot ranged between 3.6 – 9.7 MPa. The results of the investigations are σ_v = 1.35 MPa, σ_H = 2.23 ± 0.22 MPa, σ_h = 1.49 ± 0.155 MPa and the recommended orientation of the underground excavation is N110^0.

Fig. 3.2 Execution of hydraulic fracture test at Dr B R Ambedkar Pranahitha Chevella Sujala Sravanti Scheme, package – 12

- The Rupaligad re-regulating project is proposed on river Mahakali in Nepal. The project envisages construction of 83 m high concrete gravity dam and two underground powerhouses to generate 240 MW of power. For the design of the underground openings *in situ* stress parameters are required. Hence, the scope of the work was to determine the *in situ* stress parameters at the vicinity of proposed powerhouse sites for its best orientation. The stress measurements were conducted at left bank six zones were selected on the basis of core inspection from 45 to 150 m depth of the bore hole (Fig. 3.3). The shut-in pressure derived from the stress plot ranged from 3.3 - 4.4 MPa. The results of the investigations at left bank are σ_v = 4.05 MPa, σ_H = 9.95 MPa, σ_h = 3.98 ± 0.25 MPa and the recommended orientation of the underground powerhouse is N130^0. For right bank five zones were selected on the basis of core inspection. The stress measurements were conducted from 30 to 150 m

depth of the bore hole. The shut-in pressure derived from the stress plot ranged from 4.2 - 6.7 MPa. The results of the investigations are σ_v = 4.05 MPa, σ_H = 7.21 ± 1.19 MPa, σ_h = 4.81 ± 0.79 MPa and the recommended orientation of the underground excavation is N 20^0. The horizontal stresses might have been relaxed due to the influence of topography (Fig. 3.4). The direction of *in situ* stress tensor N 130^0 measured at the left bank might be perturbed by topography due to the close proximity of the valley.

Fig. 3.3 Lowering of hydraulic fracture equipment with NQ rods

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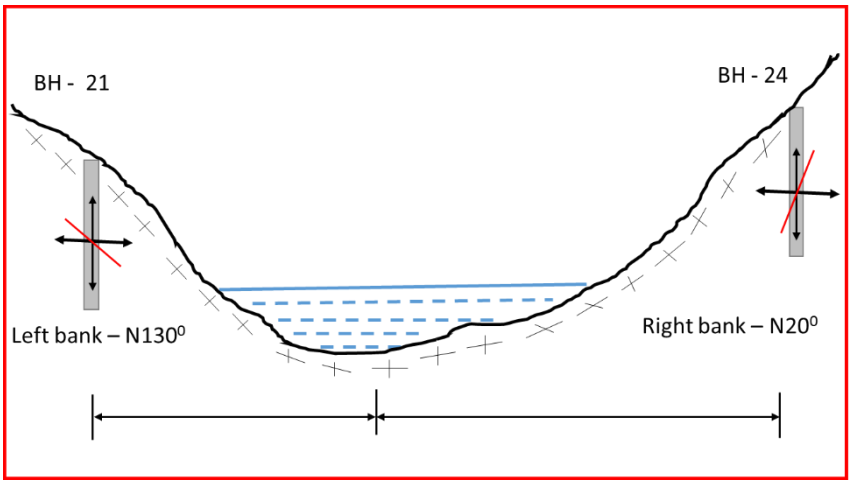

Fig. 3.4 U Shaped valley effect

Dr. B. R. Ambedkar Pranahita Chevella Sujala Sravanthi scheme envisages diversion of 160 TMC of water from river Pranahita, a major tributary to river Godavari to irrigate an ayacut of 16,40,000 acres in Adilabad, Nizamabad, Karimnagar, Medak, Warangal, Rangareddy and Nalgonda districts of Telangana. Besides irrigation, the project also provides provisions for drinking and industrial water supply. For the design of underground pump-house the i*n situ* stress parameters is of utmost importance because the stability of the underground cavern gets enhanced if the long axis of the cavern is oriented along or sub-parallel to that of maximum principal stress. Hence, the scope of

the work was to determine the i*n situ* stress parameters at the vicinity of underground pumphouse for its best orientation. The investigations are completed and final report is under progress (Fig. 3.5).

Fig. 3.5 Lowering of hydraulic fracture equipment with NQ rods

- Hutti Gold Mines Company Limited (HGMCL), a Government of Karnataka Enterprise, state owned company located to the North-Western part of the Hutti Maski belt in Raichur District, Karnataka and engaged in mining & production of gold. In this process HGML has been able to develop much needed technological expertise in the field and is preparing itself to take new challenges of growth and development. There are nine parallel gold bearing reefs exposed on the surface. Active mining is being carried out in six lodes over a strike length of around 1.3 km; the parallel lodes have a general strike of NNW-SSE & dips ranging from 60^0-70^0 due west. Presently stopes are being developed below 20^{th} level. Development works in 24^{th}, 26^{th} & 27^{th} Levels are under progress. Some capital development works at 27^{th} and 28^{th} level plat cutting is going on, hence the bottom most accessible level is 26^{th} level at which on-lode and off-lode development works were carried out. Some recently drilled exploratory drill holes are already available which is more than 30 m depth and free from any influence of mine workings. Two horizontal NX size boreholes Oakley reef (OR-2) & Zone-I reef (ZI-3) (Dia-76mm) were selected (Fig. 3.6), which emphasize investigations run smooth. *In situ* stress measurements are completed at 26^{th} level OR & ZI reef. Final report is under progress.

- Rail Vikas Nigam Limited (RVNL) proposed a Rishikesh - Karanprayag rail link project connecting the hinterland of Uttarakhand. The new broad gauge rail link between Rishikesh and Karanprayag via Devprayag (54 km), Srinagar (78 km), Rudraprayag (103 km), and Karanprayag covers 125 km. Detailed project report is under preparation, in which the tunnels and bridges layout and orientation to be indicated. Keeping this in view S.M consultants Ltd (consultant) requested NIRM to conduct the i*n situ* stress measurements and deformability parameters at the specified locations of railway alignment in new Rishikesh – Shivpuri section (6 – 20 km) of 125 km in the

state of Uttarakhand, India. Preliminary site visit is completed and preparatory works are in progress.

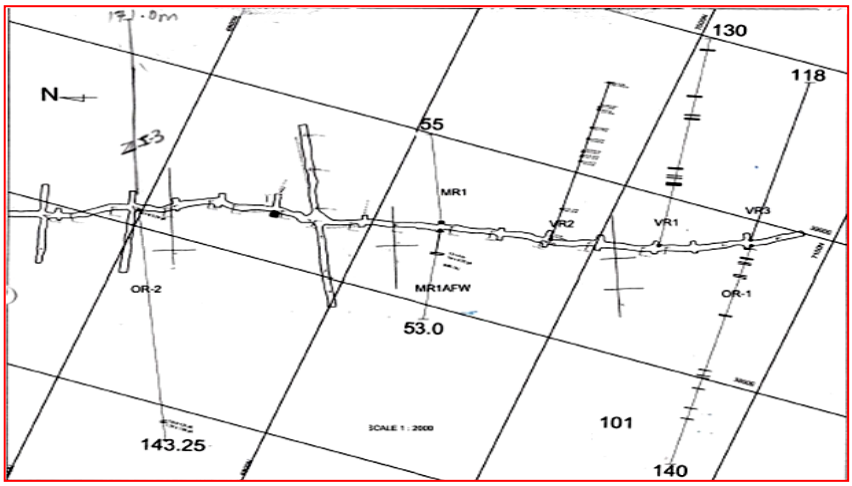

Fig. 3.6 Plan of MR 26th level with boreholes

- S&T project entitled “assessment of horizontal stress field in deeper horizons and development of roof hazard maps of coal resources in SCCL command area” is sponsored by Ministry of Coal. The objective of the project is to assess the horizontal stress field in the mines of Godavari coalfield, vis-à-vis roof hazard map, and devise suitable support systems for the coal mining blocks of SCCL. Hydraulic fracturing technique will be used to measure the state of *in situ* stress underground through a borehole. The test provides, in general the magnitudes and directions of the principal horizontal stresses. Roof hazard zonation will be carried out to identify potential weak zones in the mines. Integrating the two, a suitable methodology will be developed for devising the support systems or for change in direction of the workings for safer and productive mine workings. After establishing the stress field and preparation of suitable support design in SCCL, Guidelines will be prepared so that these investigations will be useful for the other coal fields of India for the support design. Indent has been raised for procurement of equipment’s for *In situ* stress measurements and still under process. Drilling of boreholes at SCCL command area is under progress.

5. NUMERICAL MODELING OF STRUCTURES IN ROCK

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

- Mangdechhu Hydroelectric Project is a 720 MW (4 x 180 MW) power project under construction in Bhutan. The scheme involves construction of 114 m high concrete gravity dam. The primary objective of the study was to analyse the stability of slopes along with the planned support system and suggest recommendations, if any. Slope stability analysis was carried out with UDEC software for calculating the factor of safety (FOS) and displacement contours for nine cross sections namely Section 1-1 to Section 9-9. Plots of FOS and displacement contour for section 2-2 are given in Figs. 5.1 & 5.2. Based on UDEC analysis it was found that section 5-5 to section 8-8 have low factor of safety, hence it was suggested to carry out consolidation grouting with 45 mm diameter holes, 8 m long @ 3m c/c along these sections. Analysis was done for section 5-5 to 8-8, by considering the effect of grouting with joint friction angle of 50 deg and joint cohesive strength of 300 kPa. From the analysis, it was found that, factor of safety values increased significantly.

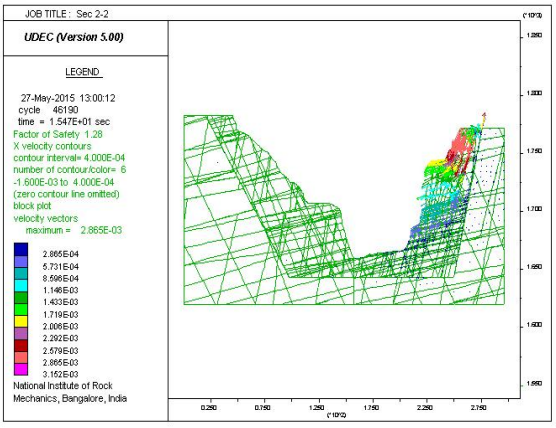

Fig. 5.1 Plot of FOS for section 2-2

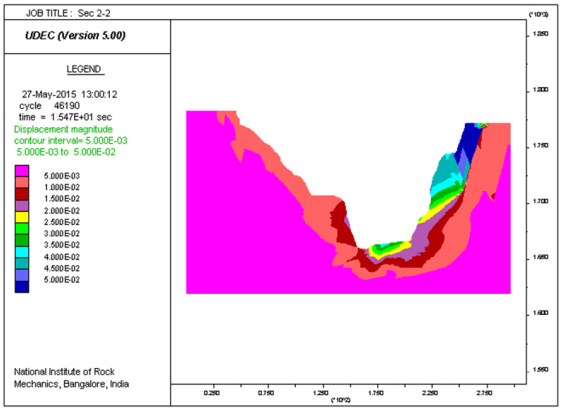

Fig. 5.2 Displacement contours for section 2-2

- Tehri hydroelectric project is one of the major project on the bank of river Bhagirathi in the state of Uttarakhand. The 2400 MW Tehri Hydro Power complex comprises of Tehri Dam & Tehri Hydro Power Project (HPP) (1000 MW) Stage-I, Koteshwar HEP (400 MW) & Tehri Pumped Storage Project (PSP) (1000 MW). THDC India Ltd. successfully commissioned the Tehri HPP during the X Plan period and Koteshwar HEP during XI Plan. The work on the Tehri PSP (1000 MW) is in progress. Tehri PSP comprising of four reversible pump turbine units of 250 MW each, would involve construction of an underground machine hall on the left bank of river Bhagirathi. Hindustan Construction Co. Ltd. is constructing the Tehri PSP underground

components. 3D numerical modelling studies for powerhouse complex, bus ducts and other tunnels at Tehri PSP were carried out using discontinuum and continuum methods. Fig. 5.3 shows the FLAC 3D model used for carrying out the stress analysis.

The following were the observations and recommendations for the support system for Tehri PSP base on FLAC 3D studies:

Powerhouse

1) Maximum crown displacement observed were as follows:
   - Centre of crown : 109.5 mm at RD 37m
   - Upstream side of crown : 92.2 mm at RD 57 m
   - Downstream side of crown : 97.8 mm at RD 67 m
2) Maximum wall displacement observed were as follows:
   - Upstream wall : 176 mm at RD 46.5 m at EL 585 m
   - Downstream wall : 172.2 mm at RD 40.7 m at EL 579 m
3) Percentage strain on the upstream wall and downstream wall were calculated using the half width of the cavern
   - Maximum strain on upstream wall : 1.34% at RD 46.5 m at EL 585 m
   - Maximum strain on downstream wall : 1.30% at RD 40.7 m at EL 579 m
4) SPT material band had considerable influence on the displacement pattern of the crown and walls. Higher displacements were occurring along the SPT material at the intersections of the Bus Duct No.1.
5) It may be noted that yield zone on upstream was extending up to 27.39m on upstream wall and 27.22m on downstream wall. In general, extent of yield zone was more near the intersection of cavern with the bus ducts and other openings or in the areas where SPT material was present.
6) At many sections, considerable amount of floor heave (> 100mm) was also observed.
7) Cable bolts in the upstream wall of the powerhouse helped in reducing the tensile stresses and reduction in nos. of bolts reaching the yield load.

Bus Ducts and other Tunnels

1) At bus ducts also the more displacements were taking place along the SPT material band or at its intersection.
2) SPT band was mostly intersecting Bus Duct No. 1 along its length and more displacements were taking place around it. Near the junction, the displacement on the wall of the bus ducts varied from 150 to 165 mm. and in the crown, the displacements varied from 120 to 150 mm.
3) At a distance of 5 m from the junction, the tensile stresses drastically reduced along the length of bus ducts. This could be due to the presence of the cable bolts. Similarly, the extent of yield zone also diminished away from the bus duct junction.
4) The failure mechanism was predominantly tensile at the bus duct junctions.
5) Stability of the bus ducts were significantly enhanced due to the presence of cable bolts.

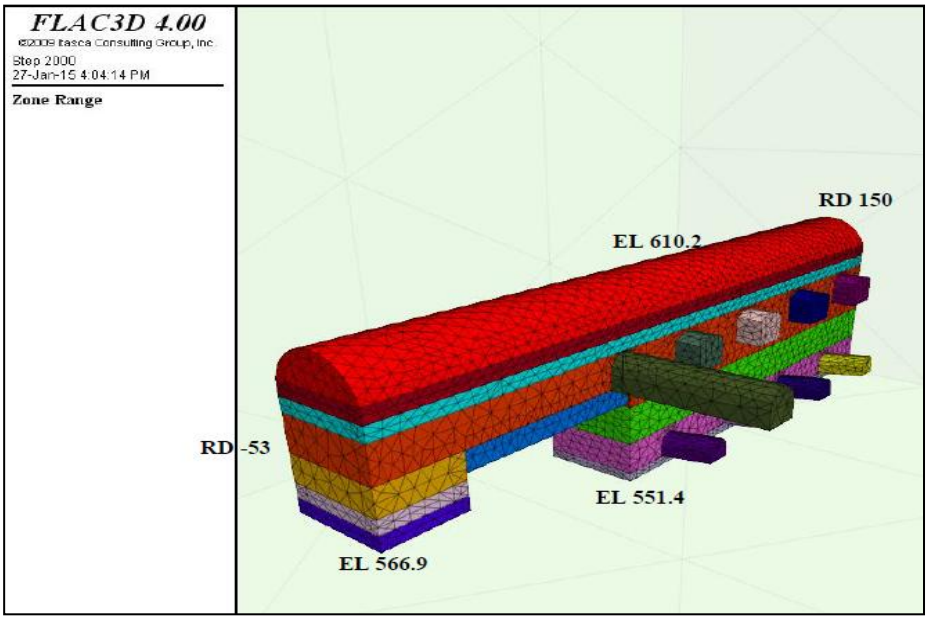

Fig. 5.3 3D view of the model showing powerhouse and other tunnels

- Mangdechhu Hydroelectric Project is a 720 MW (4x180 MW) power project under construction in Bhutan, it is run-of-the-river scheme on the Mangdechhu river in Trongsa district. In this study, the stability of the underground powerhouse complex for given excavation sequence and support system was evaluated and modifications in the support system was suggested. 3D discontinuum model was prepared using 3DEC. Actual shear zones encountered in the powerhouse area were incorporated in the model. Initial model results showed that supports in the form of rock bolts in the crown of powerhouse cavern were adequate with the additionally installed 12 m long rock bolts for further benching operations. The results also showed that the thickness of SFRS of 250 mm was adequate for control of rock mass movement. At bus ducts, stitching with the cable anchors proved effective in functioning of the rock bolts and improved the factor of safety of the pillar in between powerhouse and transformer hall cavern. Excavation sequence studies with the 3D models suggested to excavate and support entire bus ducts before the commencement of TRT manifolds and penstocks. Model results were compared between the excavation levels corresponding to the period of instrumentation data. Back analysis studies are in progress to assess the overall behavior of the caverns. The 3D model of machine hall and transformer hall cavern along with the geology is given in Figs. 5.4 & 5.5.

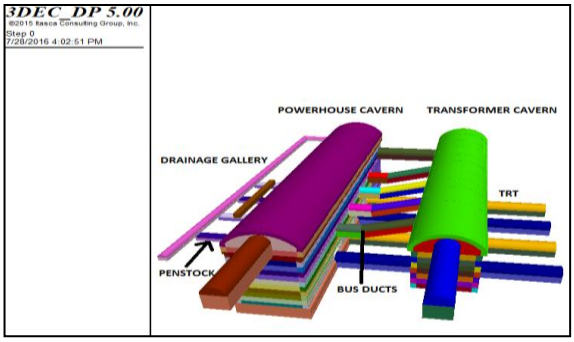

Fig. 5.4 3D model of Mangdechhu powerhouse complex

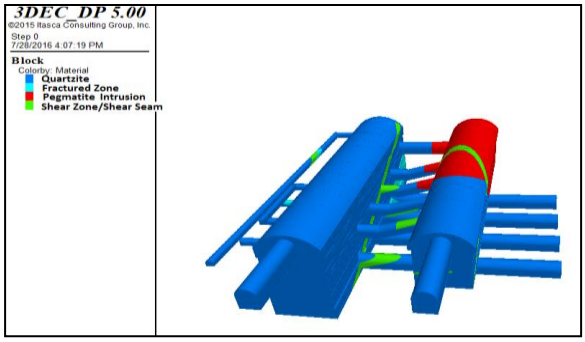

Fig. 5.5 3D model with different materials assigned

- Studies to evaluate the stability of excavations and optimization of stoping parameters and design of support system below 20th level in all the reefs of Hutti Gold Mines is in progress. NIRM scientists visited the project site to collect the relevant data required for the study. Geological mapping was completed and rock core samples were identified at site. Currently testing of the samples is in progress. 3D models of the study area is also being prepared.

Slope Stability Investigations

Slope Stability Cell works with an objective of stability analyses of surface mining excavations with increasing depth of workings to investigate the pit slope stability conditions, potential failure mechanism, slope sensitivity and to design optimum pit slope angles in terms of safety, reliability and economically profitable. This process requires the use of a variety of methods of analyses and software ranging from limit equilibrium methods to more involved numerical analyses methods such as distinct elements, finite elements and finite difference methods which can capture detailed geology input parameters and different types of failure modes. Stability of open pit slope depends on geometry of slope and rock mass characteristics.

- Stability of the pits at north east benches of A Narrain Mines, Chitradurga is under progress. NIRM scientists visited the site, had detail discussions with the site engineers, and collected the samples for testing. The objective of the present study is to evaluate the stability of the existing slope profile and optimize final bench profiles by calculating the factor of safety at identified sections using 2D limit equilibrium analysis and numerical analysis and recommend the slope parameters and other measures required for slope stability of the open pit. All the necessary data were collected and samples were tested in NIRM laboratory to determine the material properties required for the study. Presently slope stability analysis using 2D numerical methods is in progress.

- M/s Balasore Alloys Ltd. is operating Kaliapani chromite mine at Kaliapani, Jajpur District, Odisha. The chromite mine is excavated by mechanized opencast method with shovel-dumper combination. The mine having 19 benches with a height and width of 8 m each and the bench angle is less than 80^0 from horizontal. The mine management requested NIRM to study the stability of the pit slopes at Kaliapani mine from the present depth of 150 m to 190 m, under critical geographical conditions like, common boundary with other operating mines in east and west directions, and two active dumps in other directions. For carrying out the slope stability analysis, strength reduction technique method was used. The analysis was carried out using the software 'FLAC/SLOPE'. In this, the factor of safety of potential failure surface is computed for different sections, and the critical failure surface is identified. The analysis was carried out for the individual pit slopes to determine the optimum bench height and slope angle, and also for the overall slopes to determine the ultimate pit slope angle. A factor of safety of 1.3 was considered for the long term stability.

  Based on the numerical analysis, the overall slope of critical profile towards south side with a depth of 182 m with reformed dump-3 condition found to be stable with a overall angle of 26^o under fully saturated condition with a safety factor of 1.30 (Fig. 5.6), and

35.5^{o} under fully saturated with permeation grouting condition (Fig. 5.7) from 70 mRL to 0 mRL (70 m) depth of workings in the pit. The overall slope of critical profile at towards north side with a depth of 140 m with reformed dump-2 condition found to be stable with a overall angle of 25.5^{o} under fully saturated condition with a safety factor of 1.30 and 33^{o} under fully saturated with permeation grouting condition from 70 mRL to 0 mRL (70 m) depth of workings in the pit.

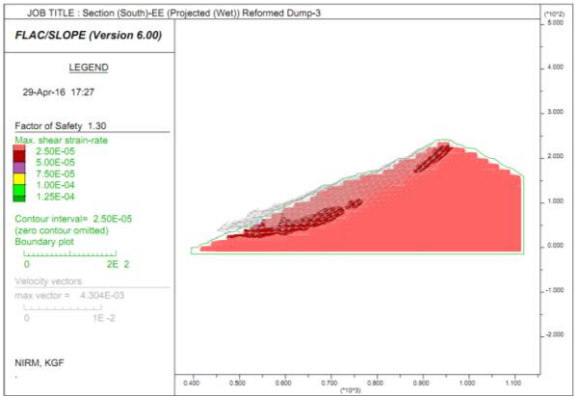

Fig. 5.6 Stability analysis of a critical section with reformed Dump-3 on south side

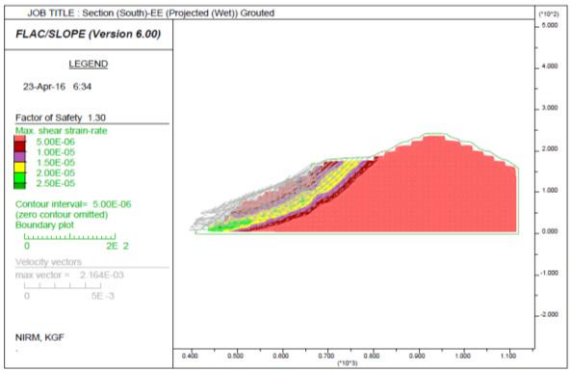

Fig. 5.7 Stability analysis of a critical section on south side with Permeation Grouting

- The Kaliapani Chromite Mine M/s Balasore Alloys Limited is operating the Chromite opencast mine in Sukinda valley Jajpur district, Odisha. The mine having three dumps (Dump-1, Dump-2 and Dump-3). The dump-2 and dump-3 located towards north and south side of the pit respectively, and dump-1 located away from the pit and nearby pit office. On the request of the mine management, NIRM carried out the study to determine the stability of dumps. For carrying out the slope stability analysis, large scale direct shear tests conducted for shear strength properties of dump material and strength reduction numerical technique method was used. The analysis was carried out for the individual dump slopes to determine the optimum bench height and slope angle, and also for the overall slopes to determine the ultimate dump slope angle. A factor of safety of 1.3 was considered for the long term stability. Based on the numerical analysis the overall safe dump slope angle for dump-1 towards north and south side under saturated condition are 35.5^{0} and 36^{0} respectively up to a height of 80 m, and for dump-3 towards north and south side are 33^{0} and 29^{0} respectively up to 82 m.

5. INSTRUMENTATION AND STRATA BEHAVIOUR MONITORING

NIRM in regualarly involved with projects related to monitoring the stability of concrete structures and underground caverns in rock mass using systematic instrumentation.

- Tala Hydroelectric Project is a 1020 MW run of the river scheme on river Wangchu in Chukha Dzongkagh of Western Bhutan. This project work is a continuation of monitoring and analysis of the existing instruments in the Tala powerhouse complex carried out by NIRM from 2002 onwards. Currently about 150 instruments are being monitored at powerhouse complex, surge shaft and pressure shaft butterfly valve chamber. Stability of the machine hall cavern was assessed based on convergence observations of the side walls, load on the rock bolts and stress distribution along the length of instrumented bolts and piezometric observations in the side walls. Based on the analysis of the instrumentation data observations made are a) Convergence at the machine hall cavern is continuing although at a lower rate (0.007 to 0.013 mm/day). The total convergence observed during the operational period (3279 days) varied from 20 to 40 mm, b)

  The caverns are undergoing time dependent deformations and stress induced deformations due to its close proximity to the Main Central Thrust, c) The failure of rock bolts is continuing as the stress redistribution is still going on in the rock mass surrounding the cavern. It may be noted that in the year 2012, there were 7 rock bolt failures in Machine Hall and 3 bolt failures in Transformer Hall Cavern, and in 2013, there were 3 rock bolts failures in Machine Hall and none in transformer hall. In 2014, 10 rock bolts have failed in Machine Hall. In 2015, 5 nos. of rock bolts have failed, d) Back analysis study using 3D numerical modelling conducted by NIRM indicated that more bolts are likely to fail.

  Recently NIRM has installed advanced Microseismics / Nanoseismics system for monitoring the activity of the surrounding rock mass. Monitoring of the powerhouse complex and surrounding rock mass using micro-seismic monitoring will aid the assessment of the stability of the cavern in the near future and e) Minor cracks are appearing on the treated portion of earlier treated shotcrete (between EL 515 and EL 520). DGPCL shall regularly monitor these cracks visually and using some markers.

- The Nathpa Jhakri Hydroelectric Project of SJVNL is a 1500 MW project with underground powerhouse complex at Jhakri, Himachal Pradesh. It consists of the largest underground desilting complex of four numbers of 525 m long with a cross section of 27 x 17 m each separated by 46 m rock pillar located at Nathpa. Analysis of the instrumentation data of powerhouse and desilting complex supplied by SJVNL was carried out to evaluate the stability of the caverns during operational stage. The instrumentation records consisted of data obtained from instruments like MPBX, piezometers, total station targets and crack meter at Desilting chambers, Powerhouse complex and TRT outfall area. The analysis of instrumentation data at various components is given below:

Powerhouse Cavern

1) The displacements at many locations on the downstream wall shows stabilizing trend.
2) At RD 80 EL 1014 -Drainage Gallery, MPBX observations show opening and closing up of cracks on regular basis.

Desilting Chambers

1) During last five years, there was no abnormal changes in the pore water pressures in the walls of desilting chambers.
2) When the chambers were emptied and refilled, pore water pressure changed accordingly.

TRT Outfall

1) At most of the places, pore water pressure was less than 1.0kg/cm^2 and showed stable trend.

- Tapovan Vishnugad Hydroelectric project is a 4 x 130MW run of the river project on Alaknanda River, being executed by NTPC Ltd. in the state of Uttarakhand. The underground powerhouse complex of the project consists of three main underground excavations i.e., i) Powerhouse ii) Transformer Hall and iii) Bus Ducts and other tunnels. NIRM carried out 3D modeling studies using three dimensional discontinuum code, 3DEC. Shear zone and biotite schist bands were simulated in the model. Subsequent to substantial excavation activities in Tapovan Vishnugad powerhouse complex, the work of "Back Analysis of Powerhouse Complex Behavior using 3D Numerical Modeling at Tapovan Vishnugad Hydroelectric Project" was taken up based on the instrumentation data provided by NTPC Ltd.

  Based on the instrumentation data and numerical modeling studies on the calibrated model, major conclusions made are: 1) Significant duration of excavation remained unmonitored due to the delay in installation of instruments leading to loss of information on initial deformation phase of caverns, 2) Maximum surface displacement of 66.4mm was measured with MPBX at RD 143m at EL 1308.12 on downstream wall of powerhouse. In the calibrated model, maximum displacement of 194.2mm was observed at RD 128.76m & EL 1302.96m on downstream wall of powerhouse and 210mm was observed at RD 86.69m & EL1302.60 on upstream wall, 3) Maximum strain calculated on the upstream and downstream walls of powerhouse were 1.84% and 1.74% respectively.

  On upstream wall of transformer hall, maximum strain was 0.71% and on downstream wall, it was 0.81%. However, strains more than 1% were occurring at few isolated patches and at most of the places in powerhouse and transformer hall cavern strains were less than 1%, 4) With effective bolting in the caverns and cable bolts in bus duct area, the strength to stress ratio was more than 1 in most of the places. Some places in the blasting affected zone i.e. within 3m from the walls and crown of the cavern, the strength to stress ratio was less than 1. Most places in the shear zone the strength to stress ratio was less than 1. However, overall stability of the cavern was not affected by the existence of such isolated zones around the caverns, 5) Displacements values obtained from calibrated model compared well with the measured instrumentation data at few places. Variation at other places could be due to variation in local geology and variation in strength parameters. However, calibrated 3D model was able to depict the overall behavior of the surrounding rock mass vis-a-vis the behavior of caverns and

other cross tunnels and 6) Both model studies and instrumentation data confirmed stable behavior of the cavern.

- Sardar Sarovar Project is one of the largest water resources projects of India across river Narmada catering to the four major states – Maharashtra, Madhya Pradesh, Gujarat and Rajasthan. It consists of concrete gravity dam having length of 1210 m (3970 feet) and maximum height of 163 m above the deepest foundation level. It has catchment area of 88,000 sq.km and designed for a FRL of 138 m and MWL of 140.2 m. The dam is still under construction. Due to the large reservoir capacity and height of the dam, it was necessary to monitor the deformation of dam, during different levels of reservoir in order to ascertain the dam stability. NIRM has taken up the geodetic monitoring of the dam for measuring the deflection at the crest of the dam. NIRM has established geodetic network for monitoring the movement at the crest of the dam. Four control points were established on both abutment of the dam using Differential Global Positioning System (DGPS). Establishment of the control points are shown in Figure 5.4. Points on the crest at different blocks were identified in consultation with SSNNL. Seven monitoring points were installed on downstream side of dam blocks and about eleven sets of data incorporating temperature corrections was collected till April 2016. Data reduction and interpretation work is in progress.

Fig. 5.4 Control points establishment at SSNNL Dam

- The behavior of underground powerhouse of Sardar Sarovar project is being monitored by NIRM since the year 2000. During construction stage, NIRM installed Magnetic Ring Multi Point Borehole Extensometers (MRMPBX), total station targets on powerhouse walls to monitor the deformations inside the cavern. During operational stage, 5 nos. of MR-MPBX were installed on surface along center line of the powerhouse. The analysis of the instrumentation data for the period December 2015 to February 2016 indicated the following: 1) During Dec'15 to Feb'16 the trend of displacement of almost all the MRMPBX's at the underground powerhouse showed stable trend, 2) The displacements measured on the columns and beams were negligible and showed stabilizing trend, 3) The surface MRMPBX data confirmed that

the area between the crown and surface is stable and no movement is currently taking place, and 4) Instruments at critical chainages like Ch 1516, Ch 1552 and Ch 1580 showed stable trend.

6. ROCK BLASTING & EXCAVATION ENGINEERING

NIRM is equipped with latest instruments like seismographs, VOD measuring systems, laser based survey systems, digital video camera, fragmentation assessment system, vibration analysis system (signature hole analysis) and state-of-the-art software for blast design. The Rock Blasting & Excavation Engineering Department has been providing innovative solutions to challenging problems in blasting for various surface and underground excavations in mining, hydroelectric, infrastructure and other civil engineering projects. The projects undertaken pertain to optimization of blast design to maximise the fragmentation, monitoring blast vibrations and air overpressure for ensuring safe charge limit and advising on controlled blast design with minimum or no fly rock. During 2014-15 the department worked on twelve industry sponsored projects, out of which eight are completed and remaining four are in progress.

- Hindustan Petroleum Corporation Limited (HPCL) is under process of laying pipeline to connect HPCL LPG Despatch Station at Mangalore to receiving station at Yediyuru and Mysore. The project envisages laying of a pipeline of 355 km length (255 km main pipe length and spur line of 100 km length). The proposed LPG pipeline is to be laid at varying distance of 4 m to 12 m from buried petroleum pipeline belonging to Petronet. The pipeline has to be laid in the Right of Use (ROU) of existing pipeline which was laid before 14 years. While trench excavation was carried out, hard rock was encountered at Ch. 81.5 Km near a river called “Paraje Hole” and at Ch. 93.5 Km near a water fall area. At these locations hard rock had to be excavated by drilling and blasting for the trench to a width of 1.0 m and a depth of 1.5 m adjacent to existing buried petroleum pipeline. The work is been carried out by M/s. ACE Pipeline Contract Pvt. Ltd. Keeping the above in view, HPCL wanted to know the effect of ground vibration on the existing pipeline while blasting is carried out for excavation of the proposed trench. The field study was carried out from 4th to 7th April, 2015. Blasts were conducted covering 3 blasts at Ch. 93.5 km near Neriya section and 4 blasts at Ch. 81.5 km near Gudhi section. Jackhammer holes of 38 mm diameter were used to drill the holes and charged with small diameter explosives. The depth of the holes depended on the rock profile at the trench and the charging of the holes was done based on the depth of the holes and distance between the existing pipeline and blast location. Shock tube initiation system was used to initiate the charge in drilled holes. Vibrations were monitored on the existing buried pipeline and at closer distances (Fig. 6.1). A predictor equation for ground vibration was derived using the monitored data (Fig. 6.2). Based on the literature survey and experience of the authors on similar works, a peak particle velocity of 50 mm/s is recommended as safe for the existing buried pipelines. Safe maximum charge per delays for different distances are computed and presented. Blast designs for further excavation of the trench for different site conditions too are presented.

Fig. 6.1 Blasting adjacent to buried petroleum pipeline

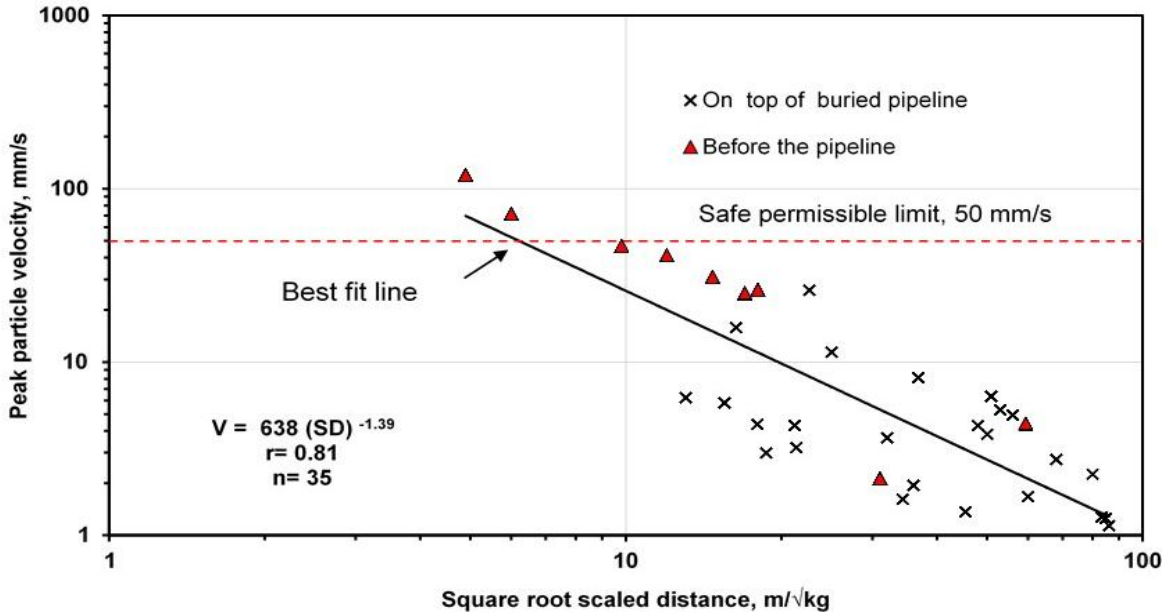

Fig. 6.2 Peak particle velocity versus scaled distance

- Kerala State Electricity Board (KSEB) Limited is under the process of expanding the existing Poringalkuthu hydroelectric scheme (of twin surface powerhouses of 4×9 MW and 1×16 MW). In view of this, a 24 MW (1x24 MW) capacity powerhouse is being constructed adjacent to the existing 16 MW capacity powerhouse (Fig. 6.3). To accommodate the proposed powerhouse the earth has to be excavated which includes both soil and hard rock. Upon their request and award of the scientific study, NIRM carried out field investigations, fifteen blasts were technically guided in powerhouse area close to existing 16 MW (1x16 MW) powerhouse. Ground vibration and air overpressure levels were monitored for all the blasts by deploying five seismographs.

A site specific predictor equation was derived by regression analysis using the ground vibration data and permissible vibration was arrived as per government norms. A safe permissible peak particle velocity limit of 25 mm/s for nearby 16 MW powerhouse structure and 10 mm/s for surface structures is recommended. This report elaborates the controlled blast designs with muffling to be adopted at the proposed SHEP complex for remaining portion of rock at different components based on the field study.

- Waddera Sangam, Karimnagar District, Telangana is operating fourteen quarries under Survey No. 493 and 497. The rock is being excavated by drilling and blasting method with jack hammer drilled holes. The blasting activities were stopped in these quarries due to complaints from the locals. Waddera Sangam approached Director of Mines Safety (DMS), Hyderabad to permit the blasting activities in their quarries. DMS, after reviewing their request, identified the quarries which are located 100 m beyond HT lines and permitted to conduct blasting in six quarries “on trial basis only” subject to use the maximum charge per delay within 2 kg, restrict the flyrock within 10 m and not to exceed ground vibration to 15 mm/s at HT lines. Field investigation were carried out in the permitted six quarries, organised three blasts in each quarry and monitored ground vibration and air overpressure towards the critical structure like HT line, railway track belongs to Kesoram Cements and the civil roads. The vibration data were regressed and a site specific predictor equation was derived. The peak particle velocity attenuates to 1 mm/s beyond a distance of 100 m which is far below the permitted peak particle velocity recommended by DMS (Fig. 6.4). Blasts were videographed to ascertain the efficacy of muffling in restricting the flyrock within 10 m. Considering some dwellings/structures that may come up in future at a distance of 100 m and beyond, a safe maximum charge per delay of 3.9 kg is arrived for a permissible level of 5 mm/s as per D GMS norms. The muffling method followed during the trials controlled flyrock within 10 m.

Fig 6.3 Blasting close to existing powerhouses

- The Nuclear Power Corporation of India Limited (NPCIL) awarded the construction of pump house which is part of the construction of nuclear power plant (Unit 7 & 8) at Rajasthan Atomic Power Plant, Rawatbhata, Rajasthan, to Gammon India Ltd. As part of this work, hard rock has to be excavated by drilling and blasting methods and the blasting has to be carried out close to the critical structures. The proposed pump house is nearby DM plant and the steel tanks which are under construction. Considering the criticality of the work involved the client requested NIRM to technically guide the controlled blasting operations and also monitor ground vibrations at critical structures. Field investigation was carried out and Fig. 6.5 shows the location of the proposed cut & cover tunnel and water pipeline. Blasts were conducted for the excavation of pump house area and presplitting blasts were carried out to reduce the wall rock damage to the excavation boundary of the pump house. Ground vibrations for these blasts were measured at different locations and it was found that they are within the permissible limits. Blast sequence and designs are suggested for excavation of CWPH-8 (cold water pump house) area to a depth of 6 m, CWPH-8 area for a depth of 8 m, trimming of the CWPH-8 floor area to a depth of 1.0 to 1.5 m with muffling and presplitting CWPH-8 area. It was concluded that the site specific predictor equation derived for the previous study at the same location is valid for this study and based on which the safe maximum charge per delay is suggested for further excavations.

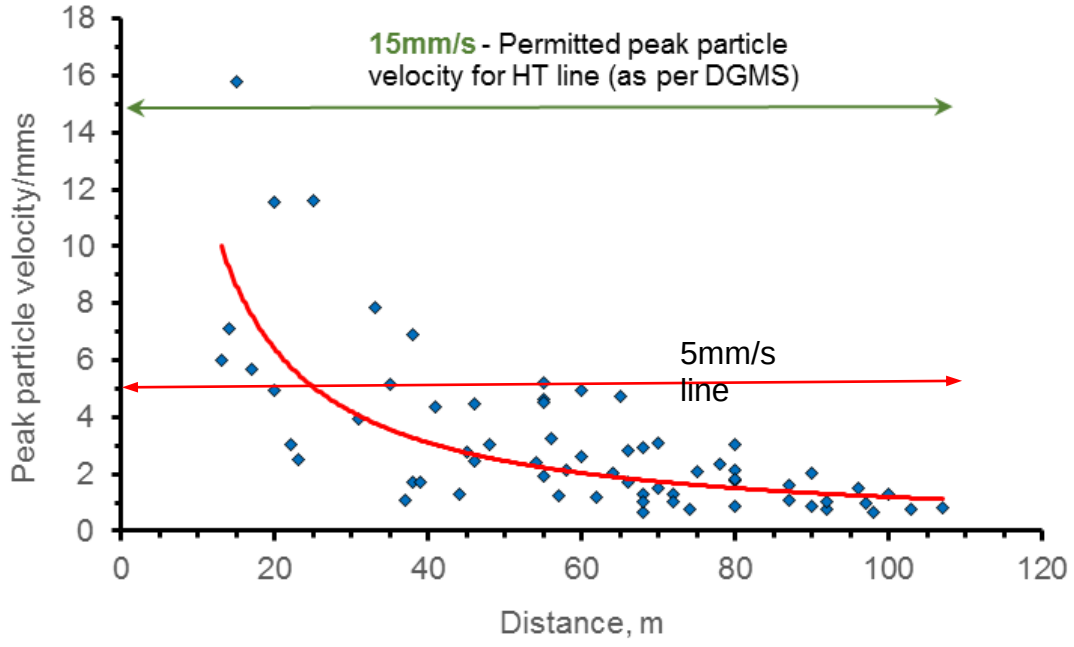

Fig. 6.4 Measured peak particle velocity versus distance (MCD up to 2 kg)

Fig. 6.5 Location of the proposed cut & cover tunnel and water pipeline

- Punatsangchhu Hydroelectric Project Authority is constructing Punatsangchhu Hydroelectric Project II (1020 MW) at Bhutan. The project envisages construction of 91.0 m high concrete dam across the river Punatsangchhu. The excavation activities for the main dam is under progress and the designed foundation levels for block 8 to 12 have been achieved. The excavation for other blocks of the dam on the right bank is also under progress as the abutment slopes had to be provided with cable anchors at drift levels. The foundation levels of the blocks 8 to 11 was taken up for treatment of shear joints/seams and later it was thought of concreting at these blocks while blasting is in progress for excavation of other blocks. Keeping this in view, WAPCOS Ltd. approached National Institute of Rock Mechanics (NIRM) to conduct a scientific study on effect of ground vibration and suggestion of blast design for control of ground vibration on green/matured concrete while blasting is under progress for excavation of rock for other blocks (Fig. 6.6). Organised 17 blasts, monitored blast vibrations at dam site with different maximum charge per delays and at different locations including block No. 8-10. A site specific predictor equation for ground vibration at 95% confidence level was derived and presented. The frequency of ground vibration recorded at the dam site is greater than 8 Hz. Based on NIRM experience the peak particle velocity was restricted to 40 mm/s and safe maximum charge per delay to be used in the blasts was computed and presented in the report. A review was made with regard to safe peak particle velocity for green/hardening/matured concrete by various researchers and presented in this report.

Fig. 6.6 Location of concrete blocks casted and experimental blast locations

- Training on Controlled Blasting & Excavation Engineering for the personnel of Border Roads Organization was organized. For Batch 2, the training course covered the main topics of controlled blasting. Lectures on introduction to rock mechanics related and related aspects were covered elaborately by faculty heads. Sufficient time was allotted for the lab visits and practical training at different departments. Relevant case studies were worked out according to their site requirements. A field demonstration was organised in a nearby stone quarry in which all aspects of blast design parameters including drilling, charging of holes, hookup pattern, initiation of blast and monitoring of ground vibration deploying seismographs were thoroughly imparted to the participants.

- Nuclear Power Corporation of India Limited have taken up the construction of 6 x 1000 Mwe Nuclear power project at Kudankulam and units 1 & 2 (2 x 1000 Mwe) in which unit # 1 is under operation and unit # 2 is under commissioning. The proposed units 3 & 4 (2 x 1000 Mwe) is being constructed near the existing units 1 & 2. As part of this work, about 7 lakh cubic meter of hard rock has to be excavated by drilling and blasting methods for foundation excavations so as to facilitate the construction of various civil structures. As the blasting operations need to be carried out in the vicinity of a commissioned Nuclear power plant, NIRM suggested blasting method statement and carried out vibration monitoring to establish the site specific predictor equation. Figure 6.7 illustrate a view of proposed excavation site RB 3 and commissioned unit 1&2. This report deals with the limits that can be prescribed for blasting in proximity to green concrete based on global and specific studies of NIRM. Enhancement of permissible vibration limits for structures and electronic equipment based on industry observations and standard practices too is suggested. Handy attenuation and predictor curves for assessment and review of blasting operations vis'-a-'vis the prescribed limits is given as a common man's ready reckoner.

Fig. 6.7 View of proposed excavation site RB 3 and commissioned unit 1&2

- Indira Sagar Polavaram Hydro Electric Project (960 MW) is to be constructed across river Godhavari, 42 km upstream of Rajahmundry by the Govt. of Andhra Pradesh. The construction of earth cum rock fill dam, spillway and foundation of this project was awarded to M/s. Transstroy-JSC EC UES Jv. under the EPC turnkey basis. As part of this project 2454 m long earth cum rock fill dam across the river, spill way with a crest level of about +25 m with 48 radial gates, excavation of approach channel split channel and pilot channel to facilitate impounding of 194 TMC of water and also excavation of foundation for power house, Tailrace pool and Tailrace Channel are to be constructed. The main dam is proposed to be constructed with rock fill material of 150 mm to 600 mm and 500 mm to 1000 mm for revetment which shall be obtained from excavation of spill way, power house etc. In order to maximise the output of the graded material from blasting, Transstroy-JSC EC UES Jv approached NIRM to provide technical advice on Rip Rap blasting for the construction of earth cum rock fill dam. NIRM carried out preliminary site investigation during September 2013. Based on the preliminary site investigation, a detailed method statement was submitted to Transstroy JSC EC UES Jv., which incorporated the tentative blast designs for rip rap blasting. First field visit was made during January 2016. During this visit, existing blast design being followed by the client was studied and reviewed. On the site suggestions was made to improve the design. Monitored ground vibration and air overpressure for the blasts conducted in different benches (Fig. 6.8). Post blast analysis was made and collected the images of fragmentation for different blasts to carry out image processing (Fig. 6.9). Second field visit was made during March 2016 and during this field, presplit blast was conducted at the top bench to obtain stable wall. The data collected from the two visits are under analysis and preparation of an interim report is in progress.

Fig. 6.8 Monitoring of ground vibration and air overpressure in front of police camp

- THDC India Limited (THDCIL) is constructing Vishnugad Pipalkoti Hydroelectric Project in the Chamoli district of Uttrakhand. As a part of this project, proposed horse shoe shaped 8.8 m high tail race tunnel (TRT) had to be excavated by drilling and blasting method for a length of about 3 km. About 400 m length of proposed tail race tunnel alignment passes below a village called Durgapur with a minimum cover of about 80 m. The structures at this village is located on the moderately thick debris zone present over granitic gneiss and amphibolite gneiss. THDCIL is having apprehensions about damages to the structures of Durgapur village due to blast vibrations from the blasts to be carried out in the portion of TRT which is located below this village and wanted to carry out a study on feasibility of blasting for excavation of TRT and also on impact of blast vibrations on the structures located in Durgapur village. First field work was carried out during the month of May 2015. A reconnaissance survey was carried out at the excavation site. Surface blasting for portal area preparation using jack hammer holes was under progress. The actual TRT portal work shall be started after completing full surface excavation and by providing suitable supports. There was apprehension from the locals of Durgapur village for conducting blasting at portal area which may cause damage to their structures, blasting was not allowed by them and they sought the help of District Administration. As per the request of THDCIL, NIRM attended a meeting with the representatives of Durgapur village, in the presence of Tehsildhar of Chamoli area, Officers of THDCIL and HCC. In the meeting, NIRM team explained their role in carrying out the studies as per scope of work. The queries raised by the Representatives of Durgapur village were clarified to their satisfaction and the need for trial blasts at TRT portal was emphasised. The Representives of Durgapur were convinced and agreed for carrying out trial blasts at TRT outfall area and the same was minuted. Two trial blasts were conducted near TRT outfall area to have a cursory idea on attenuation of ground vibration due to surface blasting. Six seismographs were installed to record the ground vibration level produced from these surface blasts. Four instruments were located

towards Durgapur village, one instrument before Durgapur village and one instrument near a structure in Durgapur village. The recorded peak particle velocity was plotted against distance in Figure 6.10 and it was observed that that the vibration is falling below 1 mm/s beyond a distance of 120 m. Further field work shall be carried out after getting intimation from the client.

Fig. 6.9 Capturing images for fragmentation analysis

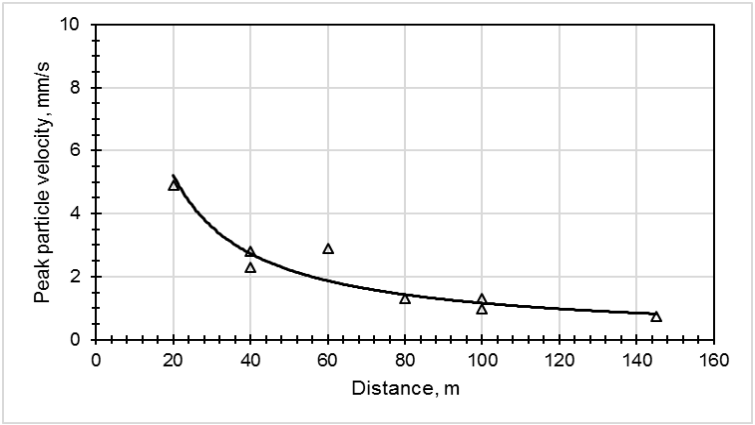

Fig. 6.10 Peak particle velocity versus distance

- National Thermal Power Corporation (NTPC) is setting up 2×800 MW super thermal power project in an area of 3000 acres near Darlipalli village in Sundargarh district of Odisha State. Soil is excavated by mechanical means and the weathered and hard rock is being excavated by using high capacity rock breaker. Quantity of hard rock excavated during three months period was about 33,000 cbm only. Later, it was found that mechanical means of excavation is not feasible to remove the remaining hard rock hence drilling and blasting method was proposed to remove the hard rock. On the request of NTPC, Dr. H S Venkatesh, HOD, RB & EE Dept. from NIRM visited the excavation site on 15th May, 2015 along with the concerned Tehsildar and his colleagues, Group General Manager, Darlipalli STPP, NTPC and respective site engineers. After the reconnaissance study carried out, a detailed discussion was held with and it was concluded broadly that the site is technically amenable for controlled blasting for the excavation of the balance hard rock. It was also deliberated that at certain locations if site constraints are restrictive for controlled blasting then alternate means of excavation shall be adopted. On awarding the project, a method statement

was submitted during November, 2015 incorporating the tentative controlled blast designs, permissible level of ground vibration etc. Phase-I field investigations was carried out during first quarter of 2016 and eighteen blasts were designed and executed on trial basis in different DSTPP components. Ground vibration and air overpressure levels was monitored for all the blasts by deploying six seismographs and a site specific predictor equation was derived (Fig. 6.11). Flyrock was analysed for the blasts carried out. An interim report was submitted describing the controlled blast design with muffling to be adopted at the proposed DSTPP site and a safe permissible peak particle velocity limit of 5mm/s for surface residential structures is recommended.

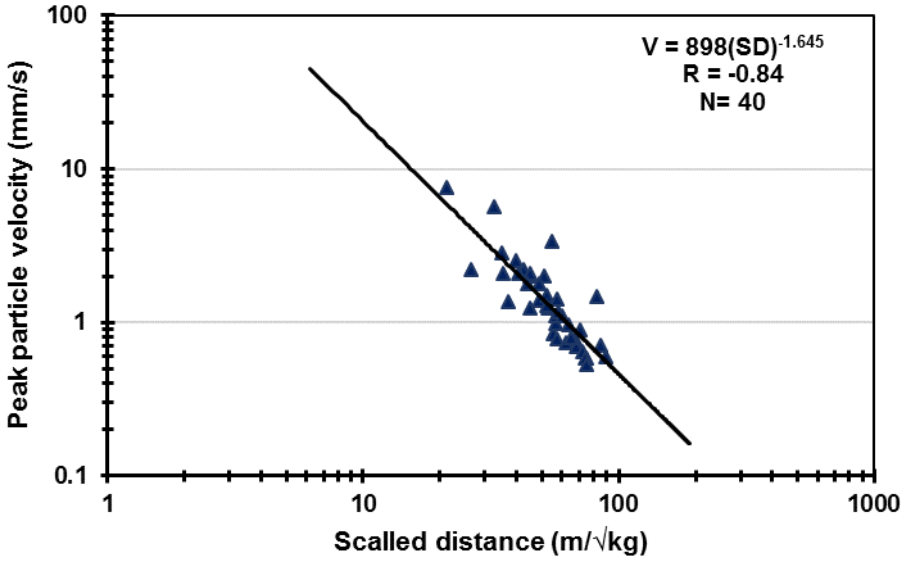

Fig. 6.11 Site specific predictor equation for Darlipalli STPP

- The Idamalayar dam being operated by Kerala State Electricity Board (KSEB) was constructed across the Idamalayar river. The reservoir storage is utilised for power generation and also for irrigation purpose. The spillway has been provided to pass flood discharge. Under Dam Rehabilitation & Improvement Project (DRIP), KSEB is planning to remove the boulders in the river channel beyond the spillway bucket to avoid development of non-uniform flow which may cause slippage of the river bank. As the boulders are to be excavated close to the dam toe (Fig. 6.12) without causing any damage to the dam and its appurtenances, KSEB approached NIRM to conduct a scientific study and to suggest suitable blasting method. To start with, NIRM furnished a brief note incorporating the quantity of blasting materials required for conducting trial blasts. Field study was carried out during March 2016 for the removal of 100 m3 of boulders which was arranged for the trial purpose. Five rounds of boulder blasts were conducted and blast vibration were monitored by deploying four seismographs covering all the dam structures. The analysis of data and preparation of report is under preparation.

Fig. 6.12 Quantity of boulders to be blasted close to dam structures

7. MICROSEISMICS AND ENGINEERING SEISMOLOGY

Microseismics and Engineering Seismology has developed expertise in real time strata monitoring of the underground excavations include hydroelectric project powerhouse caverns, oil storage caverns, transportation tunnels, mining tunnels, etc., using real time microseismics and online automation instrumentation systems for long term stability assessment.

- Thirty geophone stations/60 channels microseismic system have been installed at the powerhouse site of Tapovan Vishnugad Hydropower project of NTPC Ltd for monitoring the stability of the caverns in real time. The floods damaged system was reinstalled and updated by adding 18 new sensor stations and interfaced to central data acquisition/processing system to cover the entire powerhouse caverns During May 2015. Data acquisition and processing is in progress in near real time from both remote processing units situated at Joshimath and Bangalore (Fig. 7.1, 7.2, 7.3 & 7.4). Four NTPC Engineers were trained at NIRM, Bengaluru on microseismic system operation and data processing. Complete microseismic instrumentation installation report and first year cavern monitoring annual report were submitted along with the respective presentations at the site. During the second year monitoring period (started from 1st June 2015), the instrumentation setup was get disrupted during September 2015 due to civil construction work in the caverns. Again the entire system was reinstalled and put in operation for full-fledged monitoring in February 2016.

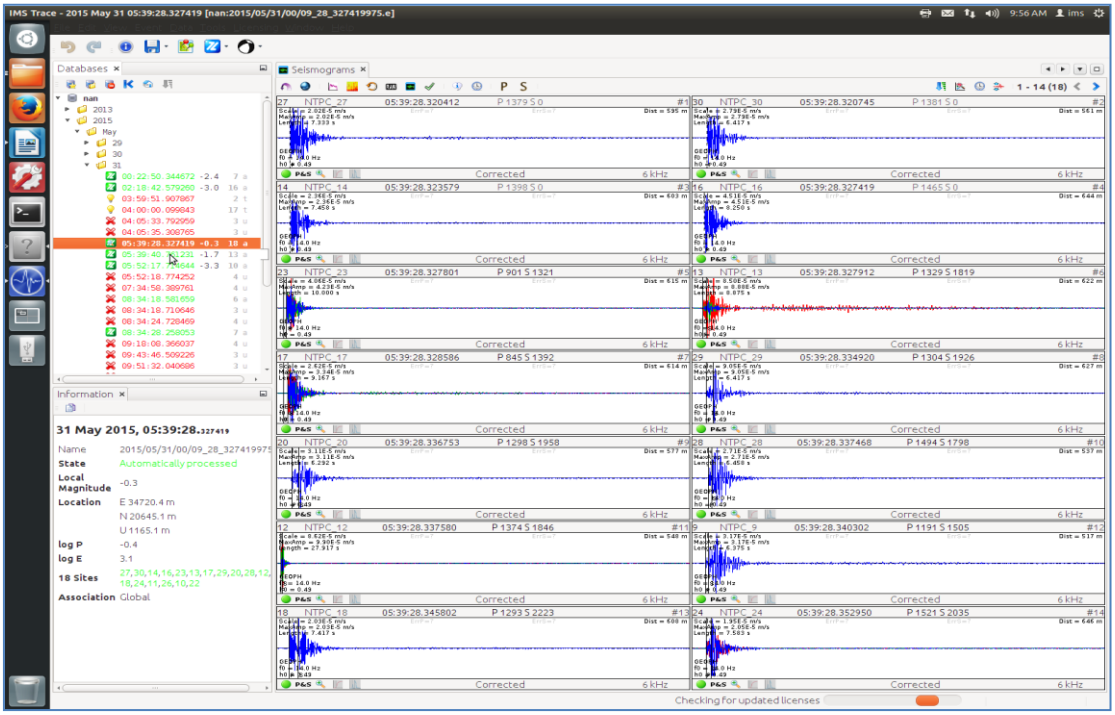

Fig. 7.1 Typical microseismic event recorded by 14 seismic stations at TVHPP powerhouse

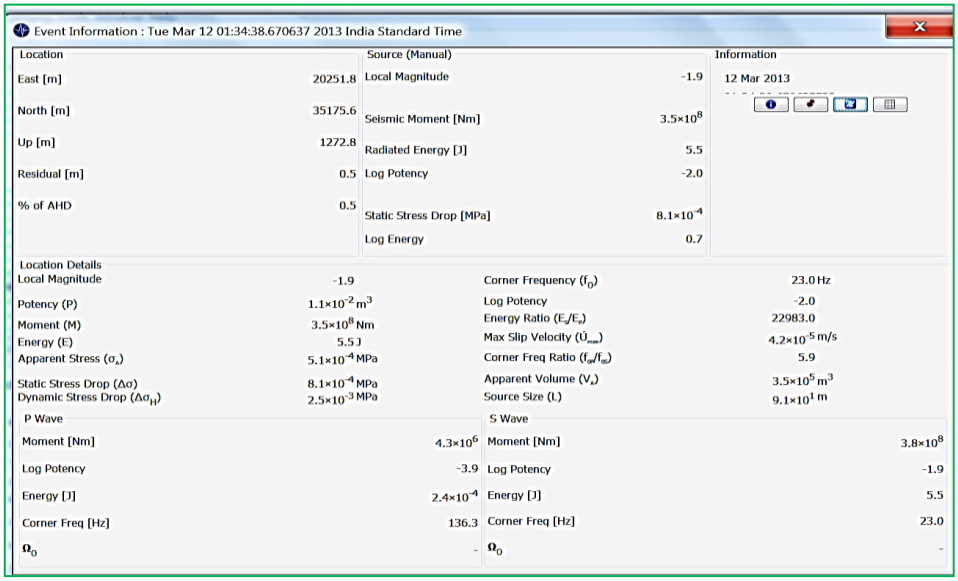

Fig. 7.2 Computed source parameters of a recorded microseismic event

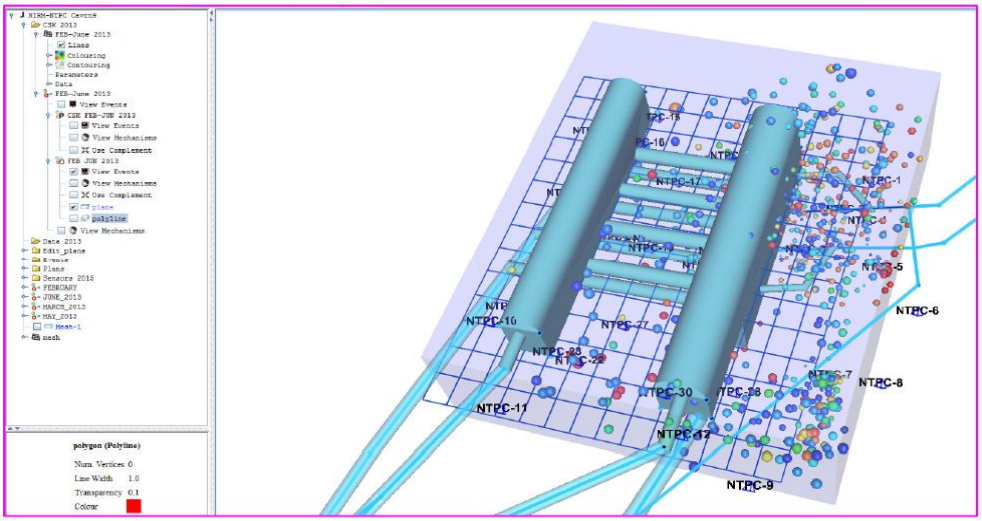

Fig. 7.3 Mapped microseismic events recorded during first year monitoring at TVHPP powerhouse caverns 3D Plan

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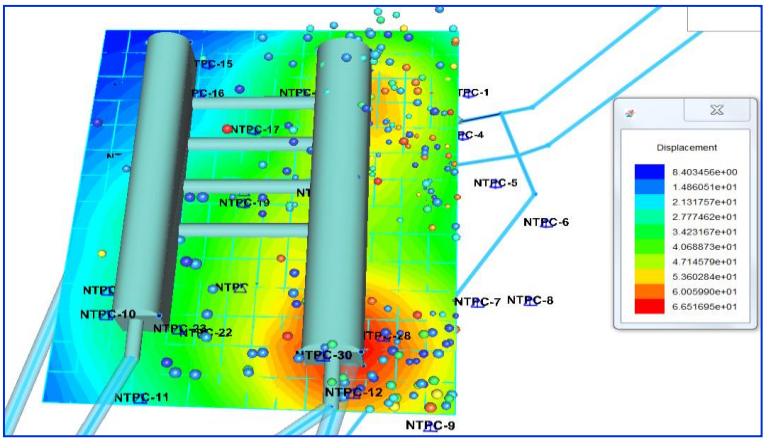

Fig. 7.4 Displacement contours computed from the data recorded during first year monitoring showing mapped and estimated displacement locations on 3D Cavern drawing

- Powerhouse stability monitoring using microseismic at THP, DGPC, Bhutan is being carried out. Sixty channel Microseismic monitoring system installed in 2013 has been functioning without any interruption and acquiring high quality strata induced seismicity data from last three years round the clock in real time and generating noise free high quality data uninterruptedly even for few hours. Data acquisition and detailed processing work is going on at THP, Rinchenste and at NIRM Bangalore unit. The data has been analyzed and interpreted for the change in strata stress conditions and to correlate with the rock bolt failures to study the mechanism. Half yearly and annual report of second year have been submitted and third year monitoring is going on. The rock bolt failure instances were correlated and back analysis of immediate previous two-week data was done to observe the microseismic activity and seismic source parameters variations and found that overall no noticeable cracking activity from the strata. During the monitoring period little microseismic activity was observed in March 2015 compare to other instances. The average events magnitudes are around -0.5 to -3.5. The processing and analysis of the recorded data provides information of stress accumulation and it's variations up to micro level. The displacement of the cavern strata from time to time and with overall activity (Jan-Dec 2015) shows very low level and at about less than 1.0 mm (Fig. 7.5). No fresh rock fracture activity from the inner zone of the strata and no block movement signals have been observed that indicates the stability of the cavern.

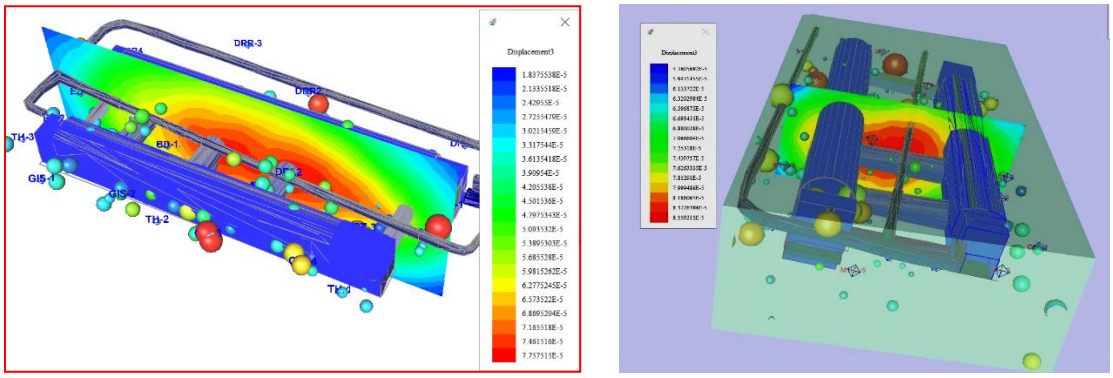

Fig. 7.5 Displacement contours for the data Jan-Dec 2015, Side View on 3D Plan

- A study on the estimation of seismic hazard in and around the BGML mines, Kolar Gold Fields is being carried out. Design of seismic monitoring instrumentation setup and sensors network layout were completed as shown in figs. 7.6 & 7.7 respectively. Specifications of the seismic monitoring equipment has been submitted for the procurement of the instrument for seismic hazard monitoring. Progress of the work has been reported in the MoM review meeting.

- The Broad Band Station, installed at the Central Seismic Station (KGF Observatory) by the Ministry of Earth Sciences, for monitoring the peninsular India is working satisfactorily. The data retrieved from the system for the period of Apr 2015-Mar 2016 has been sent to IMD, National Seismological Data Center, New Delhi and NGRI, Hyderabad. The problem in data transmission through VSAT has been reported to NGRI and it's restoration/maintenance work is under progress. The Strong Motion Accelerograph installed at NIRM is working satisfactory.

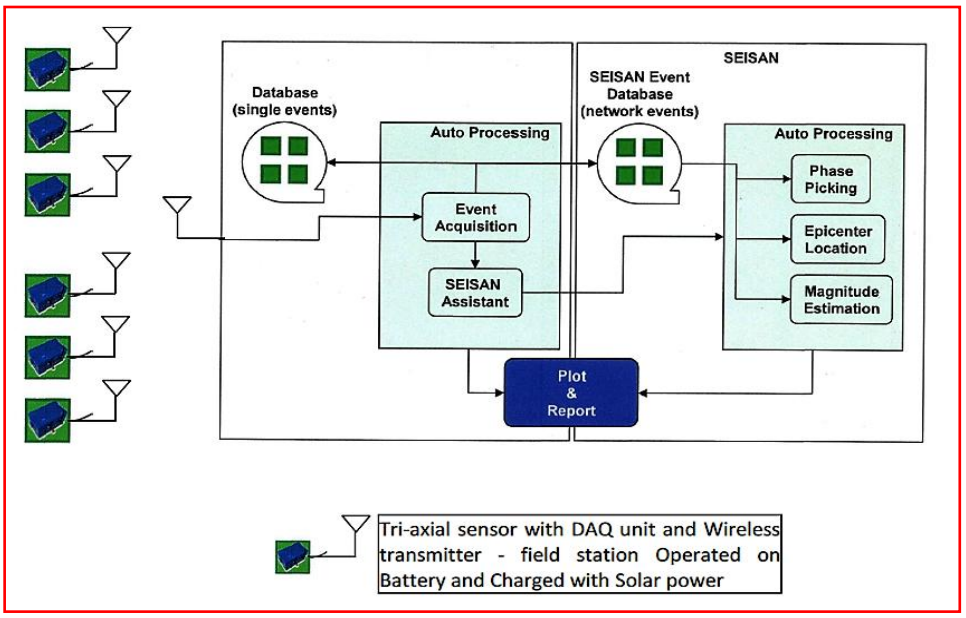

Fig. 7.6 Seismic monitoring Instrumentation system setup block diagram layout

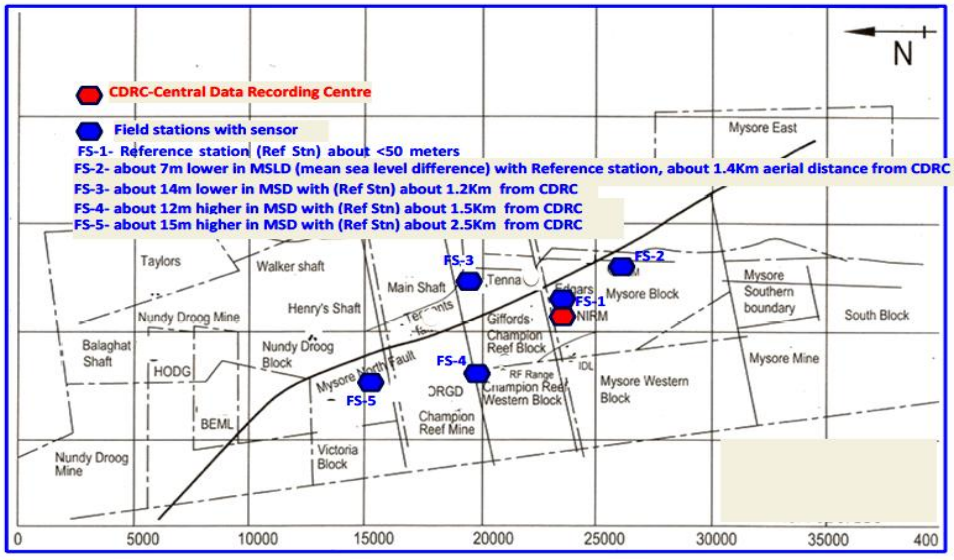

Fig. 7.7 Locations of the Field stations and sensors

- As part of the National Seismic Network, regular monitoring of seismic events are recorded at the KGF observatory is maintained and the data recorded is preserved for contribution towards National Seismic Database. Local and far distance seismic events are also recorded for processing and analysis.

- A science and technology project for estimation of seismic hazard to monitor seismic activities in and around the mined out areas of Kolar Gold Fields and identify potential zones of hazards due the mine induced seismicity is in progress. So far locations for installation of sensors on surface and monitoring station have been identified. Equipment procurement is in progress and as the job is on top priority the installation of seismic monitoring network will be completed by end of 2016.

8. TESTING SERVICES

The Material Testing Laboratory (MTL), an integral part of Centre for Testing Services (CTS) at NIRM is equipped with the testing facilities to conduct both Destructive and Non-Destructive Tests. The destructive tests include torsion test, reverse bend test, tensile test on individual wires and tensile test on complete rope sample. The non-destructive tests include visual inspection, liquid dye penetrant test, magnetic particle test, ultrasonic test and wire rope inspection using defectograph. The tests conducted are as per various standards and statutory regulations including DGMS guidelines. It is one of the unique laboratories in India manned by experienced scientific personnel. During the financial year 2015-16, the laboratory has provided services to over seventeen mining and allied industries.

Rock Fracture Mechanics (RFM) Laboratory is a unit of CTS, has the capabilities and expertise to determine the properties of intact and jointed rocks as per ISRM, ASTM and BIS standards. The RFM laboratory is equipped with the modern facilities to carryout geotechnical investigation on rock properties for modeling the underground excavations. This Laboratory has the reputation of catering to the needs on laboratory investigations on rocks from in and around the country.

A. Material Testing

- During 2015-16, destructive tests were carried out on 102 rope samples for various clients. Details of clientele and types of tests conducted during this period are as under:

Sl. No	Clients	Types of test conducted*
1	M/s Shaft Sinkers Mauritius Limited (SSML), Rajasthan.	MPT and UT
2	M/s National Aluminium Company Limited (NALCO), Damanjodi.	WRD
3	M/s Singareni Collieries Company Limited (SCCL), Kothagudem and Ramagundam.	MPT, UT and WRD
4	M/s Singareni Collieries Company Limited (SCCL), Coal Handling Plant, Ramakrishnapur.	MPT, UT, VM, UPV and IR
5	M/s Shaft Sinkers Mauritius Limited (SSML), Rajasthan.	MPT, UT and WRD
6	M/s Hindustan Zinc Limited (HZL), Zawar group of Mines, Rajasthan.	MPT, UT and WRD
7	M/s Hindustan Zinc Limited (HZL), Kayad Mines, Rajasthan.	MPT and UT
8	M/s Hindustan Zinc Limited (HZL), Rajpura Dariba Mines, Rajasthan.	MPT, UT and WRD

9	M/s Arulmigu Dhandayuthapani Swamy Thirukoil, Palani.	MPT, UT and WRD
10	M/s National Mineral Development Corporation (NMDC) Limited, Chhattisgarh.	PT, MPT, UT, VM, IR, ST, NA and WRD
11	M/s Hutti Gold Mines Limited (HGML), Raichur.	MPT and UT
12	M/s China Non-ferrous Metal Industry's Foreign Engineering and Construction Company Limited (NFC)	PLT, MPT and UT
13	M/s Hindustan Zinc Limited (HZL), Central Mochia Mines, Rajasthan.	MPT and UT
14	M/s Shaft Sinkers Mauritius Limited (SSML), Rajasthan.	MPT, UT and WRD
15	M/s Singareni Collieries Company Limited (SCCL), Kothagudem and Ramagundam.	MPT, UT and WRD
16	Karnataka Power Corporation Limited (KPCL), Shivasamudram.	MPT, UT and WRD
17	M/s Shaft Sinkers Mauritius Limited (SSML), Rajasthan.	MPT and UT
*PT - Penetrant Test, MPT - Magnetic Particle Testing, UT - Ultrasonic Testing, Noise Analysis, Stability Test, WRD - Wire Rope Defectography, PLT - Proof Load Test, IR - Infrared Thermography, VM - Vibration Measurement, UPV - Ultrasonic Pulse Velocity.		

- M/s Shaft Sinkers Mauritius (SSM) has undertaken shaft sinking operations at Rampura Agucha Mines of M/s Hindustan Zinc Limited. As a statutory requirement the equipment/components/ropes used for sinking operations has to be periodically evaluated for their fitness. As NIRM has the expertise and capability, a MoU for a period of three years was signed between M/s SSM and NIRM for providing test services. NDT such as magnetic particle tests and ultrasonic tests were conducted on winder vital components and suspension gear parts (Fig. 8.1) to identify surface, sub-surface and internal flaws on: a) 630kW double drum rock winder at South Ventilation Shaft, b) 630kW double drum man winding winder at South Ventilation Shaft, c) 190kW stage winder at Main Shaft and d) 5200HP kibble winder at Main Shaft.

Fig. 8.1 NDT on winder vital components & suspension gear parts, M/s SSM

Wire rope defectograghy was carried out to determine the local faults (LF) such as pitting, corrosion, broken wires and loss of metallic cross-sectional area (LMA) on a)

ϕ48mm multi-strand kibble ropes – 02Nos (Underlay & Overlay) at Main Shaft, b) ϕ44mm multi-strand stage winder ropes – 06Nos at Main Shaft, c) ϕ32mm multi-strand rock winder ropes – 02Nos at South Ventilation Shaft, c) ϕ18mm multi-strand man winder rope – 01No at South Ventilation Shaft. The kibble ropes, rock winder ropes and man winder rope were made to run through the magnetic head of the wire rope defectograph that is placed in a stationary position. The rope is passed through the magnetic head at a constant speed while the actual condition of the rope gets coded on the strip chart recorder (Fig. 8.2).

Fig. 8.2 Testing of kibble ropes, rock winder ropes & man winder rope, M/s SSM

For testing the stage ropes, special steel frames were fabricated at site to carry out defectograph studies. The arrangement facilitated the movement of magnetic head throughout the length of stage rope which was stationary (Fig. 8.3).

Fig. 8.3 Testing of stage winder ropes, M/s SSM

All the tests were completed successfully and the results have been evaluated. Based on results obtained on winder vital components and suspension gear parts it was concluded that they were free from surface, sub-surface and internal flaws. Analysis of the tests conducted on wire ropes of stage winder rope (ϕ44 mm) at Main Shaft, indicate that they have corroded both internally and externally. It was observed that there was an increase in the diameter of the rope (bulging) which can be inferred as the resultant due of continuous soaking of the rope in seepage water The rate of corrosion cannot be quantified due to factors such as chemical composition of the

water, salinity, hardness, dissolved solids and minerals. The chemical analysis of the water sample indicates that the contents seem to exceed the recommended limits of hazardous metals, such as Calcium, Magnesium, Sulphur and Sodium. The test results of the other ropes (ϕ48 mm, ϕ32 mm & ϕ18 mm) indicate that the ropes were free from Local Faults (LF) such as pitting, corrosion and broken wires and also there was no Loss of Metallic cross-sectional Area (LMA).

- M/s National Aluminum Company Limited (NALCO) produces Aluminum. NALCO's bauxite mine is located at Panchpatmali hills in Koraput District of Odisha State. The mined bauxite is transported to refinery plant by a multi-curve cable belt conveyor. The contour path of the belt conveyor is directed by metallic deflection pulleys through two wire ropes (Left hand side and Right hand side). These ropes have to be periodically checked for their fitness. M/s NALCO requested NIRM to evaluate the operational cable belt drive ropes i.e. WRD test. The inspection of the cable belt drive ropes are shown in figure 8.4.

Fig. 8.4 Inspection of cable belt drives, M/s NALCO

The length of each rope (left side and right side) is 30 km, which is made up of five ropes measuring 6 km each and joined (spliced). Wire rope defectograph studies were carried out on the cable belt drive ropes and the scanned strip charts were analyzed. Based on the tests results, it was concluded that: a) the left side rope which has been replaced recently has less number of fatigue cracks than the right side rope, b) the left side rope was found to have slight wear throughout the length of rope and deep wear at a few places, c) the right side rope was found to be deteriorated and characterized with remarkable defects such as excessive deep wear. While there were no broken wires, a large number of isolated fatigue cracks were found at various intervals, d) the percentage reduction in diameter of left side and right side ropes were found to be 1.69% and 6.71% respectively. The reduction in diameter of both the ropes is well below 10% and therefore the ropes can be continued to be put to use as per discard criteria. However, the right side rope is found to be deteriorating fast, e) in general, the

right side rope has undergone excessive deep wear clubbed with isolated fatigue cracks throughout its length. Continuous and careful monitoring of this rope is recommended, f) the splice length in both ropes seems to show signs of elongation. It is recommended to subject the ropes to periodic tensile tests to know the minimum breaking force and g) it was recommended to introduce non-metallic liners on the deflection pulley grooves to reduce the excessive wear.

- The project sites of M/s Singareni Collieries Company Limited (SCCL) are located at different parts of Telangana state. The operations at all the mines are carried out through shafts run by winders. The safety of operations including men and machinery is of prime importance and the Director General of Mines Safety (DGMS) has set out the guidelines for periodic evaluation of winders and all the other vital components for their fitness. In view of this, M/s SCCL vide their service order requested NIRM to carry out non-destructive testing on mine machineries. Using MPT and UT, NDT was carried out on the winder vital components and suspension gear parts (Fig 8.5) of the four winders a) 350 HP Cage winder at GDK-10 incline, Ramagundem area, b) 285 kW Cage winder at PVK-5B, Kothagudem area, c) 285kW Cage winder at VK-7 incline, Kothagudem area, d) 400 HP Cage winder at 21 incline, Yellandu area.

Fig. 8.5 NDT on winder vital components & suspension gear parts, M/s SCCL

The wire ropes used for operating the cages were also inspected (Fig. 8.6) using wire rope defectograph equipment which include a) 32 mm FLC ropes – 02 Nos at GDK-10 incline, b) 32 mm FLC ropes – 02 Nos at PVK-5B, iii) 32 mm FLC ropes – 02 Nos at VK-7 and iv) 32 mm FLC ropes – 02 Nos at 21 incline.

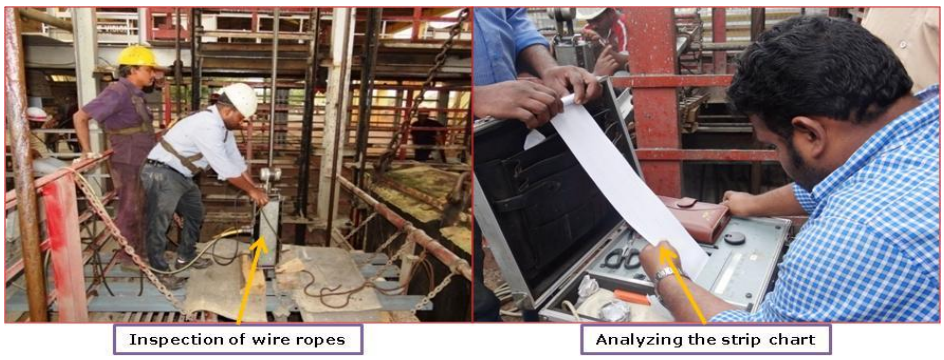

Fig. 8.6 Inspection of wire ropes, M/s SCCL

All the tests were completed successfully. Based on the tests conducted on winder vital parts and suspension gear parts it was concluded that all the tested components were free from surface, sub-surface and internal defects. The results of the tests conducted on wire ropes did not show notable defects. All the wire ropes were found to be free from local faults (LF) such as pitting, corrosion and broken wires and also had no loss of metallic cross-sectional area (LMA). Therefore, it was concluded that the tested components can be put use. It was also recommended to conduct periodic tests to ensure safety.

- Coal Handling Plant (CHP) is the place where the coal is washed and handled from its receipt point and transferred to bunkers. To access the fitness of the CHP, M/s SCCL requested NIRM to take up the NDT works on the steel structures of the CHP. NIRM conducted the required tests using NDT techniques on the steel structures of the CHP (Fig. 8.7).

Fig. 8.7 NDT on steel structures of Ramkrishnapur Coal Handling Plant (CHP), Mandamarri Area. M/s SCCL

The study was conducted using various NDT techniques such as visual inspection, magnetic particle test, ultrasonic test, ultrasonic pulse velocity, infrared thermography, vibration analysis, rebound hammer and thickness measurement gauge. The results of visual inspection on the identified gantry steel structures indicate significant deterioration of the steel structures due to surface corrosion. It was recommended to apply non-corrosive painting periodically. Magnetic particle test on the welded joints of strengthening plate of the bins reveals that they were free from surface and sub-surface defects. Ultrasonic test on all the foundation bolts of gantry steel structures and discharge gate operating shaft pins indicated that the scanned pins were free from internal flaws and their integrity seems good. As a qualitative assessment test, ultrasonic pulse velocity test was conducted on different locations of the concrete foundations of gantry steel structures. The measured values of pulse velocity on

concrete foundations of the identified structures were in the range of 3.5 to 4.5 km/s. Hence the concrete is classified under 'Good' grade concrete as per velocity criterion prescribed in IS 13311 (Part I): 1992 for concrete quality grading. Infrared thermography study on the stressed zones of gantry steel structures and concrete foundations of gantry steel structures show that there was no thermal anomaly. This indicates that no significant stress zones were present on the steel structures and the concrete foundations were free from voids, cracks, moisture and de-lamination. Vibration levels at different locations of engine online pre-weigh wagon loading system and on the platform of belt conveyor drive system was measured. As the power of the belt conveyor drive system is 125 kW, it falls on the Class V Machines. The observed velocity did not exceed 28 mm/s (as per the Vibration standards) the severity of the vibration is 'Moderate'. By improving the regular maintenance schedule, the vibration level can be brought down to the 'Normal' level. The measured Rebound values on the concrete foundations of the steel structures were found to be in the range of 38 to 44. As per IS 13311, part-2:1992, BS: 6089-81 & BS: 1881: Part-202 from table 4, the quality of the concrete lies between 'Good and Very Good grades'. The thickness measured at different locations of the bins of Pre-weigh wagon loading system varies from 9.11mm to 11.28 mm – which reveals that there is a meagre loss of wall thickness of the bins, as the original thickness is 12 mm. The integrity and stability of all audited steel structures & bins at engine online pre-weigh wagon loading system is sound and safe. It was recommended that conventional painting of gantry steel structures has to be upgraded on Shot blasting as per BS 4232. Primer shall be zinc silicate as per BS 5493 and paint shall be epoxy coating as per BS 5493. Periodic overall house-keeping is mandatory to avoid premature failures of the critical components.

- Zawar group of mines is a unit of Hindustan Zinc Limited located at Udaipur District, Rajasthan. The operation at these mines is carried out by shafts run by winders. As a statutory requirement, the winders and all their associated vital components must be periodically evaluated for their fitness. Based on the service order, the required tests were conducted on vital components of the winders and suspension gear parts (Fig. 8.8) of the - a) 383 HP cage winder at Balaria mine, b) 560 HP skip winder and 70 HP cage winder at Zawar Mala mine, c) 236 HP cage winder at West Mochia mine and d) 400 HP skip winder and 200HP cage winder at Central Mochia mine

Fig. 8.8 NDT on winder vital components & suspension gear parts, Zawar Group of Mines, M/s HZL

In addition, wire rope inspection was carried out on 17 Nos of wire ropes (Fig. 8.9). The details of the tested wire ropes are: a) 32 mm FLC cage ropes – 02 Nos at Balaria mine, b) 16 mm FLC cage ropes – 02 Nos at Zawar Mala mine, c) 30 mm FLC skip ropes – 02 Nos at Zawar Mala mine, d) 20 mm FLC cage ropes – 30 Nos at West Mochia mine, e) 24 mm FLC skip ropes – 04 Nos at Central Mochia mine, f) 16 mm FLC cage ropes – 04 Nos at Central Mochia mine. Based on the test results of winder vital parts and suspension gear parts, the observations were made are: a) Two cracks were noticed on South-Western side chain links (10^{th} link from the bottom) at cage side suspension gear attachments of Balaria mine, b) Two cracks were noticed on North-Eastern side chain links (one on 5^{th} link and one on 6^{th} link from the bottom) at cage side suspension gear attachments of Balaria mine. The results of other tested components indicated that they were free from surface, sub-surface and internal flaws. The results of the wire rope inspection indicated that the tested ropes were free from local faults such as pitting, corrosion and broken wires and also there was no loss of metallic cross-sectional area. It was recommended to periodic tests on the components.

Fig. 8.9 Inspection of wire ropes, Zawar group of mines, M/s HZL

- Kayad mine of M/s Hindustan Zinc Limited is situated at Ajmer District in Rajasthan. To ensure the safety operations of their mine machineries, M/s HZL requested NIRM to take up the NDT works on their components through a service order. Accordingly the required NDT were conducted on 60 HP winder vital components, suspension gear parts, EOT cranes (02 Nos) and air receivers (Fig. 8.10). Based on the test results of NDT, it was concluded that all the tested components were free from surface, sub-surface and internal flaws. It was recommended to conduct periodic tests on the components to ensure safety.

- Rajpura Dariba mine operating at Rajsamand District in Rajasthan is a part of M/s Hindustan Zinc Limited. As a statutory requirement the mine machineries have to be periodically evaluated for their fitness. Through a service order M/s HZL invited NIRM to conduct the required tests on their components. NDT was carried out using MPT and UT on winder vital components and suspension gear parts (Fig. 8.11) of the following winders: a) 236 kW cage winder at Main shaft, b) 740 kW skip winder at Main shaft and c) 225 kW cage winder at Auxiliary shaft

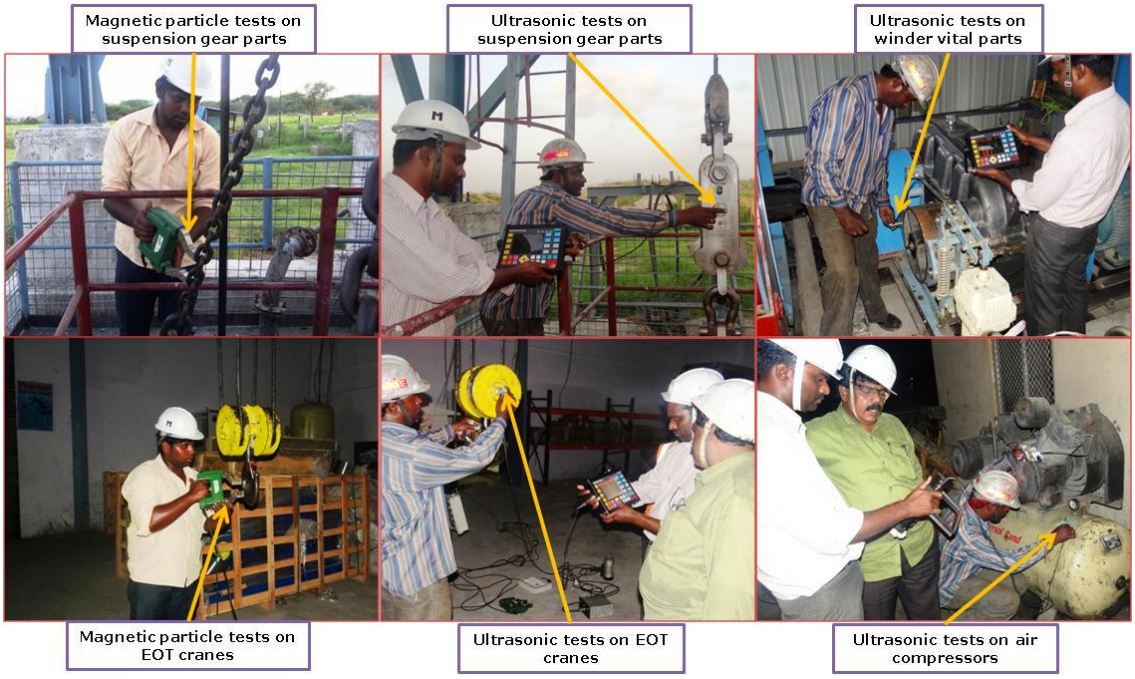

Fig. 8.10 NDT on winder vital components, suspension gear parts, EOT cranes, and air compressors at Kayad mines, M/s HZL

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Fig. 8.11 NDT on winder vital components & suspension gear parts, Rajpura Dariba Mines, M/s HZL

The wire ropes functioning at project site were also inspected using wire rope defectograph (Fig. 8.12). The inspected wire ropes include a) 18 mm FLC cage ropes – 05 Nos at Main shaft, b) 24 mm FLC skip ropes – 04 Nos at Main shaft and c) 32 mm FLC cage ropes – 02 Nos at Auxiliary shaft. The NDT results on winder vital components and suspension gear parts did not indicate any anomaly. However, the test results on wire ropes indicated that wear and mechanical abrasion on cage side rope of auxiliary shaft. This wear is due the sheave pulley shaft bush, which has been recommended to be replaced. The test results of other ropes did not indicate any defects.

- M/s Arulmigu Dhandayuthapani Swamy Thirukoil, Palani Temple is situated at 56 km from Dindigul, Tamilnadu. To visit the temple which is situated 290 m from base station, the devotees are taken from the base station to the hill by winch and rope car system. There are three winches (Winch 1, 2 & 3) of capacity 36 seats each. As per

statutory guidelines, the winches and rope car system and all their associated vital components should be periodically evaluated for their fitness. As NIRM has the capability and expertise to carry out the Non-Destructive Evaluation (NDE) of winches, rope car system and ropes, M/s. Arulmigu Dhandayuthapani Swamy Thirukoil vide their service order requested NIRM to conduct Non-Destructive Testing (NDT) of winches and associated components at Palani Temple. The vital parts of the winches (1, 2 & 3) and riding car attachments were subjected to NDT (Fig. 8.13).

Fig. 8.12 Inspection of wire ropes, Rajpura Dariba mines, M/s HZL

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Fig. 8.13 NDT on winch vital parts and man riding car attachments, M/s ADST

In addition, wire ropes (04 Nos) were also inspected using wire rope defectograph (Fig. 8.14). Based on the test results of winch critical parts and man riding car attachments, it is concluded that all the tested components were free from surface, sub-surface and internal flaws. The results on wire rope inspection indicated isolated fatigue cracks on winch-I and winch-II ropes. The test results of winch-III rope did not indicate any anomaly. It was strongly recommended to replace winch-I and winch-II ropes at the earliest. It is also recommended to conduct periodic tests to ensure safety.

- M/s Hutti Gold Mines Limited (HGML) is the only mine now in India which produces gold. The project sites are situated at Raichur District and it is undertaken by the Government of Karnataka. The operations at all the mines are carried out through shafts operated with winders. As per DGMS guidelines, the winders and all their associated vital components should be periodically evaluated for their fitness. As NIRM has the capability and expertise to carry out the Non-Destructive Evaluation

(NDE) of winders, M/s HGML vide their service order requested NDT of winders and associated components. The required tests were conducted on winder vital components and suspension gear parts (Fig. 8.15) of the following winders: a) 1200 HP cage winder at Mallappa shaft, b) 1130 kW skip winder at Mallappa shaft, c) spare winder parts at Mallappa shaft, d) 40 HP single drum winder at 2600 level at Mallapa shaft, e) 550 HP double drum winder at Central shaft, f) 32 HP single drum winder at 2400 level at Central shaft, g) 120 HP double drum winder at Village shaft, h) 40 HP single drum winder at Gray shaft, i) 40HP single drum winder at Uti mine and j) 120 HP double drum winder at Heerabuddinni mine. Based on the test results of NDT, it was observed that all the tested components were free from surface, sub-surface and internal flaws.

Fig. 8.14 Inspection of winch ropes, M/s ADST

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Fig. 8.15 NDT on winder vital components, suspension gear parts, M/s HGML

- M/s China Coal No.5 Construction Private Limited (CC5C) has undertaken and completed shaft sinking operations for M/s Hindustan Zinc Limited (HZL) at Dariba, Rajasthan. Subsequent to shaft sinking operations M/s China Nonferrous Metal Industry's Foreign Engineering & Construction Company Limited (NFC) has taken up the erection of winding engine, suspension gear assembly and head gear structure operations. Prior to installation, as per the DGMS guidelines the new components have to be subjected to proof load tests, non-destructive tests and break load tests. As NIRM has the expertise and capability to carry out the tests, the original equipment manufacturer, M/s Xuzhou Coal Mine Safety Equipment Manufacture Co. Ltd., China, requested NIRM to take up the required tests at the NIRM laboratory. As required, proof load tests, non-destructive tests and break load tests were carried out NIRM

laboratory on the following suspension devices: a) auto equilibrator for cage, b) auto equilibrator for skip, c) wedge cappel for cage, d) wedge cappel for skip, e) round tail rope for cage and f) round tail rope for skip. The proof load tests and break load tests were conducted using horizontal Universal Testing Machine (UTM). After the tests, the components were subjected to non-destructive tests such as magnetic particle tests and ultrasonic tests (Fig. 8.16). The test results are summarized below:

- **Proof load test:** The applied proof load is 3 times the safe working load of the components tested. It was observed that the components did not undergo any deformation.

  Proof Load (PL) = 3 x Safe Working Load (SWL)

- **Magnetic particle tests:** The tests results revealed that the components were free from surface and sub-surface flaws.
- **Ultrasonic tests:** The scanned results indicated that the tested components were free from internal flaws.
- **Break load test:** The components were permanently deformed on application of breaking load.

  Breaking Load (BL) = 10 x Safe Working Load (SWL)

Based on the above test results it was concluded that the suspension device may be put to use at the proposed installation at S K Mines shaft of M/s HZL.

Fig. 8.16 Proof load test, NDT & break load tests on the suspension devices, M/s NFC

- M/s Karnataka Power Corporation Limited (KPCL), a company owned by the Government of Karnataka, is engaged in generation of hydroelectric power. The hydroelectric power station at Shivasamudram is located on the banks of River Kaveri. For the transportation of men from the bank to the turbine house, trolleys are used which are driven by winders. To ensure its safe operations, the vital parts of the winder, trolley attachments and wire ropes have to be periodically inspected. In view of this, M/s KPCL requested NIRM to conduct non-destructive tests at Shiva and

Shimsha power houses. The winder vital parts and trolley attachments of the following winders were subjected to NDT (Fig. 8.17) a) 22 kW Cage winder at Shiva power house, b) 30 HP Cage winder at Shimsha power house.

Fig. 8.17 NDT on winder vital components & trolley attachments, M/s KPCL

In addition non destructive tests were also conducted on ϕ19 mm multi-strand ropes (Fig. 8.18) at Shiva power house-02 Nos (left & right side rope) and Shimsha power house-02Nos (left & right side rope). The tests were completed successfully. Based on the tests conducted on the winder vital parts and trolley attachments, it was noticed that the wheel axial shaft (Right side trolley- Rear wheel) had welded joint. This was confirmed by the absence of end echo on ultrasonic test indicating a discontinuity in the axial shaft. It was recommended to change the axial shaft as soon as possible. The other tested components were found to be free from internal flaws. The main observations made on the wire ropes are: a) Shiva power house – Left side rope: The results indicated wear at several places of the rope. This might be due to improper booking of the rope on the drum, misalignment of drum and pinion shaft etc, b) Shiva power house – Right side rope: two isolated fatigue cracks were noticed (one lies between 129 m to 132 m and the other between 188 m to 197 m from the cappel end), c) Shimsha power house – Left side rope: The scanned length or working length of the rope revealed that there was no anomaly and it was also free from local faults (LF) such as pitting, corrosion and broken wires and there was no loss of metallic cross-sectional area (LMA) and d) Shimsha power house – Right side rope: The test results indicated continuous wear on the rope. This was due to abrasion of the rope on metallic roller bearings. It was recommended to conduct periodic tests on the components to ensure safety.

- NIRM ventured into a new field of Heavy Earth Moving Machineries (HEMM) at M/s National Mineral Development Corporation (NMDC) Limited. M/s NMDC is a state-controlled mineral producer of the Government of India. It is owned by the Government of India and is under administrative control of the Ministry of Steel. It is involved in the exploration of iron ore, copper, rock phosphate, limestone, dolomite, gypsum, bentonite, magnesite, diamond, tin, tungsten, graphite etc. The operations at Bacheli complex, Chhattisgarh are facilitated by Heavy Earth Moving Machineries (HEMM). As per the DGMS guidelines, HEMM equipment has to be periodically inspected for their

fitness. In view of this M/s NMDC Limited requested M/s National Institute of Rock Mechanics (NIRM) to conduct Non-destructive test and stability test on HEMM operating at Bacheli complex.

Fig. 8.18 Inspection of wire ropes, M/s KPCL

Stability tests, proof load tests and NDT are being conducted on the following HEMM's. Various NDT techniques applied on HEMM's are shown in figure 8.19.

Sl. No.	List of Equipment	Quantity
1	Electric Rope Shovel – BEML Bucyrus	04
2	Electric Rope Shovel – Taiyuan	01
3	Hydraulic Shovel – Tata Hitachi	03
4	Front end loader – CAT	02
5	Dumper – BH-85, BEML	17
6	Dumper – BH-100S, BEML	01
7	Dumper – 777D, CAT	02
8	Drill – DMH, Atlas Copco	03
9	Drill – IDM 70E, Atlas Copco	05
10	Dozer – D355, BEML	10
11	Dozer – D11T , CAT	02
12	Dozer – WD600, L&T	01
13	Motor grader – BG825, BEML	04
14	Water sprinkler – WS28-1, BEML	06
15	EOT cranes	07
16	Mobile Crane	05
17	Mono Rail	01

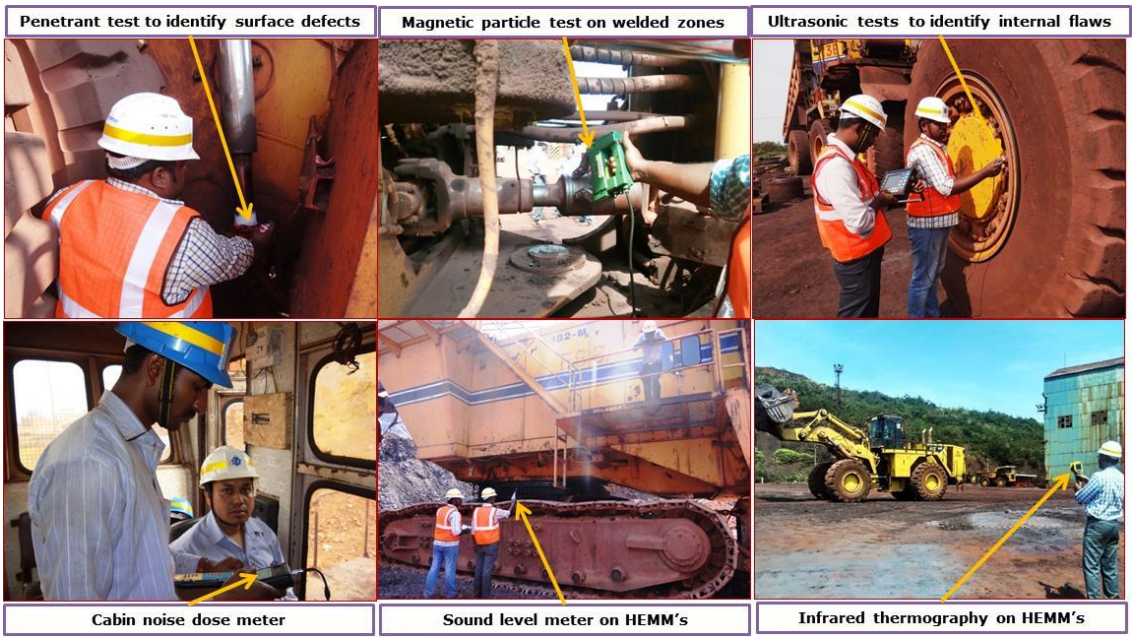

Fig. 8.19 Various NDT techniques on HEMM's

B. Rock Sample Testing

- The Oil and Natural Gas Commission (ONGC) is in the process of drilling deep boreholes for exploration purpose. The Centre of Delivery – Basement Exploration, ONGC, Mumbai, requested National Institute of Rock Mechanics (NIRM) to carry out laboratory geotechnical investigations on core samples from wellbores namely BH-22, IG-4, BH-52, SH-5 and SY-5, from RGL, ONGC, Panvel. The scope of work includes determination of Density, P-wave velocity, Tensile strength, Uniaxial compressive strength, Young's modulus and Poisson's ratio, Cohesion and Friction angle from triaxial compression test (Multiple failure method). The samples were prepared and tested for various physico mechanical properties. All the tests were carried out as per ISRM Standard on the prepared core specimens (Fig. 8.20) and the final report was submitted to the client.

Fig. 8.20 Ultrasonic pulsar, probe and oscilloscope

- SECON Private Limited (SECON) based in Bangalore offers Civil Engineering Consultancy Services in the areas of Surveying, Geotechnical investigations, Planning and Design of Civil Engineering structures. Presently they are carrying out Geotechnical investigations for Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam, Tamil Nadu. As part of their study and services, SECON requested National Institute of Rock Mechanics (NIRM) to carry out laboratory geotechnical investigations on core samples from Location-I of IGCAR. The scope of work includes determination of the following mechanical properties of the rock for both dry and saturated conditions a) Uniaxial Compressive Strength (UCS) on dry and saturated samples, b) Young's modulus and Poisson's ratio on dry samples, c) Cohesion and Friction angle from triaxial compression test (Multiple failure method) on both dry and saturated samples (Fig. 8.21 & 8.22) and d) Laboratory geotechnical investigations were carried out on Charnokite samples from Location - I of Indira Gandhi Centre for Atomic Research at Kalpakkam, Tamil Nadu. The mechanical properties were determined in the laboratory as per International Society for Rock Mechanics (ISRM) suggested methods. It was observed that there is a marked variation of strength values for dry and saturated samples. However, no significant variation in the average friction angle value for dry and saturated samples was noticed.

Fig. 8.21 Compression testing set up and Data Acquisition System

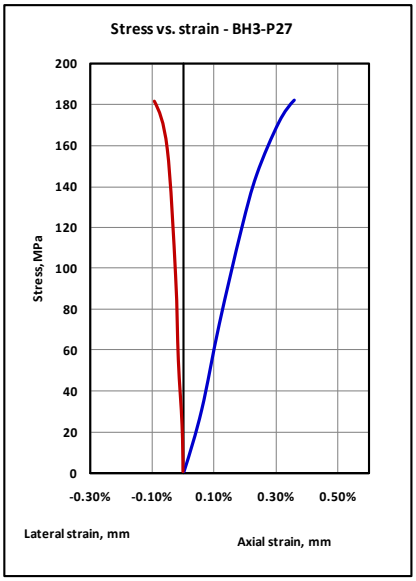

Fig. 8.22 Stress Strain curve of uniaxial compression test

- The Oil and Natural Gas Commission (ONGC) is in the process of drilling deep boreholes for exploration purpose. The Institute of Drilling Technology (IDT), Dehradun, ONGC requested National Institute of Rock Mechanics (NIRM) to carry out laboratory geotechnical investigations on core samples from wellbores of Jwalamukhi area of Frontier Basin JMI-1 and JMI-2; Banskandi field of Cachar Forward Base, Silchar, Assam & Assam Arakan (A&AA) Basin (Assam) BK-1 AND BK-12 and from Panidihing and Lakwa field of Assam Asset, Sivasagar PD-1, PD-2, L-578, Deharadun. The test results will form input parameters for geomechanical modelling of wellbore stability by IDT. The scope of work includes determination of Density, P-wave velocity, Tensile strength, Uniaxial compressive strength, Young's modulus and Poisson's ratio,

Cohesion and Friction angle from triaxial compression test (Multiple failure method). Laboratory geotechnical investigations on Shale core samples from two wellbores (JMI 7 and JMI 2) from Jwalamukhi area of Frontier Basin, Deharadun, were carried out. Both physical and mechanical properties were determined in the laboratory as per International Society for Rock Mechanics (ISRM) suggested methods. Core samples of about 100 mm diameter were received at NIRM. Re-coring was done to obtain test specimens of 54 mm/42 mm diameter for the determination of physico-mechanical properties (Fig. 8.23 & 8.24).

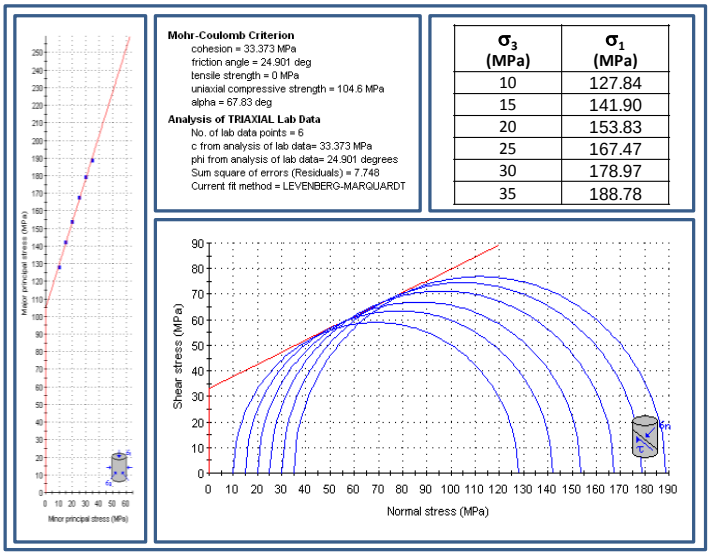

Fig. 8.23 Mohr Coulomb plot for sample from Jwalamukhi area

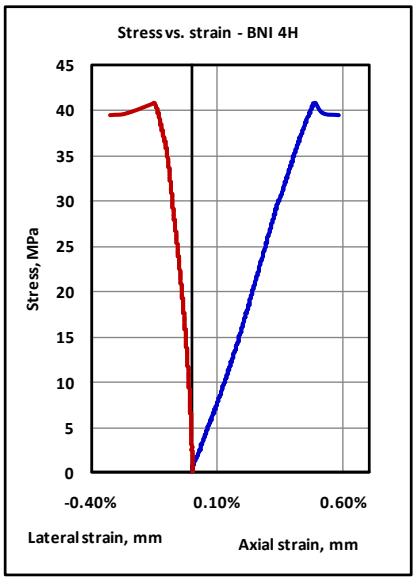

Fig. 8.24 Stress Strain curve of uniaxial compression test, Banskandi area

- The Oil and Natural Gas Commission (ONGC) is presently carrying out 1D geo mechanical modelling in the Nohta-Damoh-Jabera PML, Son valley, Vindhyan Basin for understanding the stress regime and safe mud window which will facilitate the drilling of high angle slanted wells. The Office of Block Manager, Vindhyan Block, ONGC, Frontier Basin, Dehradun, requested National Institute of Rock Mechanics (NIRM) to carry out laboratory geotechnical investigations on core samples of Rohtas Limestone, Son Valley, Vindhyan Basin. The scope of work includes determination of the following physical and mechanical properties a) Density, b) P-wave velocity, c) S-wave velocity, d) Uniaxial compressive strength (UCS), e) Young's modulus and Poisson's ratio, f) Cohesion and Friction angle from triaxial compression test (Multiple failure method). Laboratory geotechnical investigations were carried out on Rock samples from Rohtas Limestone, Son Valley, Vindhyan Basin. The Physico mechanical properties were determined in the laboratory as per International Society for Rock Mechanics (ISRM) suggested methods (Fig. 8.25).

- The Uranium Corporation of India Limited (UCIL) is operating an underground mine near Tummalapalle in YSR district, Andhra Pradesh, to mine the ore of uranite mineral / pitchblende. They desired NIRM to carry out the rock mechanics investigations for the optimisation of Ramanant, crown and Sill pillar sizes for the maximum safety and

extraction ratio. As part of this study, rock properties of various rock types were determined at RFM lab which will be used for modeling and empirical design.

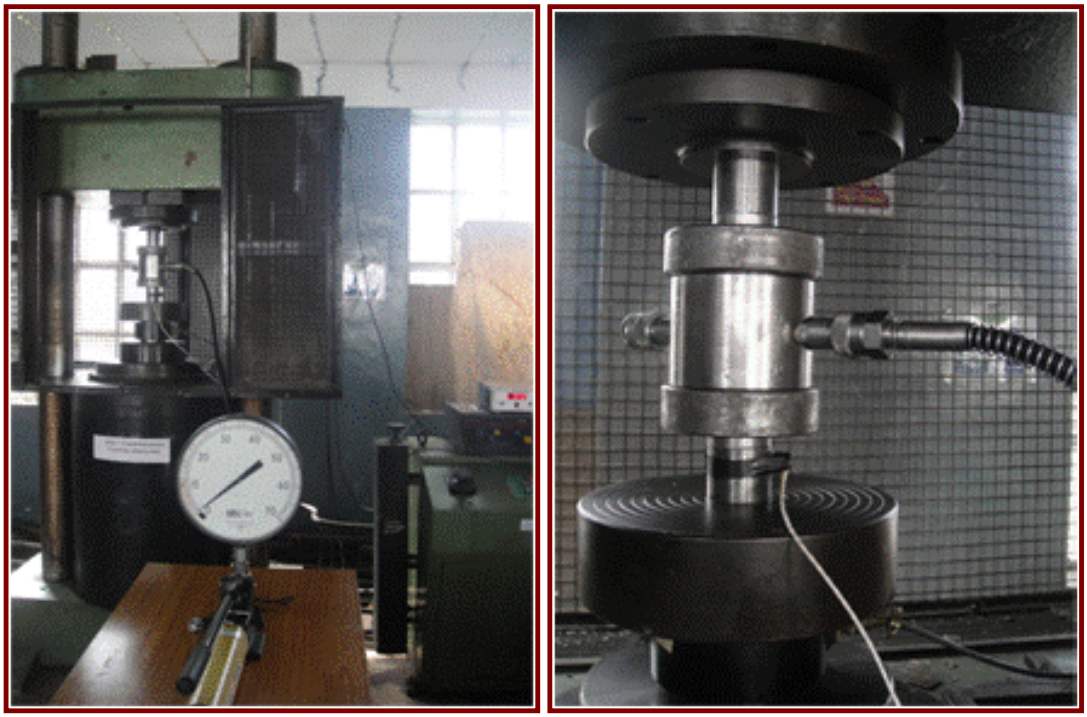

Fig. 8.25 Compression testing machine with Hoek triaxial cell

- MOIL Ltd (formerly Manganese ore India limited) operates 10 mines. Out of this 7 mines are underground. Munsar mine is one of the underground mines. As part of the design of stoping parameters for Munsar mine, rock properties were determined for various rock types collected from the mine. The results will be utilized in the modeling and empirical designs for the project.

- Rock samples were received from various clients viz. Granite Industry, Educational Institutions and other mining companies for laboratory Geotechnical Investigations. The details of the work carried out are given below:

Sl. No	Job & Client
1	Laboratory Testing of Rock samples from Bijapur Main Canal from Km. 10.00 to 20.00 and structures under MLI stage-III, KBJNL, Govt. of Karnataka.
2	Laboratory Testing of granite samples from PSG College of Technology, Coimbatore.
3	Laboratory Testing of Granite samples from Archean Granite, KGF
4	Laboratory Testing of cement samples from Baker and Hughes Singapore Pte. Vakalapudi, Kakinada,

- Laboratory determination of physico-mechanical properties of rocks from Hutti, Uti and Hirabuddini gold mines for project on optimization of stoping parameters is in progress.

- Laboratory geotechnical investigations on rock core samples from pump house and surge pool of Pranahitha-Chevella LIS-Pkg-12, MEIL (Hyderabad) is in progress.

9. TRAINING PROGRAMMES

During 2015-16, NIRM conducted short-term technical training courses for the practicing engineers and professionals, and internship programmes for students. These programmes are detailed below :

- Training was conducted on controlled blasting & excavation engineering for the Engineers of Border Roads Organization (BRO), Govt. of India, for one week at NIRM Registered Office, KGF from 22-27 July 2015.

- One-week training programme was conducted on “Nanoseismics/microseismics application for underground powerhouse cavern strata monitoring” for four NTPC engineers at NIRM KR Puram, Bengaluru unit from 24-29 August 2015.

- Training was conducted on controlled blasting & excavation engineering for the Engineers of Border Roads Organization (BRO), Govt. of India, for one week at NIRM Registered Office, KGF from 26-31 October 2015.

- Training Programme was conducted on “Tunnelling Technology” for civil engineers of the Indian Railways (IRSE – Civil) for two-weeks at Norwegian Geotechnical Institute, Oslo from 16-24 October 2015 and two-weeks at NIRM, Bengaluru from 5-14 January 2016.

- Summer training and internship programme was conducted for three students of III semester, B Tech Mining Engineering, NIT Surathkal for three weeks between 16th December 2015 and 4th January 2016 on various aspects of Rock Mechanics.

Training on Controlled Blasting & Excavation Engineering for the personnel of Border Roads Organization was organized. The training course covered the main topics of controlled blasting. Sufficient time was allotted after each lecture and a detailed technical interaction was made and the clarifications raised by the participants were duly cleared. Relevant case studies were worked out according to their site requirements. Lectures on brief introduction to the rock mechanics related aspects were also covered by faculty heads. A field demonstration was organised in a nearby stone quarry in which all aspects of blast design parameters including drilling, charging of holes, hookup pattern, initiation of blast and monitoring of ground vibration deploying seismographs were thoroughly imparted to the participants. Figure 9.1 shows a group photo of the BRO officials, participants and NIRM officials during training programme conducted for Batch I.

Fig. 9.1 Group photo of the BRO officials, participants and NIRM officials

ANNUAL ACCOUNTS

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Chartered Accountants

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INDEPENDENT AUDITORS' REPORT

To

The Members of National Institute of Rock Mechanics,

Report on Financial Statements.

We have audited the accompanying financial statements of NATIONAL INSTITUTE OF ROCK MECHANICS ("the Institute"), which comprise the Balance Sheet as at 31 March, 2016, the Income and Expenditure Account and the Receipts & Payments` Account for the year then ended, and a summary of significant accounting policies and other explanatory information.

Management's Responsibility for the Financial Statements

The Institute's Management is responsible for the preparation of these financial statements that give a true and fair view of the financial position, financial performance of the Institute in accordance with auditing standards generally accepted in India. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the Institute's preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances but not for the purpose of expressing an opinion on the effectiveness of the entity's internal control. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

GRSM & Associates Bangalore Chartered Accountants

e-mail : services@grsmca.com *Website : www.grsmca.com*

Basis for qualified opinion

i. *Non confirmation of balances by parties as described in item no.8 of Notes on Accounts to the financial statements, the impact of which is unascertained.*

ii. *Non verification, non-reconciliation of fixed assets and non-maintenance of fixed assets register, the impact of which is unascertained.*

Opinion:

In our opinion and to the best of our information and according to the explanations given to us, except for the effects of the matter described in the Basis for Qualified Opinion paragraph, the financial statements give a true and fair view:

a. in the case of he Balance Sheet, of the state of affairs of the Institute as at 31 March, 2016; and
b. in the Case of Income and Expenditure Account, of the excess of Income over expenditure for the year ended on that date.
c. in the case of the Receipts & Payments Account, of the Receipts & Payments for the year ended on that date.

For GRSM & Associates,
Chartered Accountants
(FRN 000863S)

Place: Bangalore
Date: 31/08/2016

Gopalkrishna Hegde
Partner
M. No. 208063

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

SCHEDULE-31

ACCOUNTING POLICIES AND NOTES ON ACCOUNT FORMING PART OF BALANCE SHEET AND INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDING 31ST MARCH 2016.

1. ACCOUNTING POLICIES :-

A. Background:

The entity is an autonomous body under the administrative control of Ministry of Mines, Government of India, registered as Society under the Karnataka Societies Registration Act, 1960. It carries on activities of research in the field of Rock Engineering.

Basis of Preparation:

The financial statements have been prepared under the historical cost convention on an accrual basis. The accounting policies have been consistently applied by the Society and are consistent with those used in the previous year.

B. Fixed Assets:

Fixed Assets are initially recorded at acquisition cost, as and when the asset is put to use by the Institute and carried at such cost less accumulated depreciation and impairment loss, if any.

C. Foreign Exchange Transactions:

Foreign currency transactions are recorded in the reporting currency by applying to the foreign currency amount the exchange rate between the reporting currency and the foreign currency at the date of the transaction. Monetary items, if any, are reported using the exchange rate prevailing at the closing rate. Exchange differences, if any are recognized as income or expense in the income and expenditure statement.

D. Revenue Recognition:

Revenue from services as well as from research and consultancy projects are recognized under Completed Service Contract Method. Revenue in respect of Interest is recognized on time proportion basis taking into account the amount outstanding and the rate applicable.

E. Treatment of Government Grant:

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

GRSM & Associates Bangalore Chartered Accountants

The Capital Grant for 'Plan' receivable as per sanction order received from Ministry of Mines, is credited to Deferred Government Grants Account and is allocated to income over the period in the same proportion as the depreciation is charged on the depreciable assets purchased out of these Capital Grant. Balance of capital grants appear as Deferred Government Grants in balance sheet under "Other Funds". Non Plan grants, being revenue in nature, when received are directly taken as Revenue in Income and Expenditure Account.

F. Retirement / Long Term Employee Benefits:

The Institute has made arrangement with Life Insurance Corporation of India for payment of gratuity and leave encashment under the Group Gratuity Scheme and group leave encashment scheme. Expenses for the gratuity and leave encashment is accounted as per calculation made under Projected Unit Credit Method and intimated by the Insurance Company and is charged as expense in the Income and Expenditure Statement under "Pay & Allowances".

Regarding Provident Fund accumulation, this Institute has been enrolled with the Employees Provident Fund Organization. The Institute's contribution towards the Provident Fund is charged as expense in the Income and Expenditure Statement under "Pay & Allowances".

G. Depreciation:

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

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

2. NOTES ON ACCOUNTS: -

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

2. The land and building transferred during the year 1988-89 by BGML to the Institute is subject to receipt of direction from the Government of India. Registration of the transfer of land with sub-registrar and other related formalities are pending. The title of these land and buildings in the name of the Institute is thus subject to the foregoing.

3. Accounting for expenses and liability towards group leave encashment and group gratuity is based on contributions sought by LIC of India, with whom the Institute has entered into an arrangement for payment of gratuity and leave encashment. The demand received from LIC of India did not cover the

GRSM & Associates Bangalore Chartered Accountants

liability of leave encashment of six newly recruited employees during the year. The liability if any, in respect of their services for the year would get covered in future contributions.

4. Fixed Assets are subject to physical verification and reconciliation.

5. Provision for the income tax has been measured at the amount expected to be paid to the tax authorities in accordance with the Income Tax Act, 1961. Tax Expenses debited to the income & expenditure account comprises of provision of current tax for the year & the differences between tax deducted at source claimed by the Institute and that allowed by the department for the past years.

6. Tax deducted at source receivable, as mentioned in the schedule 13 to the balance sheet is subject to reconciliation and adjustments, if any.

7. The Institute has filed audited accounts & relevant returns up to 31/03/2015 with District Registrar of Societies, Kolar, as required under the Societies Registration Act, for renewal without the requisite fee. The Institute has made an adhoc provision in the books of accounts for Rs.2,00,000/- towards society registration renewal fees as the intimation of amount of fee to be remitted is not received from the said authority.

8. The balances of parties' account are subject to confirmations and adjustments, if any.

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

31/8/16
(A.N.Nagarajan)
Registrar & Secretary

31.8.2016
(V.Venkateswarlu)
Director

(A.Sundaramoorthy)
Member
Governing Body

Refer our report of even date
For GRSM & ASSOCIATES
Chartered Accountants

(Gopalkrishna Hegde)
Partner
M.No: 208063

GRSM & Associates Bangalore Chartered Accountants

Place: Bangalore
Date: 31/08/2016

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

CONSOLIDATED BALANCE SHEET AS AT 31ST MARCH 2016

(Amount in Rs)

Liabilities	Sch No.	Balance as on 31-03-2016	Balance as on 31-03-2015	Assets	Sch No	Balance as on 31-03-2016	Balance as on 31-03-2015
CAPITAL FUND	1						
a) Capital Reserve		32,44,334	32,44,334	**CURRENT ASSETS**	8		
b) Internal Capital Reserve		2,50,42,413	2,50,42,413	a) Cash in Hand		1,72,411	1,68,267
				b) Cash at Bank		22,57,311	5,01,76,031
OTHER CAPITAL FUNDS	2			c) Stock - Stationery Items		1,43,080	1,54,009
a) Deferred Government Grant		7,31,52,489	5,04,48,246	**INVESTMENTS**	9		
b) Institute's Development Fund		4,60,00,000	4,60,00,000	a) Fixed Deposits - Institute Development Fund		4,60,00,000	4,60,00,000
				b) Short term deposits against project advances received from clients		13,52,36,052	5,79,97,930
CURRENT LIABILITIES							
a) Sundry creditors - pay roll deductions	3	-	5,29,068	**Deposits**	10	5,46,628	4,14,580
b) Sundry Creditors - Staff	4	14,09,807	10,65,057	**LOANS AND ADVANCES**			
c) Sundry Creditors - Others	5	83,58,692	69,34,148	a) Advances - Staff	11	5,97,783	12,65,096
d) Project Advaces Received	6	17,52,68,397	15,52,34,082	b) Advances - Suppliers	12	1,15,77,729	88,23,079
e) Provisions	7	1,78,28,292	1,47,68,443				
				Other Current Assets	13	3,86,25,281	3,25,24,459
				Expenses on Ongoing Projects	14	5,19,24,598	5,51,20,801
				Sundry Debtors	15	1,87,82,688	-
				FIXED ASSETS	16	2,37,30,567	2,10,22,391
				Income & Expenditure A/c. (Dr)	17	2,07,10,296	2,95,99,148
TOTAL		**35,03,04,424**	**30,32,65,791**	**TOTAL**		**35,03,04,424**	**30,32,65,791**

For National Institute of Rock Mechanics

31/8/16
(A. N. Nagarajan)
Registrar & Secretary
Place : Bangalore
Date:31/08/2016

V. Venkat 31.8.16
(V. Venkateswaru)
Director

(A.Sundaramoorthy)
Member
Governing Body

As per our Report of even date
For GRSM & Associates
Chartered Accountants
FRN:000863S

Hegde
(Gopalkrishna Hegde)
Partner
M.No:208063

GRSM & Associates Bangalore Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

CONSOLIDATED INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2016

(Amount in Rs)

Expenditure	Sch No	2015-16	2014-15	Income	Sch No	2015-16	2014-15
Administrative Expenses	18	95,86,072	89,91,696	Grant-in-Aid received from Ministry of Mines	25	5,00,00,000	5,43,00,000
Pay & Allowances	19	7,12,56,121	7,57,24,516	Amount Received Against Completed Projects	26	8,77,86,746	6,44,96,688
Travelling Expenditure	20	8,42,727	3,37,093	Interest Received	27	1,42,74,223	1,25,47,821
Upkeep of Assets	21	10,30,529	7,02,843	Miscellaneous Income	28	2,59,660	7,49,478
Expenditure on Completed Projects	22	4,58,40,253	2,67,69,680	Withdrawal of Depreciation	29	7,95,757	1,51,754
Depreciation on Fixed Assets	16	56,49,940	49,84,156	Prior Period Income	30	-	12,07,985
Prior Period Expenses	23	5,18,369	3,71,941				
Tax Expenses	24	95,03,523	42,37,363				
Excess of Income over Expenditure		88,88,852	1,13,34,438				
Total:-		**15,31,16,386**	**13,34,53,726**	**Total:-**		**15,31,16,386**	**13,34,53,726**

For National Institute of Rock Mechanics

31/8/16

(A. N. Nagarajan)
Registrar & Secretary
Place : Bangalore
Date: 31/08/2016

31.8.16

(V. Venkateshwarlu)
Director

(A.Sundaramoorthy)
Member
Governing Body

As per our Report of even date
For GRSM & Associates
Chartered Accountants
FRN:000863S

(Gopalkrishna Hegde)
Partner
M.No:208063

GRSM & Associates Bangalore Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

Consolidated Receipts and Payments Account for the year ending on 31st March 2016

(Amount in Rs)

	Receipts	Amount	Amount		Payments	Amount	Amount
1	2	3	4	5	6	7	8
To	Opening Balance			By	Payment of Provision for Gratuity		6,00,000
	Cash	1,68,267		"	Payment of Provision for Income Tax		30,00,000
	Bank	5,01,76,032	5,03,44,299	"	Staff Welfare (Fund)		6,48,828
"	Capital Grant Received		2,35,00,000	"	TDS Remittances - Contractors Payment		5,694
"	Grant in Aid (Non Plan) Received		5,00,00,000	"	TDS on Fixed Deposits		5,01,389
"	Licence Fee Received		36,005	"	TDS Payable		55
"	Other Income Received		1,00,315	"	TDS receivable on Project Receipts		59,40,563
"	Miscellaneous Income Received		87,660	"	Remittances of Payroll Deductions		17,72,049
"	Security Deposits Recovered		11,129	"	Release of Retention Money (net)		62,880
"	Penalty recovered		35,680	"	Payment of Retirement Benefits (net)		7,47,499
"	Interest Received on Savings Bank Deposits		4,50,925	"	Purchase of Computer Hardware		8,33,450
"	Interest Received on Term Deposits		71,14,338	"	Purchase of Computer Software		47,24,980
"	Interest Received on Institute Development Fund		89,33,924	"	Purchase of Lab Equipment		6,62,105
"	Recovery of Defect Liability (net)		4,759	"	Transfer to Fixed Deposits		8,33,64,701
"	Earnest Money & Sec. Deposit received (net)		94,000	"	Prepaid Expenses - AMC & Insurance		13,588
"	Undisbursed Payment to Employees (Net)		8,720	"	Deposit with BESCOM - Bangalore		1,00,550
"	Staff Advance Recovered		32,285	"	Deposit for Telex & Telephone		31,498
"	Fixed Deposits Matured		61,26,579	"	CenVAT Credit on Expenses		2,46,611
"	Advance Received - R&D Projects		6,96,200	"	Advances to Others		38,64,298
"	Advance Received - Sponsored Projects		1,54,29,650	"	Project Institute Adjustment Account		39,69,813
"	Advance Received - Centre for Testing service		4,56,652	"	Prior period Expenses		3,242
"	Advance Service Tax Paid-Testing (net)		39,785	"	Administrative Expenses		92,69,223
"	Advance Service Tax Paid-Project (net)		10,06,814	"	Salaries & Wages		7,00,85,049
"	Travel Advance (net)		4,58,721	"	Travelling Expenses		9,82,608
"	Advances - Material Purchases (Net)		1,72,400	"	Up Keep of Assets		13,22,652
"	Realisation of Sundry Debtors-Project		7,04,07,073	"	Accrued Expenses		1,30,251
"	Realisation of Sundry Debtors-C T S		30,30,510	"	Project Contingency (B)		2,98,884
"	Defect Liability Recovered		594	"	Honorarium/ Incentive (Projects / MTL)		87,02,285
"	Institute-Project Adjustment Account		7,58,275	"	Advances to Others (net)		10,42,524
				"	Remittances of Service Tax Payable (Net)		98,86,992
				"	Payment of Advance Income		40,00,000

GRSM & Associates Bangalore Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

Consolidated Receipts and Payments Account for the year ending on 31st March 2016

(Amount in Rs)

	Receipts	Amount	Amount		Payments	Amount	Amount
1	2	3	4	5	6	7	8
				"	Advances - Capital Material (net)		4,48,865
				"	Imprest Payment		5,000
				"	Expenditure on R&D Running Projects		69,889
				"	Expenditure on Completed Sponsored Projects		1,82,26,048
				"	Contigency - Centre for Testing Servcies		3,24,587
				"	Stationery items Purchased		4,49,585
					Expenditure on Completed Sponsored Projects		5,69,334
					Closing Balance		
					Cash	1,72,411	
					Bank	22,57,311	24,29,722
	Total:-		23,93,37,291		Total:-		23,93,37,291

As per our Report of even date

For GRSM & Associates

Chartered Accountants

FRN:000863S

For National Institute of Rock Mechanics

31/8/16

(A. N. Nagarajan)
Registrar & Secretary
Place : Bangalore
Date: 31/08/2016

31.8.16

(V. Venkateswarlu)
Director

(A.Sundaramoorthy)
Member
Governing Body

(Gopalkrishna Hegde)
Partner
M.No:208063

GRSM & Associates' Bangalore Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS
Champion Reefs Post, Kolar Gold Fields - 563 117.

Schedule - 16

DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2016

(Amount in Rs)

		Gross Block						Depreciation				Net Block	
Name of the Assets	Rate of Depreciation %	Balance as on 01-04-2015	Assets Written off/Trans-ferred	Purcchases up to 30.09.2015	Purchases between 1.10.2015 to 31.12.2015	Purchases After 01.01.2016	Total as on 31.03.2016 (Total of Col 3 to Col 7)	Balance as on 01-04-2015	Depreciation written off	Depreciation for the year	Total Depreciation as on 31-03-2016 (Total of Col 9 to Col 11)	As on 31-3-2016 (Col 8 - Col 12)	As on 31-3-2015
1	2	3	4	5	6	7	8	9	10	11	12	13	13
Buildings	5	91,08,642	-	-	-	-	91,08,642	88,80,935	-	2,09,462	90,90,397	18,245	2,27,707
Plant & Machinery	7.5	3,29,20,234	-	-	-	-	3,29,20,234	3,17,94,150	-	1,28,218	3,19,22,368	9,97,866	11,26,084
Water Supply	5	3,28,926	-	-	-	-	3,28,926	3,09,513	-	12,060	3,21,573	7,353	19,413
Power supply	5	5,03,434	-	-	-	-	5,03,434	5,03,334	-	-	5,03,334	100	100
Furniture	5	45,66,256	-	-	-	-	45,66,256	25,40,500	-	1,93,269	27,33,769	18,32,487	20,25,756
Office Equipment	5	27,60,664	-	-	-	-	27,60,664	15,76,288	-	1,15,073	16,91,361	10,69,303	11,84,376
Vehicle	7.5	7,83,835	-	-	-	-	7,83,835	7,83,735	-	-	7,83,735	100	100
Laboratory Equipment	7.5	3,14,93,865	-	6,62,105	9,75,850	-	3,31,31,820	2,04,53,316	-	20,48,993	2,25,02,309	1,06,29,511	1,10,40,549
Technical Books	5	46,93,917	-	-	-	-	46,93,917	30,59,746	-	2,34,761	32,94,507	13,99,410	16,34,171
Computer Software	15	1,36,33,054	-	2,81,936	-	44,43,044	1,83,58,034	1,16,76,313	-	16,32,208	1,33,08,521	50,49,513	19,56,741
Computer Hardware	20	1,37,99,918	-	8,33,450	-	-	1,46,33,368	1,36,42,316	-	7,51,556	1,43,93,872	2,39,496	1,57,602
Conversion of Power line	5	17,99,459	-	-	-	-	17,99,459	12,44,438	-	89,973	13,34,411	4,65,048	5,55,021
Env Geo Tech Lab	7.5	21,13,409	-	-	-	-	21,13,409	14,51,088	-	1,52,068	16,03,156	5,10,253	6,62,321
PROJECT:													
Vehicle	7.5	8,06,889	-	-	-	11,61,731	19,68,620	3,74,439	-	82,299	4,56,738	15,11,882	4,32,450
Total:-		**11,93,12,502**	**-**	**17,77,491**	**9,75,850**	**56,04,775**	**12,76,70,618**	**9,82,90,111**	**-**	**56,49,940**	**10,39,40,051**	**2,37,30,567**	**2,10,22,391**
Advance for capital material purchase		-	-	-	-	-	-	-	-	-	-	-	-
(Previous year figures)		***11,60,37,446***	-	**9,17,124**	**58,216**	**22,99,716**	**11,93,12,502**	**9,33,05,955**	**-**	**49,84,156**	**9,82,90,111**	**2,10,22,391**	**2,27,31,491**

Note: 1. Items not put into use : NIL
2. Depreciation has been charged on Straight Line Method.

GRSM & Associates
Bangalore
Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

BALANCE SHEET AS AT 31ST MARCH 2016

Institute A/c (Amount in Rs.)

Liabilities	Sch No.	Balance as on 31-03-2016	Balance as on 31-03-2015	Assets	Sch No	Balance as on 31-03-2016	Balance as on 31-03-2015
		Rs. Ps.	Rs. Ps.			Rs. Ps.	Rs. Ps.
1	2	3	4	5	6	7	8
CAPITAL FUNDS	1			**CURRENT ASSETS**	8		
a) Capital Reserve		32,44,334	32,44,334	a) Cash in Hand		12,970	1,06,169
b) Internal Capital Reserve		2,50,42,413	2,50,42,413	b) Cash at Bank		22,57,311	5,01,76,031
OTHER CAPITAL FUNDS	2			**INVESTMENTS**	9		
a) Deferred Government Grant		7,31,52,489	5,04,48,246	a) Fixed Deposit (IDF)		4,60,00,000	4,60,00,000
b) Institute's Development Fund		4,60,00,000	4,60,00,000	b) Fixed Deposits - Short Term		13,03,56,854	4,69,92,153
				DEPOSITS	10	5,46,628	4,14,580
CURRENT LIABILITIES							
				LOANS AND ADVANCES			
a) Sundry Creditors - Pay Roll Deductions	3	-	5,29,068	a) Advances - Staff	11	2,50,085	1,84,931
b) Sundry Creditors - Staff	4	14,08,592	10,64,436	b) Advances - Others	12	1,15,47,329	85,89,401
c) Sundry Creditors - Others	5	69,20,982	63,17,679				
d) Provisions	6	1,78,28,292	1,47,68,443	Other Current Assets	13	79,90,657	97,26,479
e) Project Account	7	32,04,83,035	27,60,10,814				
				FIXED ASSETS	14	2,22,18,685	2,05,89,941
				Income & Expenditure Account (Dr)	15	27,28,99,618	24,06,45,748
TOTAL		**49,40,80,137**	**42,34,25,433**	**TOTAL**		**49,40,80,137**	**42,34,25,433**

For National Institute of Rock Mechanics

31/8/16

(A. N. Nagarajan)

Registrar & Secretary

Place : Bangalore

Date: 31/08/2016

V. Venkateshwarlu 31.8.16

(V. Venkateshwarlu)

Director

(A.Sundaramoorthy)

Member

Governing Body

As per our Report of even date

For GRSM & Associates

Chartered Accountants

FRN:000863S

(Gopalkrishna Hegde)

Partner

M.No:208063

GRSM & Associates * Bangalore * Chartered Accountants

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

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2016

Institute A/c (Amount in Rs.)

EXPENDITURE				INCOME			
Sch No	Head of Account	2015-16	2014-15	Sch No	Head of Account	2015-16	2014-15
1	2	3	4	5	6	7	8
16	Administrative Expenses	95,86,072	89,91,696	21	Grant-in-Aid received from Ministry of Mines	5,00,00,000	5,43,00,000
17	Pay & Allowances	7,12,56,121	7,57,24,516	22	Miscellaneous Income	1,29,630	3,56,127
18	Travel Expenditure	8,42,727	3,37,093	23	Prior Period Income	-	54,868
19	Up Keep of Assets	10,30,529	7,02,843	24	Interest Received	1,24,51,974	95,37,719
20	Prior Period Expenses	5,18,369	3,71,941	25	Withdrawal of Depreciation	7,95,757	1,51,754
14	Depreciation on Fixed Assets	55,67,641	49,23,639		Excess of Expenditure over Income	3,22,53,870	3,08,88,623
	Tax Expenses	68,29,772	42,37,363				
	Total:-	**9,56,31,231**	**9,52,89,091**		**Total:-**	**9,56,31,231**	**9,52,89,091**

As per our Report of even date

For National Institute of Rock Mechanics

(A. N. Nagarajan)
Registrar & Secretary
Place : Bangalore
Date: 31/08/2016

(V. Venkateswarlu)
Director

(A.Sundaramoorthy)
Member
Governing Body

For GRSM & Associates
Chartered Accountants
FRN:000863S

(Gopalkrishna Hegde)
Partner
M.No:208063

GRSM & Associates * Bangalore * Chartered Accountants *

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

BALANCE SHEET AS AT 31ST March 2016

Project A/c

(Amount in Rs)

Liabilities	Sch No.	Balance as on 31-03-2016	Balance as on 31-03-2015	Assets	Sch No	Balance as on 31-03-2016	Balance as on 31-03-2015
OTHER CAPITAL FUNDS				**CURRENT ASSETS**			
Income & Expenditure Account	1	25,21,89,322	21,10,46,600	a) Cash in Hand	5	1,59,441	62,098
				b) Institute Account	6	32,04,83,035	27,60,10,814
CURRENT LIABILITIES				c) Stock - Stationery Items	7	1,43,080	1,54,009
a) Project Advances Received	2	17,52,68,397	15,52,34,082				
b) Sundry Creditors - Others	3	14,37,710	6,16,469	**INVESTMENTS**			
c) Sundry Creditors - Suppliers & Employees	4	1,215	621	a) Short Term Deposits against Project Advances received from clients	8	48,79,198	1,10,05,777
				LOANS AND ADVANCES			
				a) Advances - Staff	9	3,47,698	10,80,165
				b) Advances - Suppliers	10	30,400	2,33,678
				Other Current Assets	11	3,06,34,624	2,27,97,980
				Expenses on Ongoing Projects	12	5,19,24,598	5,51,20,801
				Sundry Debtors	13	1,87,82,688	-
				Fixed Assets	14	15,11,882	4,32,450
TOTAL		**42,88,96,644**	**36,68,97,772**	**TOTAL**		**42,88,96,644**	**36,68,97,772**

For National Institute of Rock Mechanics

31/8/16

(A. N. Nagarajan)

Registrar & Secretary

Place: Bangalore

Date: 31/08/2016

V. Venkateswarlu 31.8.16

(V.Venkateswarlu)

Director

(A.Sundaramoorthy)

Member (Governing Body)

As per our Report of even date

For GRSM & Associates

Chartered Accountants

(Gopalkrishna Hegde)

Proprietor

M.No:208063

GRSM & Associates Bangalore Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31ST MARCH 2016

Project A/c

(Amount in Rs)

	Expenditure		2015-16	2014-15		Income		2015-16	2014-15
TO	Expenditure on Completed Projects	15	4,58,40,253	2,67,69,680	By	Amount Received Against Completed Projects	16	8,77,86,747	6,44,96,688
"	Depreciation on Fixed Assets - Vehicle	14	82,299	60,517	"	Interest Received	17	18,22,249	23,66,626
"	Tax Expenses		26,73,751	-	"	Prior Period Income	18	-	11,53,117
"	Excess of Income over Expenditure		4,11,42,722	4,22,23,061	"	Other Income	19	1,30,029	10,36,827
	Total:-		**8,97,39,025**	**6,90,53,258**		**Total:-**		**8,97,39,025**	**6,90,53,258**

As per our Report of even date

For GRSM & Associates

Chartered Accountants

For National Institute of Rock Mechanics

31/8/16

(A. N. Nagarajan)

Registrar & Secretary

V.Venkat 31.8.2016

(V.Venkateswarlu)

Director

(A.Sundaramoorthy)

Member (Governing Body)

(Gopalkrishna Hegde)

Partner

M.No:208063

GRSM & Associates Bangalore Chartered Accountants

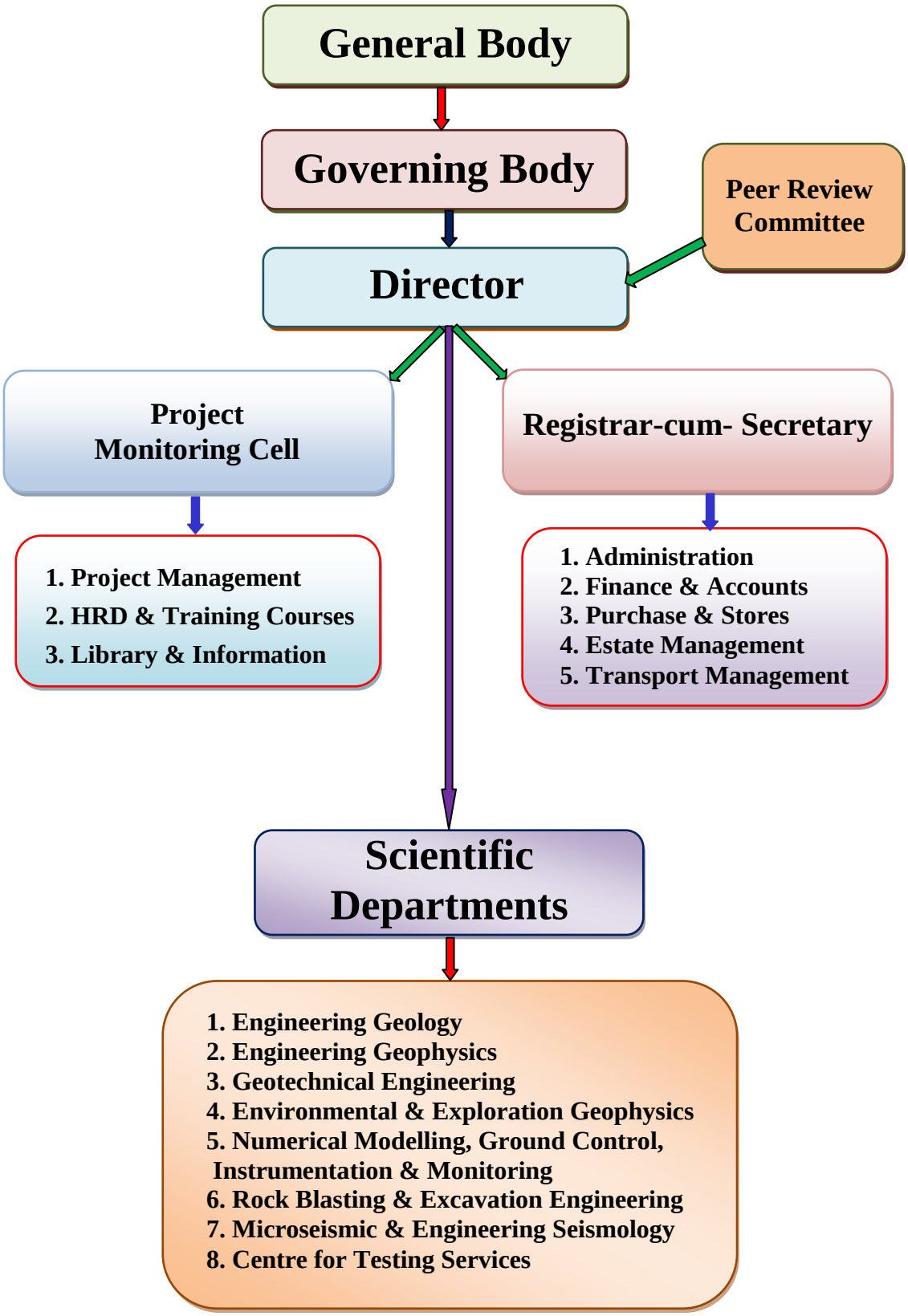
Place : Bangalore

Date: 31-08-2016

ANNEXURES

Annexure - 1

ORGANISATION CHART



Annexure – 2

MEMBERS OF THE GENERAL BODY
(2014-16)

Chairman

Sri Balvinder Kumar, IAS
Secretary to the Government of India
Ministry of Mines
III Floor, A Wing, R. No. 320
Shastri Bhawan, Dr Rajendra Prasad Road
New Delhi – 110 115

Members

Sri R Sridharan, IAS
Addl. Secretary to the Govt. of India
Ministry of Mines, R No. 308-A
III Floor, A Wing, Shastri Bhawan
New Delhi – 110 115

Ms Sujata Prasad
Jt. Secretary & Financial Advisor
Ministry of Mines, R.No.321A
III Floor, A Wing, Shastri Bhawan
New Delhi – 110 115

Sri Sudhaker Shukla
Economic Advisor
Ministry of Mines, R.No. 305
III Floor, D Wing, Shastri Bhawan
New Delhi – 110 115

Dr Joyesh Bagchi
Dy Secretary (Technical)
Ministry of Mines, R No. 306
III Floor, D Wing, Shastri Bhawan
New Delhi – 110 115

Sri Harbans Singh
Director General
Geological Survey of India (GSI)
Kolkata - 700 016

Prof BB Dhar
Formerly : Director – CIMFR; Director (Research) – AIU; Director (R&IC) - Amity University, Advisor - HESRT&SD
New Delhi – 110 048

Sri Rahul Guha
Director General
Directorate General of Mines Safety
Dhanbad ─ 826 001
Jharkhand

The Director
CSIR- Central Institute of Mining & Fuel Research
Dhanbad – 826 015

Prof DC Panigrahi
Director
Indian School of Mines
Dhanbad – 826 003

Sri AS Walvekar
Executive Director (Geology / R&D Div.)
National Hydro-Power Corporation Ltd
NHPC Office Complex, Sector-33
Faridabad – 121 003, Haryana

Sri B Ramesh Kumar
Director (Operations)
Singareni Collieries Company Limited
Kothagudem Collieries – 507 101

Sri A Sundaramoorthy
Director General (Retd.), GSI
Chennai – 600 099

Sri AK Rudra
Retd. Director General of Mines Safety
Kolkata – 700 002

Dr V Venkateswarlu
Director
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Secretary (Non-member)

Sri AN Nagarajan
Registrar-cum-Secretary
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Annexure – 3

MEMBERS OF THE GOVERNING BODY
(2014-16)

Chairman

Sri Balvinder Kumar, IAS
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Ministry of Mines
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Members

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III Floor, A Wing, Shastri Bhawan
New Delhi – 110 001

Sri Rahul Guha
Director General
Directorate General of Mines Safety
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Jharkhand

Ms Sujata Prasad
Jt. Secretary & Financial Advisor
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III Floor, A Wing, Shastri Bhawan
New Delhi – 110 001

Sri Subhas Chandra
Joint Secretary
Ministry of Mines
III Floor, A Wing, Shastri Bhawan
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Sri Sudhaker Shukla
Economic Advisor
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III Floor, D Wing, Shastri Bhawan
New Delhi – 110 001

The Director
CSIR- Central Institute of Mining & Fuel Research
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Prof DC Panigrahi
Director
Indian School of Mines
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The Director General
Geological Survey of India (GSI)
Kolkata - 700 016

The Director (Operations)
Singareni Collieries Company Limited
Kothagudem Collieries – 507 101
Khammam District, T.S.

The Member (D&R)
Central Water Commission
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RK Puram, New Delhi – 110 066

Sri AK Rudra
Retd. Director General of Mines Safety
Kolkata – 700 002

The Executive Director
(Geology / R&D Div.)
National Hydro-Power Corporation Ltd
NHPC Office Complex, Sector-33
Faridabad – 121 003, Haryana

Alternate

The Advisor (Projects)
Ministry of Coal
3rd floor, A Wing, Shastri Bhawan
New Delhi – 110 001

Sri A Sundaramoorthy
Director General (Retd.), GSI
Chennai – 600 099

Prof BB Dhar
Formerly : Director – CIMFR; Director (Research) – AIU; Director (R&IC) - Amity University, Advisor - HESRT&SD
New Delhi – 110 048

Dr. V. Venkateswarlu
Director
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Secretary (Non-member)

Sri AN Nagarajan
Registrar-cum-Secretary
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Annexure - 4

MEMBERS OF THE PEER REVIEW COMMITTEE
(2014-16)

Chairman

Sri AK Rudra
Director General of Mines Safety (Retd.)
Kolkata – 700 002

Members

Alternate Chairman

Sri A Sundaramoorthy
Director General (Retd.)
Geological Survey of India
Chennai – 600 099

The Director, C-TEMPO
Ministry of Mines, Govt. of India
New Delhi – 110 003

Prof VR Sastry
Mining Engineering Department
National Institute of Technology
Mangalore – 575 025

The HoD (Geophysics)
Exploration Dept
Central Mine Planning & Design Instt HQ
Ranchi – 834 008

Sri Achyuta Krishna Ghosh
Chief Scientist, CSIR-CIMFR
Professor, AcSIR-CIMFR
Central Institute of Mining & Fuel Research
Dhanbad – 826 015

Dr. V. Venkateswarlu
Director
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

The General Manager (R&D)
Corporate
Singareni Collieries Company Limited
Kothagudem Colleries – 507 101

Dr Asim Kumar Sinha
Director (S&T)
Directorate General of Mines Safety
DHANBAD – 826 001

Secretary (Non-member)

Sri AN Nagarajan
Registrar-cum-Secretary
National Institute of Rock Mechanics
Champion Reefs
Kolar Gold Fields - 563 117

Annexure - 5

SUPPORTING ORGANIZATIONS & MAJOR CLIENTELE

Central Government Ministries & Departments

Border Roads Organization, Government of India
Department of Science & Technology, Government of India
Ministry of Coal, Government of India
Ministry of Earth Sciences, Government of India
Ministry of Mines, Government of India
Indian Railways, Government of India

State Government

Andhra Pradesh Heavy Machinery and Engineering Limited (APHMEL)
Andhra Pradesh Power Generation Corporation (APGENCO)
Karnataka Power Corporation Limited (KPCL)
Kerala State Electricity Board (KSEB)
Shri Mata Vaishno Devi Shrine Board (SMVDSB), J&K
Singareni Collieries Company Limited
Telangana State Power Generation Corporation (TSGENCO)

Public Sector Organizations

Atomic Minerals Directorate (AMD)
Chennai Metro Rail Corporation Limited (CMRL)
Engineers India Limited (EIL)
Hindustan Copper Limited. (HCL)
Hindustan Petroleum Corporation Limited (HPCL)
Hindustan Zinc Limited (HZL)
Hutti Gold Mines Limited (HGML)
Indian Oil Corporation Limited (IOCL)
Manganese Ore India Limited (MOIL)
National Aluminium Company Ltd. (NALCO)
National Hydroelectric Power Corporation (NHPC Limited)
NTPC India Limited
Nuclear Power Corporation of India Limited (NPCIL)
Oil and Natural Gas Commission (ONGC)
Sardar Sarovar Narmada Nigam Limited (SSNNL)
Satluj Jal Vidyut Nigam Limited (SJVNL)
South Eastern Coalfields Limited (SECL)
THDC India Limited
Uranium Corporation of India Limited (UCIL)
Western Coalfields Limited (WCL)

Private Companies

Alliance Minerals Pvt. Ltd.
Bagmane Estates Pvt. Ltd.
Balsore Alloys Limited Ltd
Boyance Infrastructure Private Ltd.
China Coal No.5 Constructions Pvt Ltd.
Cosme Costa & Sons
Covenant Stones Pvt. Ltd.
Dalmia Cement (Bharat) Ltd.
Deepak Fertilizers and Petrochemicals Company Limited (DFPCL)
Ferro-Alloys Corporation Limited (FACOR)
Gammon India Ltd.
HES Infra Private Ltd
Hindustan Construction Company Limited (HCC)
India Cements Limited
India Resources Limited.
IOT Infrastructure & Energy Services Ltd
Jindal Power Limited
Kare Power Resources Private Limited (KPRPL)
Larsen & Toubro (L&T) Construction
Mantri Developers Pvt. Ltd.
Megha Engineering & Infrastructures Ltd
Navayuga Engineering Company Limited
Navyuga Kommu Venkateshwara Metal Miners
Patel Engineering Ltd.
Prathima Infrastructures Ltd.
Ramco cements Ltd.
Sesa Mining Corporation Ltd.
Shaft Sinkers Mauritius Ltd.
Shriram EPC Limited
SNC-Lavalin Infrastructure Private Ltd.
Soham Renewable Energy Private Limited (SREPL)
The India Cements Limited (ICL)
Transstroy-AFCONS JV, Chennai
Transstroy-JSC-EC-UES, AP
Waddera Sangam
Zeenath Transport Company (ZTC)
Zuari Cement Limited

International Organizations

Druk Green Power Corporation Limited (DGPCL), Bhutan
Mangdechhu Hydroelectric Project Authority (MHPA), Bhutan
Punatsangchhu II (1020 MW) HEP, Bhutan

Annexure – 6

LIST OF PROJECTS

Sl. No	Title of Project	Persons involved	Status
1	Engineering geological, geotechnical, laboratory testing and support design for the underground surge pool and pump house project of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme – P 12), Telangana State.	AK Naithani, LG Singh & Prasnna Jain	Completed
2	Engineering geological investigations of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (Package-6), (Phase-II), T.S.	AK Naithani & Devendra Singh Rawat	Completed and Ongoing
3	Engineering geological investigation of Pulichintala Hydroelectric Scheme (4 x 30 MW), Guntur District, A.P.	AK Naithani, LG Singh & Prasnna Jain	Completed
4	Construction stage engineering geological mapping of Natural Draft Cooling Towers (NDCT) foundations of Rajasthan Atomic Power Project (RAPP) Units 7 & 8, Rawatbhata, Rajasthan.	AK Naithani, LG Singh & Prasnna Jain	Completed
5	Geotechnical Assessment of the Foundation of 1.5 MLD Capacity Over Head Tank at NR Park, Bellary, Karnataka.	AK Naithani, LG Singh & Prasnna Jain	Completed
6	Construction stage engineering geological mapping of pond floors and pump houses of Natural Draft Cooling Towers (NDCT) of Rajasthan Atomic Power Project (RAPP) Units 7&8, Rawatbhata, Rajasthan.	AK Naithani, LG Singh & Prasnna Jain	Ongoing
7	Engineering geological, geotechnical, laboratory testing and support design for the underground pump house complex area of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (Package-12), Telangana State.	AK Naithani, LG Singh & Prasnna Jain	Ongoing
8	Engineering geological investigations of the cave area of Shri Mata Vaisno Deviji, Reasi District of Jammu and Kashmir State	AK Naithani	Ongoing
9	Seismic Refraction Survey along the cut off trench for saddle dam at Yargol, Karnataka.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Completed

Sl. No	Title of Project	Persons involved	Status
10	Seismic Refraction Survey at Vishnugad-Pipalkoti Hydel Project, Uttarakhand.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Final Report submitted
11	Seismic Refraction Survey for determining D-wall excavation depth at Prestige Leela Housing Construction.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Completed
12	Development of a viable technique for assessment of safety of structures under settling environment.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	ongoing
13	Cross-hole Seismic Tomography Survey for S60 foundation of Special Bridge across River Chenab at Kauri village of USBRL Project, J & K.	PC Jha, N Sandeep, YV Sivaram, B Butchi Babu & Sashinath Varma	Final Report submitted
14	Cross-hole GPR survey for mapping probable extensions of old working at 200mRL of RD Mines, Dariba.	PC Jha, N Sandeep, YV Sivaram, B Butchi Babu & Sashinath Varma	Ongoing
15	In situ soil mechanic tests carried out for storage of stop logs at left bank of TLD-III barrage.	DS Subrahmanyam, G. Shyam, K. Vamshidhar, S. Vikram	Completed
16	Determination of in situ stress at the proposed underground pump house of Dr. B.R. Ambedkar Pranahita Chevella Sujala Sravanthi project, package 12.	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram & KN Shashidhara	Completed
17	Determination of in situ stress parameters at the proposed powerhouse sites of Rupaligad re-regulating project, Nepal.	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram & KN Shashidhara	Completed
18	Determination of in situ stress tensor at underground surge pool/pump house of Pranahita Chevella Lift Irrigation Scheme (PCILS, package no 11).	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram & KN Shashidhara	Ongoing
19	Determination of in situ stress parameters at Hutti Gold mine for the design of stopes below 20th level.	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram & KN Shashidhara	Ongoing
20	Determination of in situ stress and deformability parameters at new Rishikesh – Shivpuri section of 125 km rail link project.	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram & KN Shashidhara	Ongoing
21	Assessment of horizontal stress field in deeper horizons and development of roof hazard maps of coal resources in SCCL command area – (Ministry of Coal).	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram & KN Shashidhara	Ongoing
22	Estimation of seismic hazard in and around the mined out areas of Kolar Gold Fields.	VR Balasubramaniam, Praveena D Jennifer & Goverdhan Kantepudi	Ongoing

Sl. No	Title of Project	Persons involved	Status
23	Identification of hidden signatures of suspected lineament through geophysical and geological investigations.	VR Balasubramaniam, Praveena D Jennifer & Goverdhan Kantepudi	Completed
24	Evaluation of Light House Lineament related with Jaithapur Nuclear Power Plant, through trench studies, Ratnagiri, Maharashtra.	VR Balasubramaniam, Praveena D Jennifer & Goverdhan Kantepudi	Completed
25	Seismic monitoring	VR Balasubramaniam, Praveena D Jennifer & Goverdhan Kantepudi	Ongoing
26	Slope stability analysis of abutment cut slopes for concrete gravity dam at Mangdechhu Hydroelectric Project, Bhutan.	Sripad R Naik, BH Vijay Sekar, Rabi Bhusan & K Sudhakar	Ongoing
27	Instrumentation, monitoring and data analysis at powerhouse complex Tala Hydropower Plant, Bhutan.	Sripad R Naik, K Sudhakar, Rabi Bhusan & BH Vijay Sekar	Completed and Ongoing
28	3D analysis of underground caverns of powerhouse complex with bus bar tunnels and penstock entry at Tehri PSP, Uttarakhand.	Sripad R Naik, K Sudhakar, Rabi Bhusan & BH Vijay Sekar	Completed
29	Analysis of instrumentation data of dam, desilting complex, powerhouse complex of NJHPS, SJVNL, Shimla.	Sripad R Naik, K Sudhakar, Rabi Bhusan & BH Vijay Sekar	Completed and Ongoing
30	Back analysis of powerhouse complex behavior using 3D numerical modeling at Tapovan Vishnugad Hydroelectric Project.	Sripad R Naik, Roshan Nair & K Sudhakar	Completed
31	Geodetic monitoring of Sardar Sarovar Dam, SSNNL, Kevedia, Gujarat.	Sripad R Naik, K Sudhakar, Rabi Bhusan & BH Vijay Sekar	Ongoing
32	Deformation monitoring of underground powerhouse cavern of Sardar Sarovar Project, Gujarat.	Sripad R Naik, K Sudhakar, Rabi Bhusan & BH Vijay Sekar	Completed and Ongoing
33	3D analysis of underground powerhouse complex of Mangdechhu Hydroelectric Project, Bhutan.	Sripad R Naik, BH Vijay Sekar, Rabi Bhusan & K Sudhakar	Ongoing
34	Pit slope stability analysis of North East benches of A Narrain Mines, Chitradurga, Karnataka.	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Ongoing
35	To carryout rock mechanics investigations, evaluation of the stability of excavations & optimization of stoping parameters, design of support system etc. below 20th level in all the reefs of Hutti Gold Mines,	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar, Aditya Mishra, BNV Siva Prasad, Amrith Renaldy & K Sudhakar	Ongoing

Sl. No	Title of Project	Persons involved	Status
	Karnataka.		
36	To carryout rock mechanics investigations, evaluation of the stability of excavations & optimization of stoping parameters, design of support system at Uti and Hirabuddini mines of the Hutti Gold Mines Company Limited, Karnataka.	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar, Aditya Mishra, BNV Siva Prasad, Amrith Renaldy & K Sudhakar	Ongoing
37	Stability analysis of rock slopes for pothead yard location at Mangdechhu Hydroelectric Project, Bhutan.	Sripad R Naik, BH Vijay Sekar, Rabi Bhusan & K Sudhakar	Ongoing
38	Temporary and permanent support design of underground surge pool and pump house draft tube and delivery main tunnel using 3D numerical modeling at PCSSLIS- Package 12, Telangana.	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Ongoing
39	Support design of underground surgepool and pump house by 3D Numerical Modelling of Pranahita-Chevella Sujala Sravanthi Lift Irrigation Scheme (PCSSLIS) Package-11, Telangana.	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar, Aditya Mishra, BNV Siva Prasad & K Sudhakar	Ongoing
40	Advice on controlled blasting for excavation of pipeline trench adjacent to existing pipeline, Mudigere, Karnataka.	G Gopinath, AI Theresraj, R Balachander, GC Naveen & HS Venkatesh	Completed
41	Training on Controlled Blasting & Excavation Engineering for the Personnel of Border Roads Organization.	HS Venkatesh, AI Theresraj, G Gopinath, R Balachander & GC Naveen	Completed
42	Technical guidance on controlled blast design and monitoring ground vibration and air overpressure produced from blasting at powerhouse complex, Poringalkuthu SHE Project (1×24 MW), KSEB, Kerala.	GC Naveen, AI Theresraj, R Balachander, G Gopinath & HS Venkatesh	Completed
43	Study on ground vibration and assessment of flyrock at quarries of Sy. No. 493 & 497, Waddera Sangam, Karimnagar District, AP.	AI Theresraj, G Gopinath, R Balachander, GC Naveen & HS Venkatesh	Completed
44	Controlled blast design for pump house excavation and ground vibration measurement near operating Units of 5 and 6 Nuclear Plant, RAPP, Rawatbhata, Gammon India.	G Gopinath, R Balachander, GC Naveen, AI Theresraj & HS Venkatesh	Completed
45	Blast design for control of ground vibration on green and matured	R Balachander, G Gopinath, AI Theresraj, GC Naveen &	Completed

Sl. No	Title of Project	Persons involved	Status
	concrete and ground vibration monitoring at dam site of Punatsangchhu II (1020 MW) HEP, Bhutan.	HS Venkatesh	
46	Training on Controlled Blasting & Excavation Engineering for the Personnel of Border Roads Organization.	HS Venkatesh, AI Theresraj, G Gopinath, R Balachander & GC Naveen	Completed
47	Study on vibration and air overpressure for the blast conducted to construct unit 3 & 4 of Kudankulam nuclear power plant, Kudankulam, Tamil Nadu.	G Gopinath, AI Theresraj, R Balachander, GC Naveen & HS Venkatesh	Completed
48	Technical Advice on Rip Rap Blasting for the Construction of Earth Cum Rock Filled Dam, Indira Sagar Polavaram Project, East Godhavari District, Andhra Pradesh.	G Gopinath, AI Theresraj, R Balachander, GC Naveen & HS Venkatesh	Ongoing
49	Study on feasibility of blasting for excavation of Tail Race Tunnel of Vishnugad Pipalkoti HEP (444 MW) passing under Durgapur village, Chamoli, Uttrakhand, THDC India Ltd.	R Balachander, AI Theresraj, GC Naveen, G Gopinath & HS Venkatesh	Ongoing
50	Blast vibration study, proof checking and monitoring of blast induced vibration at nearby structures (HT line and villages), Darlipalli super thermal power project (DSTPP), Stage-I (2×800 MW), NTPC Limited, Odisha.	GC Naveen, AI Theresraj, G Gopinath, R Balachander & HS Venkatesh	Ongoing
51	Blasting guidance for removal of boulders and excavation of rock in the river channel of Idamalayar dam spillway bucket area, KSEB.	AI Theresraj, R Balachander, G Gopinath, GC Naveen & HS Venkatesh	Ongoing
52	Stability Monitoring using Nanoseismics/ Microseismics in the power house cavern at TVHPP, UK.	Sivakumar Cherukuri & Vikalp kumar	Ongoing
53	Powerhouse Stability monitoring using microseismics at THP, DGPC, Bhutan.	Sivakumar Cherukuri & Vikalp Kumar	Ongoing
54	Estimation of Seismic Hazard in and around the BGML mines, Kolar Gold Fields.	Sivakumar Cherukuri, VR Balasubramanium, Praveena Das Jennifer & Vikalp Kumar	Ongoing
55	Broad Band Seismic Station at KGF.	Sivakumar Cherukuri, Praveena Das Jennifer & Vikalp Kumar	Ongoing
56	In-situ non-destructive testing for M/s Shaft Sinkers Mauritius, Rajasthan.	A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar,	Completed

Sl. No	Title of Project	Persons involved	Status
		S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	
57	In-situ non-destructive evaluation on cable belt drive ropes for M/s National Aluminum Company Limited, Damanjodi, Odisha.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Completed
58	In-situ non-destructive testing for M/s Singareni Collieries Company Limited, Telangana.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Completed
59	In-situ non-destructive testing on steel structures of Ramkrishnapur Coal Handling Plant, Mandamarri Area, M/s Singareni Collieries Company Limited, Telangana.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, S.Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Completed
60	In-situ Non-destructive testing for M/s Hindustan Zinc Limited – Zawar Group of Mines, Rajasthan.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D. Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Completed
61	In-situ non-destructive testing for M/s Hindustan Zinc Limited – Kayad Mines, Rajasthan.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Completed
62	In-situ non-destructive testing for M/s Hindustan Zinc Limited – Rajpura Dariba Mines, Rajasthan.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Completed
63	In-situ non-destructive testing for M/s Arulmigu Dandayuthapani Swamy Thirukoil, Palani.	M Victor, GD Raju, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S Babu &	Completed

Sl. No	Title of Project	Persons involved	Status
		S Arvind Kumar	
64	In-situ non-destructive testing for M/s Hutti Gold Mines Limited, Karnataka.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Completed
65	Proof-load test, non-destructive tests & break load test on suspension device of cage & skip of M/s China Non Ferrous Metal Industry's Foreign Engineering & Construction Co., Ltd., Rajasthan.	M Victor, A Rajan Babu, S Udhayakumar, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S. Babu & S Arvind Kumar	Completed
66	In-situ non-destructive testing for M/s Karnataka Power Corporation Limited, Karnataka.	A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S. Babu & S Arvind Kumar	Completed
67	In-situ stability test and proof load test on HEMM's & non-destructive evaluation on EOT cranes. M/s National Mineral Development Corporation Limited, Bacheli Complex, Chhattisgarh.	GD Raju, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, S Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	Ongoining
68	Laboratory Geotechnical Investigations on Rock Core Samples from Wellbores, BH-22, IG-4, BH-52, SH-5 and SY-5, from RGL, ONGC, Panvel.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
69	Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of Location - I, Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
70	Laboratory Geotechnical Investigations on Rock Core Samples from Wellbores, JMI-1 AND JMI-Jwalamukhi area of Frontier Basin; BK-1 and BK-2, Banskandi field of Cachar Forward Base, Silchar, Assam & Assam Arakan (A&AA) Basin (Assam) and PD-1, PD-2, L-578 Panidihing and Lakwa field of Assam Asset, Sivasagar.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
71	Laboratory Geotechnical Investigations on Rock Core Samples from Rohtas Limestone, Son Valley, Vindhyan Basin area, Deharadun.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
72	Determination of Physico mechanical properties for pillar optimization project	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed

Sl. No	Title of Project	Persons involved	Status
	at Thummala palli mine, UCIL, AP.		
73	Determination of Physico mechanical properties for design of stoping parameters for Mansar mine, MOIL ltd.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
74	Laboratory Testing of Rock samples from Bijapur Main Canal from Km. 10.00 to 20.00 and structures under MLI stage-III, KBJNL, Govt. of Karnataka.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
75	Laboratory Testing of granite samples from PSG College of Technology, Coimbattore.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
76	Laboratory Testing of Granite samples from Archean Granite, KGF.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
77	Laboratory Testing of cement samples from Baker and Hughes Singapore Pte. Vakalapudi, Kakinada,	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
78	Determination of rock properties for Optimisation of stoping parameters Project, Hutti Uti & Hirabuddini Gold Mines.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Ongoing
79	Laboratory Geotechnical Investigations on Rock Core Samples from Pump house and Surge pool of Dr. B.R.A. Pranahitha Chevela LIS-Pkg-12, MEIL, Hyderabad.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Ongoing
80	Slope Stability Studies at Kaliapani Chromite Mine, Kaliapani, Jajpur District, Odisha.	SK Reddy & A Rajan Babu	Ongoing
81	Dump material testing and analysis of Kaliapani chromite mine at Kaliapani, Jajpur District, Odisha.	SK Reddy & A Rajan Babu	Ongoing
82	Seismotectonic evaluation of Kudankulam Atomic Power Plant within 30-50 km radius, Tamilnadu.	Biju John, Yogendra Singh, Divyalakshmi KS, DT Rao, C Srinivasan & VR Balasubramanian	Completed
83	Identification of L2 lineament related to KKNPP through MASW survey and Trench studies.	Biju John, Yogendra Singh, Divyalakshmi KS & V.R. Balasubramaniam	Completed
84	Evaluation of Light House Lineament related with Jaithapur Nuclear Power Plant, through trench studies, Ratnagiri, Maharashtra.	Biju John, Yogendra Singh, Divyalakshmi KS, Akhil T, VR Balasubramaniam & A Rajan Babu	Ongoing
85	Geological and geomorphic characterization of the frontal thrust fault at central and northeast Himalaya.	Biju John	Ongoing

Annexure – 7

LIST OF PUBLICATIONS

1. AK Naithani, LG Singh and Prasnna Jain, 2015: Engineering geological investigations of tail race pool and tail race channel foundations of Pulichintala hydroelectric scheme (4 x 30 MW), Guntur and Nalgonda Districts of Telangana State, India. Indian Journal of Power and River Valley Development, vol. 65, Nos. 7&8, pp 99-108.

2. AK Naithani, Prasnna Jain and LG Singh, 2015: The problems of rockslides/cut slopes and their mitigation measures – a case study. Journal of Indian Landslides, vol. 8(1&2), pp 1-8.

3. AK Naithani, PC Nawani, LG Singh and DS Rawat, 2015: Engineering geological and geotechnical investigations of dam of the Bunakha hydroelectric project (180 MW), Chukha Dzong, Bhutan Himalaya. Journal of Nepal Geological Society, vol. 47, pp 77-94.

4. AK Naithani and LG Singh, 2016: Geotechnical assessment of a deep surge pool foundation – a case study. ISRM (India) Journal, vol. 5, No. 1, pp 30-39

5. A Salimi, C Moormann, TN Singh and Prasnna Jain, 2015: TBM performance prediction in rock tunneling using various artificial intelligence algorithms. Proc. 11th Iranian and 2nd Regional Tunneling Conference (Tunnels and the Future).

6. Biju John, Yogendra Singh, E Praseeda, 2016: Neotectonic evidences associated with shear zones of south India in AP Pradeepkumar, E Shaji (eds) Shear Zones and Crustal Blocks of Southern India vol.3 Proc UGCSAPDRS II & CTESS seminar, vol. 3, pp. 2-9.

7. Biju John, 2016: Issues pertaining to active fault identification in cratonic regions: example from Peninsular India, 7th International Workshop on Paleoseismology, Active Tectonics, and Archaeoseismology ("PATA Days") to be held at Creston USA (Accepted).

8. Butchi Babu B, PC Jha, YV Sivaram and PK Khan, 2016: Foundation evaluation of structures using correlation between SPT- N value and seismic wave velocity, communicated to Nearsurface Geophysics.

9. Butchi Babu B, N Sandeep, YV Sivaram, PC Jha and PK Khan, 2016: Foundation Evaluation of a Repeater Installation building using Seismic Refraction Tomography and Electrical Resistivity Imaging, communicated to Nearsurface Geophysics.

10. CP Rajendran, Biju John and K Rajendran, 2015: Medieval pulse of great earthquakes in the central Himalaya: Viewing past activities on the frontal Belt. Journal of Geophysical Research –Solid Earth. Vol. 120(3), pp. 1623–1641 doi:10.1002/2014JB011015.

11. CP Rajendran, Kusala Rajendran, Biju John, Jaishri Sanwal and Revathy Parameswaran, 2016: Geological results and archival information on the central Himalayan earthquakes and their implications for seismic source zones. Annual

meeting of Seismological Society of America.

12. DS Rawat, AK Naithani and G Srinivasa Rao, 2015: Treatment of cavities during construction of twin tunnels in an irrigation project – a case study. ISEG Golden Jubilee Special Publication Journal of Engineering Geology, pp 495-502.

13. DS Subrahmanyam, 2015: Influence of dyke on in situ stress parameters, measured in the vicinity of a proposed, underground pump house location Journal of Resources, Energy and Development, vol. 4(2), pp 9-12.

14. DS Subrahmanyam, RK Sinha and G Shyam, 2015: Deformability and shear strength properties of rock mass in shear zone area and their impact on the design of major underground structures in hydro-electric projects. Journal Indian Geological Congress, vol. 7(2).

15. DS Subrahmanyam, G Shyam, K Vamshidhar, and Vikram Shankar, 2016: Hydraulic fracturing stress measurements in fractured rock mass at a hydroelectric project, ISRM News Journal, vol.19.

16. DS Subrahmanyam, G Shyam, K Vamshidhar, and Vikram Shankar, 2016: Influence of In situ stress on the alignment of head race tunnel due to the intersection of anticlines at one of the hydroelectric projects. Tunneling Association of India (Paper accepted).

17. E Praseeda, Biju John, C Srinivasan, Yogendra Singh, KS Divyalakshmi and Pijush Samui, 2015: Thenmala fault system, southern India: implication to Neotectonics. Journal of Geological Society India, vol. 86, pp. 391-398.

18. G Gopinath, R Balachander and HS Venkatesh, 2016: Controlled blasting for twin tunnels with a shallow cover under an operating railway line. 11th International Symposium on Rock Fragmentation by blasting, Fragblast11, August 24 – 26 Sheraton on the Park, Sydney, Australia.

19. HS Venkatesh and G Gopinath, 2016: Visit to tunnel boring machine site of Bangalore Metro Rail Corporation Limited. Journal of the Geological Society of India, vol. 85(4), pp 514-515.

20. HS Venkatesh, AI Theresraj, G Gopinath and R Balachander, 2015: Status of blasting research in India. Visfotak, Explosives Safety & Technology Society, Nagpur, vol 9, PP 43 – 53.

21. LG Singh and AK Naithani, 2015: Rock mass assessment of a deep pump house area- A case study. ISEG Golden Jubilee Special Publication Journal of Engineering Geology, pp 630-641.

22. Manoj Kumar, Pijush Samui and A.K. Naithani, 2016: Determination of stability of epimetamorphic rock slope using Minimax Probability Machine. Int. Jour. Geomatics, Natural Hazards and Risk, Publ. by Taylor & Francis, vol. 7 (1), pp 186-193.

23. Prasnna Jain, A.K. Naithani and T.N. Singh, 2015: Performance characteristics of tunnel boring machines and correlation with empirical prediction model – case study from Mumbai, India. ISEG Golden Jubilee Special Publication Journal of Engineering Geology, pp 642-651.

24. Prasnna Jain, A.K. Naithani and T.N. Singh, 2015: Evaluation of engineering geological properties and performance characteristics of tunnel boring machine in basaltic rocks – a case study from India. Proceedings International Conference on Tunnel Boring Machines in Difficult Grounds (TBM DiGs), Singapore, pp 350-357.

25. Prasnna Jain, AK Naithani and TN Singh, 2016: Estimation of the performance of the tunnel boring machine (TBM) using uniaxial compressive strength and rock mass rating classification (RMR) – a case study from the Deccan Traps, India. Journal Geological Society of India, vol. 87, pp 145-152.

26. R Balachander, HS Venkatesh and G Gopinath, 2016: Tunnel excavation on the abutment of an existing Dam. 42nd Annual Conference on Explosives and Blasting Technique, February 01 – 03, 2016 Las Vegas, Nevada.

27. RN Sripad, 2015: Back analysis and validation. Symposium on Advances in instrumentation, Geo-monitoring and validation, 23-24 July 2015, New Delhi.

28. Sandi Kumar Reddy and Vedala Rama Sastry, 2016: Stress distribution on blasting gallery barrier pillar due to goaf formation during extraction, Journal of Institution of Engineers Limited (India), 02 September 2015.

29. Sandi Kumar Reddy and A Rajan Babu, 2016: Cavability studies of immediate roof of seam No. 3 of GDK-10 Incline, SCCL- A Case Study. Proceedings of Seminar on Recent Practices and Innovations in Mining Industry, 19-20 February, 2016, Raipur.

30. Sivakumar Cherukuri, Kencho Dorji and Karma Dorji, 2015: Real time stability evaluation of large underground powerhouse caverns - application of microseismics. ARMA-2015-333, 49th U.S. Rock Mechanics/ Geomechanics Symposium, 28 June-1 July 2015, San Francisco, California.

31. Sivakumar Cherukuri, Vikalp Kumar and Ajay Kumar Singh, 2016: Microseismics for hydro power project tunnels and cavern real time stability monitoring, 26th Mine Seismology Seminar, 16-17 May 2016, Hobart, Australia.

Annexure-8

NEWS LETTER

- Dr HS Venkatesh was nominated as Member of the Expert Committee of the Ministry of Environment & Forests and Cabinet Committee, and periodically attended its meetings.

- Dr HS Venkatesh was nominated as the Convener – Organizing Committee for the International Conference on Recent Advances in Rock Engineering (RARE 2016).

- Dr HS Venkatesh has been nominated as Member to the High Level Committee (Expert Advice) to inspect the site to provide the feasibility of the implementation of the recommendations of NIRM and to make specific recommendations in the matter to enable the government whether to allow the quarry operations in surrounding the Yeluru projects

- Mr A Rajan Babu has become a Fellow of the Institute of Engineers for 2015.

- Dr AK Naithani is nominated as a permanent member of Technical Evaluation Committee (TEC) of National Disaster Management Authority (NDMA), Govt. of India for evaluation of Detailed Project Reports on Landslide Mitigation submitted by State Governments to be funded under “Centrally Sponsored Umbrella Pilot Scheme to Demonstrate Benefits of landslide mitigation”.

- Dr HS Venkatesh, G Gopinath and GC Naveen were nominated as Editorial Members for the Workshop on Natural Resources of Chitradurga District, 13th April 2015, GSI Training Institute, Chitradurga organised by MEAI Bangalore Chapter and Geological Society of India.

- Mr BH Vijay Sekar and Mr K Sudhakar attended “Matlab Expo-2015” held at Bengaluru on 23rd April 2015.

- Dr AK Naithani attended International Symposium on “tackling the challenge of slope stabilization and landslide prevention”, jointly organized by Uttarakhand Disaster Recovery Project (GoU), The World Bank and Japan International Cooperation Agency at Dehradun from 27-29 April 2015 and presented Invited Paper in the symposium.

- Dr Thomas Fechner, Geophysicist, Geotomographie Gmbh, Germany, visited NIRM in May 2015, and gave a 3-day training on Borehole Deviation Probe.

- Mr RN Sripad presented a keynote on "Back Analysis and Validation" in a Symposium on Advances in Instrumentation, Geo-monitoring and validation organized by CBIP at New Delhi from 23 to 24 July 2015, New Delhi.

- Mr K Sudhakar, Mr BH Vijay Sekar and Dr Rabi Bhusan attended “Survey India National Conference-2015” held at Bengaluru on 5th-6th August 2015.

- Dr AK Naithani, Dr DS Rawat, Dr LG Singh and Dr Prasnna Jain attended International Golden Jubilee Conference of ISEG Organized by the Indian Society of Engineering Geology from 27-29 October 2015 at IIT Delhi.

- Mr Sivakumar Cherukuri delivered two lectures at ISM Kolkatta Center in the Short Course on "Application of advanced geophysical methods for rock physics modelling and monitoring seismicity in mines safety" in December 2015.

- Mrs Praveena Das Jennifer, visited the 4th International Exhibition on Metal, Materials and Metallurgical Technology, Equipment & Suppliers (MetEx) on 04th Dec, 2015 at Bangalore International Exhibition Centre, Bengaluru.

- Dr AK Naithani attended 103rd Indian Science Congress organized by University of Mysore from 3rd to 7th January 2016 at Mysuru.

- Mr BH Vijay Sekar attended Second National Dam Safety Conference held at IISC-Bengaluru on 12th-13th January 2016.

- Dr Biju John and Mr Yogendra Singh presented keynote papers on seismotectonic studies, hazard assessment and active fault identification, in the National Seminar on "Earthquake Prediction and Preparedness" on 28th January 2016.

- Dr Biju John delivered an invited lecture during the UGC seminar on Shear Zones and Crustal Blocks of Southern India held at Kerala University on 15th February16.

- Dr V Venkateswarlu and Dr AK Naithani attended the 2nd International Conference on Sustainable Energy and Built Environment organized by VIT University at Vellore on 10th March 2016.

Degree Awarded / Award Received

- Mr GC Naveen was awarded Master of Science (Engg.) by Visveswaraiah Technological University, Belgaum on 9th May, 2015.

- Ph.D Degree was awarded to Mrs Divyalakshmi KS by University of Madras under the supervision of Dr V Ram Mohan, for her work on "Tsunami Threat Assessment of Northern Part of Kancheepuram District, Tamil Nadu, Southeast Coast of India by Numerical Modelling and GIS"

- Dr AK Naithani is a recipient of the Indian Science Congress Association (ISCA), Govt. of India Best Paper (Poster) Award for 2015-2016 in the section of Engineering Sciences.

- Ph.D. Degree was awarded to Mr. Sandi Kumar Reddy by National Institute of Technology Karnataka, Surathkal under the supervision of Prof VR Sastry, Mining Engineering department. The title of his PhD thesis is "A study on stability of barrier pillar and development of design guidelines for blasting gallery panels in thick coal seams in India".

Training Programmes Attended

- Dr VR Balasubramaniam and Mr Goverdhan Kantepudi participated in the training on “Geotechnical aspects of earthquake engineering” at IIIT, Hyderabad July 25-27, 2015.

- Dr DS Subrahmanyam attended the training programme on Science Administration and Research Management conducted by Administrative Staff College of India, Hyderabad from 17th to 28th August 2015.

- Mr G Shyam and Mr S Vikram attended short term course on “Fundamentals of soft computing and its Applications” 09-13 September 2015, Department of Computer Science & Engineering, ISM Dhanbad.

- Dr LG Singh, Dr. Rabi Bhusan and Mr G.C. Naveen attended the training programme on Communication and Presentation Skill (CAPS), organized by the Institute of Management Training & Research, Goa and sponsored by Department of Science & Technology at IMTR, Goa during 21-25 September 2015.

- Mr BH Vijay Sekar participated in Department of Science & Technology (DST) sponsored training programme on “Entrepreneurship Development & Management” in Ahmedabad from 7th-11th December 2015.

- Dr VR Balasubramaniam, participated in the training on Science Administration and Research Management conducted by Administrative Staff College of India (ASCI), Hyderabad during 01-12 February 2016.

- Dr. Sandeep Nelliat attended one week training programme on Managerial Effectiveness Enhancement, organized by the Institute of Management Training & Research, Goa and sponsored by Department of Science & Technology at IMTR, Goa during January 2016.

- Dr SK Reddy attended training programme on Numerical Simulation of Landslide Studies organized by the Department of Mining Engineering, ISM, Dhanbad, during 15-17 February 2016.

- Dr SK Reddy attended training programme on Science Governance and Management organized by the Administrative College of India, Hyderabad, during 29 February - 04 March, 2016.

Foreign Visits

- Mr G Gopinath attended and presented a technical paper in the 11th International Symposium on Rock Fragmentation by Blasting, Fragblast11, during August 24 – 26, at Sheraton on the Park, Sydney, Australia.

- Mr R Balachander attended and presented a technical paper in the 42nd Annual Conference on Explosives and Blasting Technique, during February 01 – 03, 2016, at Las Vegas, Nevada, USA. The paper was adjudged as the Best Paper of the Year.

Annexure - 9

STAFF ON ROLL

(as on 31.03.2016)

Director
Dr V Venkateswarlu

Departments & Regular Staff

Engineering Geology

Dr AK Naithani
Dr Devendra Singh Rawat
Dr L Gopeshwor Singh
Dr Prasnna Jain

Engineering Geophysics

Dr PC Jha
Dr Sandeep Nelliat
Mr Butchi Babu Bongu
Mr YV Sivaram
Mr Sashi Nath Varma

Geotechnical Engineering

Dr DS Subrahmanyam
Mr G Shyam
Mr K Vamshidhar
Mr Vikram S
Mr Shashidhara KN

Environmental & Exploration Geophysics

Dr VR Balasubramaniam
Mrs Praveena D Jennifer
Mr Goverdhan Kantepudi

Numerical Modelling

Mr Sripad R Naik
Dr Rabi Bhusan
Mr BH Vijay Sekhar
Mr K Sudhakar
Mr Aditya Mishra
Mr BNV Siva Prasad

Rock Blasting & Excavation Engg

Dr HS Venkatesh
Mr G Gopinath
Mr GC Naveen
Mr AI Theresraj
Mr R Balachander

Microseismics & Engineering Seismology

Mr C Sivakumar
Mr Vikalp Kumar

Centre for Testing Sercices

Mr A Rajan Babu
Dr GD Raju
Mr S Udayakumar
Mr D Joseph
Mr Sagaya Benady

Mr Royston A Victor
Mr D Prashanth Kumar
Mr Syed Asgar
Mr R Prabhu
Mr S Babu
Mr N Selvaraj

Dr Biju John

Mr Amrith T Renaldy
Mr Yogendra Singh

Mr S Kumar Reddy
Mr AY Bharath Kumar

Project Monitoring Cell

Mr Sultan Singh Meena
Mr A Vijaya Kumar

Administration

Mr AN Nagarajan
Mr S Ravi
Mr JV Sastry
Mrs S Lourdu Mary
Mr N Jothiappa
Mrs CV Lalitha
Mr J Raja
Mrs P Janaki Bhavani

Drivers

Mr P Venkata Reddy
Mr K Manjunath

Mrs KS Divyalakshmi

Staff Resigned during the Year

Mr Pankaj Kumar
Mr Ashok Kumar

Staff Retired during the Year

Mr C Nagaraj
Mr M Victor
Mr N Sounderrajan

Total staff on roll : 60 *(including Director)*

Field demonstration for the Engineers of Border Roads Organization (BRO) during a training course on controlled blasting & excavation engineering Organized by NIRM at KGF from 26-31 October 2015

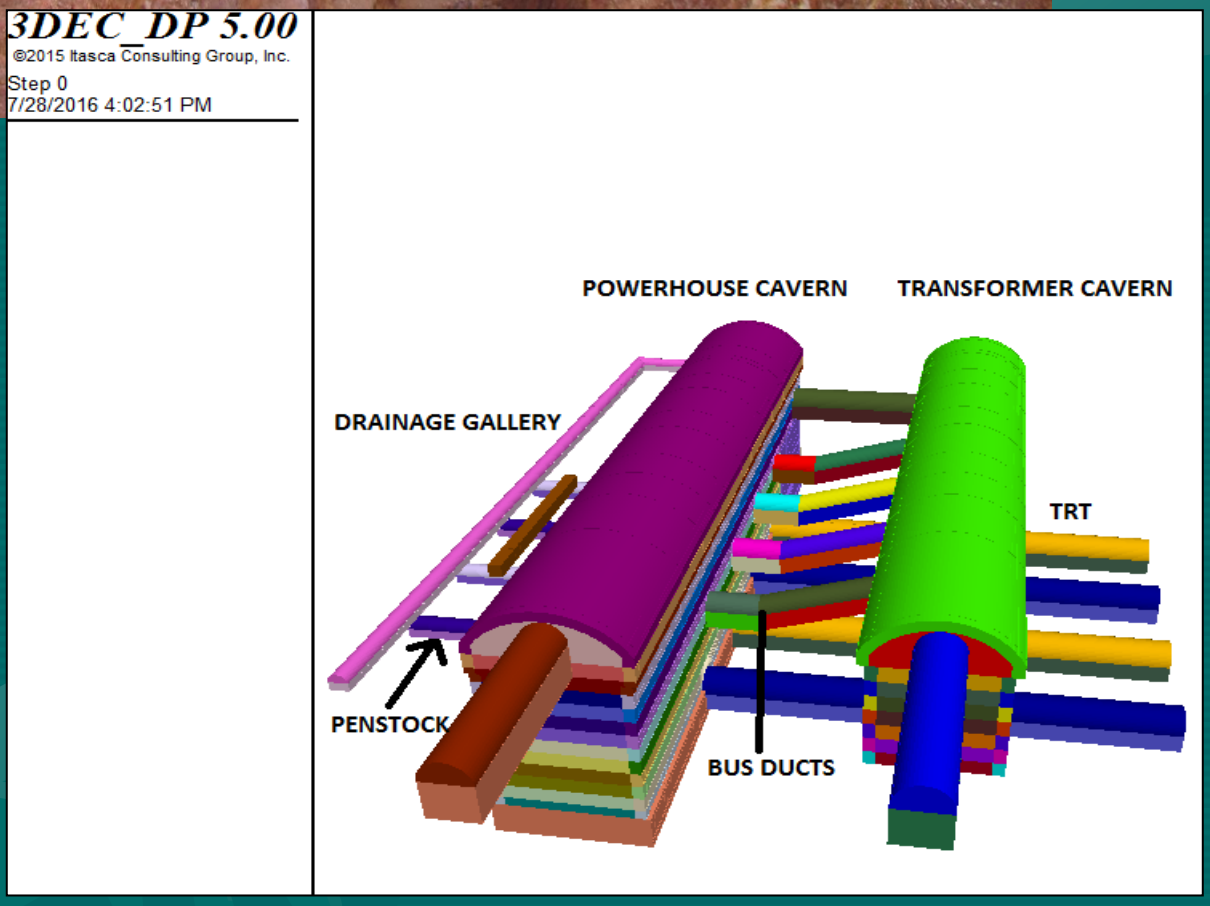
QUALITY OBJECTIVE

NIRM works to:

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

2. Disseminate the knowledge and expertise through publications of papers in national and international journals and seminars.

3. Facilitate skill enhancement through training and workshops.



NIRM is dedicated to carry out advanced research in the areas of rock mechanics and rock engineering to remain a centre of excellence