वार्षिक प्रतिवेदन
ANNUAL REPORT

नेशनल इन्स्टीट्यूट ऑफ रॉक मैकेनिक्स
National Institute of Rock Mechanics

(Ministry of Mines, Government of India)

Champion Reefs
Kolar Gold Fields – 563 117
Karnataka, India

L&T Executives during a training course on Rock Mechanics and Tunnelling Technology Organized by NIRM at Bangalore/KGF during June 23 to 27 June 2014

Field excursion for the Indian Railways Officers during a training course on Tunnelling Technology Organized by NIRM & NGI, Norway during May 19 to 10 June 2014

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Front Cover: Open 75 m deep surge pool view of MGKLIS-PII

Back Cover: 1. Main Access to pump house complex of PCSSLIS-P8
2. View of Padur underground crude oil cavern

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DIRECTOR'S REPORT

The National Institute of Rock Mechanics (NIRM) has been carrying out research and consultancy work in the areas of rock mechanics and rock engineering. The Institute has unique expertise in the key areas of rock mechanics and rock engineering. We are extending our R&D support to whole of the mining industry, civil engineering projects involving underground caverns and tunnels, and to infrastructure projects like underground metros, LPG / crude oil storage caverns, etc. in the country. I am privileged to present the 27th Annual Report of the Institute.

Major Achievements during 2014-15

Our involvement with various projects has continued during 2014-15 with substantial addition in the number of projects and earnings to the Institute. The projects of national importance carried out by the Institute during the year include the geological mapping and design of rock support systems for the underground tunnels and structures for irrigation projects in Telangana, geophysical investigations for hydel projects, numerical modelling for mine shafts and underground caverns of hydroelectric projects, rock blasting close to structures, blast design for limestone mines and canal works, and proof testing and non-destructive testing (NDT) of wire ropes, mining machinery and their accessories.

Site Characterization

NIRM Scientists completed the site characterization studies for various packages of Pranahita-Chevella Sujala Sravanthi irrigation project in Telengana. These included engineering geological and geophysical investigations, and determination of in-situ stress parameters.

Engineering geological studies were also carried out for estimation of the stability of surge pool and pump house area of Mahatma Gandhi Kalvakurthi Lift Irrigation Scheme in Mahabubnagar district, Telangana, during and after its construction. Geophysical investigations for the Dam & Desilting Area of Nikachhu Hydropower project, Tashiling, Trongsa, Bhutan, have been completed.

Design & Monitoring

NIRM carried out numerical modelling for stress analysis, stability evaluation and support design for various hydel, mining and other infrastructure projects. NIRM carried out analysis of instrumentation data of dam, dam area, desalting complex, power house complex, TRT outfall area and Surge Shaft area of Nathpa Jhakri Power House Scheme, Himachal Pradesh. Similar studies have been continued at the Power House Complex and Desilting Chamber at Tala Hydel Project, Bhutan.

Excavation Engineering

A number of projects have been taken up and completed by NIRM Scientists in the area of blast design. Controlled blasting techniques were applied for the excavation of various components of Peruvannamoozhi, Pazhassi Sagar and Bhoothathankettu Small

Hydroelectric Projects, Kerala. The technique was successfully used for safe blasting close to existing urban structures for Bagmane Developers Pvt. Ltd., Bengaluru. Similar design was made for excavation of the hot and cold water tunnels near 5 x 6 Operating Units of Rawatbhata Atomic Power Plant, Rajasthan.

NIRM Scientists have developed an approach for speedy construction of Road Under Bridges. With this approach, it would be possible for the Railways to complete the excavation in hard rock and RUB erection within 10 hours as compared to the conventional one-month operations. This method would be useful where the critical structures (which should not get disturbed due to blasting) are beyond 200 m.

To study the velocity of detonation of ANFO and bulk explosives, ground vibration and air overpressure studies were made at Nawabpet Talamanchipatnam Limestone Mines of Dalmia Cement (Bharat) Limited, Kadapa (AP), at the Ramagundam mines of Singareni Collieries Co Ltd (Telangana), at Sangam Kalan limestone mines of India Cement Ltd (Tandur, AP), and at Morbi Branch Canal Project, Sardar Sarovar Narmada Nigam Ltd (Gujarat).

Testing Services

As an accredited test laboratory, NIRM has carried out proof testing and non-destructive testing of mining components in the mines of Singareni Collieries Co Ltd, Hindustan Zinc Ltd. and NALCO. Services were also rendered to other private companies for testing works both in-situ and in the laboratory, for testing of rocks, wire ropes, mining machinery and their accessories, as per the standards of the International Society for Rock Mechanics, and the guidelines of Directorate General of Mines Safety and as per international standards.

Training Courses

NIRM conducted four training programmes during the financial year 2014-15. One of them is for the Indian Railways, in which 20 executives of the Indian Railways were trained on the subject “Tunnelling Technology”, for a period of two weeks at Bengaluru and for one week at Norway. Similar course was conducted at NIRM for the engineers of L&T in two batches – senior level and junior level.

Performance at a Glance

During 2014-15, NIRM completed 39 research projects, and continued investigations for another 58 projects. NIRM scientists contributed a total of 21 technical papers in various national/international journals and symposia.

NIRM is thankful to all the government organizations and private industries for sponsoring the research projects. The guidance from the Peer Review Committee has been invaluable; and the support from the Governing Body and General Body of the Institute is gratefully acknowledged. The self motivated army of Scientists and staff of the Institute have made it possible for the Institute to see one more successful year. We are hopeful that the future years would be still more productive for the Institute.

V Venkateswarlu
Director

1. ENGINEERING GEOLOGICAL INVESTIGATIONS

Engineering geological investigation provides comprehensive geological and geotechnical information for different civil engineering structures during pre-construction, construction and post-construction stages. The inputs of geological and geotechnical 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 2014-15, department undertakes works related to detailed geological investigations in various stages of the project developments and completed three projects, and five projects are in progress.

- Construction stage engineering geological investigations of the foundation levels and excavated vertical surfaces of surge pool and pump house (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme–II, Mahaboobnagar of Telangana State were carried out. The objective was to advise suitable measures for stabilization all the sides of surge pool and pump house and to advice suitable engineering measures for the treatment of foundations of surge pool, pump house, service bay, annexure part-A and part-B based on detailed engineering geological investigations (Fig. 1.1 & 1.2). Geological mapping on the 1:200 scale of the pump house and surge pool walls and foundations was carried out using crane and traverse method. In between surge pool and pump, rock ledge was mapped, on which multiple storey annexure building is being constructed. For the granite rock masses of the walls of surge pool and pump house the assessment of Tunnelling Quality Index 'Q' was done based on the rock joints characteristics, while for granite rock mass of rock ledge between surge pool and pump house, floors of pump house, surge pool, service bay, annexure part-A and part-B the assessment of RMR was done. The excavation was delayed by more than 36 months because of the uncontrolled blasting and very unfavourable geological discontinuities in the surge pool and pump house areas. Rock on all the sides of the surge pool and pump house was partly slided, due to presence of unfavourable discontinuities and shear zones. Excavation has completed in July 2014 with great difficulty and with controlled blasting.

Fig. 1.1 Walls of pump house are supported with the SFRS and rock bolting

Fig. 1.2 False portal for the construction of draft tube

- The IOT Infrastructure & Energy Services Ltd assigned the job of assessment of foundation condition and for advising on stability of vertical cuts/excavated surface of Plant Water Pump House (PWPH) area at Rajasthan Atomic Power Project (RAPP) Units 7&8. After investigations approved original design was modified. In the design, six numbers of shear keys were provided in the foundation, which were eliminated by changing the angle of repose (from 30^{o} to 80^{o}-85^{o}). It was observed that there will be no lateral movement as the rock are very low dipping (up to 5 degree) and self standing for the last 10 years. As per the foundation condition consolidation grouting was also eliminated. PCC of M15 grade filling in the area between PWPH walls and excavated rock face, from the rock bed at the bottom of the raft up to the ground surface was recommended, if adhesion between concrete and rock mass is to be considered. As per IS: 13063 – 1991, an adhesion value of 1-2.5 kg/cm^2 between concrete and rock mass was recommended.

- 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 and transformer cavern 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. 1.3 & 1.4). This scheme comprises of 2.5 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 pump house and transformer cavern is being done from access tunnels, which are joining the caverns from left side. As per the agreement Phase-II (up to March 2015) is successfully completed and for Phase-III investigation work is being carried out.

Fig. 1.3 Overbreak in left main tunnel (LMT) which was day-lighted at Ch. 3.400 km

Fig. 1.4 Views of 25 m dia and 47 m deep cone shaped chimney at the surface

- The Package - 12 of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (PCSSLIS) is being 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 (Fig. 1.5). 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 are carried out for the underground surge pool and pump house. 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 is 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). All the investigations are completed and synthesis of data is being carried out.

Fig. 1.5 Earlier open pump house and surge pool were proposed which are now underground structures

- Engineering geological investigations are 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 (Fig. 1.6). 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 is 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 are done on the basis of the geological discontinuities observed on the slope.

Fig. 1.6 TRP and TRC area of Pulichintala hydro electric scheme

- Construction stage engineering geological mapping 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, identification of geological defects and recommendations of suitable engineering measures. The floors were examined on a grid to grid basis; the size of grid is 1 m x 1 m. All the lithological and structural features are observed and mapped using Total Station Surveying equipment (Fig. 1.7). Classification of rock mass using Rock Mass Rating is done and based on investigations recommendations for the treatment of foundations are being given. Three reports pertains to NDCT 7A, 7B and 8A are submitted.

Fig. 1.7 Foundation level of NDCT-8A of RAPP Unit 8

- Engineering geological investigation of the Over Head Tank (OHT) foundation has been carried out for SNC-LAVALIN. SNC-LAVALIN has 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 are 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 (Fig. 1.8 & 1.9). 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. Field investigations are completed and final report is under preparation.

Fig. 1.8: View of foundation towards NW direction

Fig. 1.9: View of foundation towards SE direction

2. ENGINEERING GEOPHYSICAL INVESTIGATIONS

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 2014-15, six projects were undertaken including one S&T project sponsored by the Ministry of Mines. Details of the work done in these projects are:

- Dr. B. R. Ambedkar Pranahita Chevella Sujala Sravanthi Lift Irrigation Scheme (PCSSLIS) envisages diverting 160 TMC of water from Pranahita River to Chevella Reservoir through multistage lifting, series of canals, tunnels and storage tanks. This project creates irrigation facility for 16.50 lakh hectare areas in drought prone districts of Adilabad, Nizamabad, Karimnagar, Medak, Warangal, Nalgonda and Rangareddy. The entire project is divided into 28 packages for operational convenience and rapid implementation. The present work is sought from Package-24 which consists of 4.625 km gravity canal and 1.530 km long, 7m dia. horse shoe type tunnel from 119.180 to 120.710 km with a discharge capacity of 79.20 cumecs of water. The alignment of the tunnel is N20°W - S20°E and water flow towards south southeast direction. This water will be drawn from Poddutur tank and carried through gravity canal, tunnel and by lifting/pumping into Chevella tank to create irrigation facility to the neighboring 13,200 acres of land. In order to investigate the rock mass conditions along the proposed tunnel alignment, surge pool and pump house at the end of tunnel, geophysical survey using seismic refraction method was carried out between chainage 119.180 - 120.940 km. Entire stretch was covered in 10 survey lines, out of which four lines of 230 m each was surveyed with explosive source and remaining six lines of 115m each with hammer source. Seismic refraction survey was carried out along the proposed tunnel alignment with geophone spacing of 5m/10m covering total length of 2 km using explosive source. Velocity sections were obtained from the seismic survey and correlated with the borehole data (Fig. 2.1). Based on the observation of seismic velocity, tunneling medium along the proposed tunnel alignment is categorized into four categories. (i) The subsurface with insufficient strength to hold overburden where open cut excavation was recommended. (ii) Subsurface medium OK for tunneling but required support system. (iii) Subsurface medium good tunneling medium, and (iv) The proposed excavation may be made deeper than proposed. The final report on the subsurface medium below the proposed tunnel alignment along with the recommendations and the rock types was submitted in August 2014.

- Seismic refraction survey at the Etalin Hydro Power Project, Arunachal Pradesh, EHEPCL was carried out. The Etalin Hydroelectric Power Project envisages constructions of diversion dam along two rivers, namely Dri and Tangon, both being tributaries of river Dibang and having their confluence at Etalin Village. The project has two limbs, one each on Dri and Tangon river. The water conductor system in this

project consists of intake structure, desilting basin and two head race tunnels of 12 km and 12.5 km length. These two HRT's leads to a combined power house location near Eatalin Township. The proposed 155 m high dam across the Dri River is near Eron village about 25 km from Etalin and 90 m high dam across Tangon river is near Avonli village about 17km from Etalin. With this set-up it is proposed to generate 3097 MW hydropower through this project.

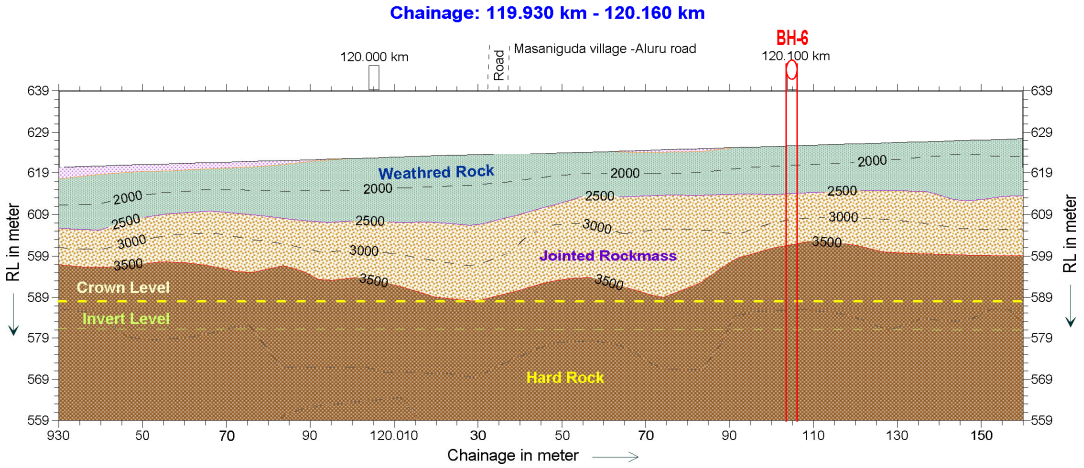

Fig. 2.1 Seismic velocity section between the chainage 119.930 km to 120.160 km

As part of the geotechnical investigations during DPR stage, surge shaft and pressure shaft areas of Tangon and Dri limbs were investigated by six drill holes. Out of these six drill holes, one was at the surge shaft and another one at pressure shaft. Borehole data revealed the presence of sand and weathered rock mass, which extended down to 50 m to 60 m depth. In order to map the lateral and depth extension of such zones (sandy strata), EHEPCL requested to carry out detailed geophysical investigations along the suspected lines. Accordingly, seismic refraction survey was carried out along 10 lines at surge shaft area to delineate presence of sand deposit and assessing the bed rock profile. In addition to the surge shaft area, survey was also carried out at Dri-Mat, Tangon DT outlet and Plunge pool areas for assessing the bed rock profile and estimate subsurface rock mass condition. Explosive source was used in the survey layout for six seismic profile lines with geophone spacing of 10 m in the surge shaft area and two profile lines in each Dri mat and Tangaon River. The entire data was processed using MK6 and Rayfract software's and prepared the seismic velocity sections for the respective lines. The velocity sections obtained from this survey was correlated with geology and borehole data. Correlation of seismic sections with the available borehole sections showed that at most of the places both seismic and borehole sections matched well within the error limits of the data processing (Fig. 2.2). As regards sand deposits encountered in a few boreholes, their level matched with the velocity index of 1500-2000 m/sec which form upper part of the weathered layer rock mass. It appeared that the sand deposits were highly compact in nature giving rise to such a high velocity (normal velocity in sand is less than 1200 m/sec). Physical observation in the river cutting along the right bank of Tangaon river revealed the presence of thick sand and river borne material (RBM) which was confirmed in the presence of a thick overburden along the survey lines (TDT-2) of that area. Going by the disposition of OB-WR interface, it was suspected that the thick sand layer might be

present all along the Dri Limb area. Final report incorporating the results of the seismic survey was submitted to EHEPCL highlighting the subsurface medium and presence of sand deposit on the DRi Limb in the surge shaft area.

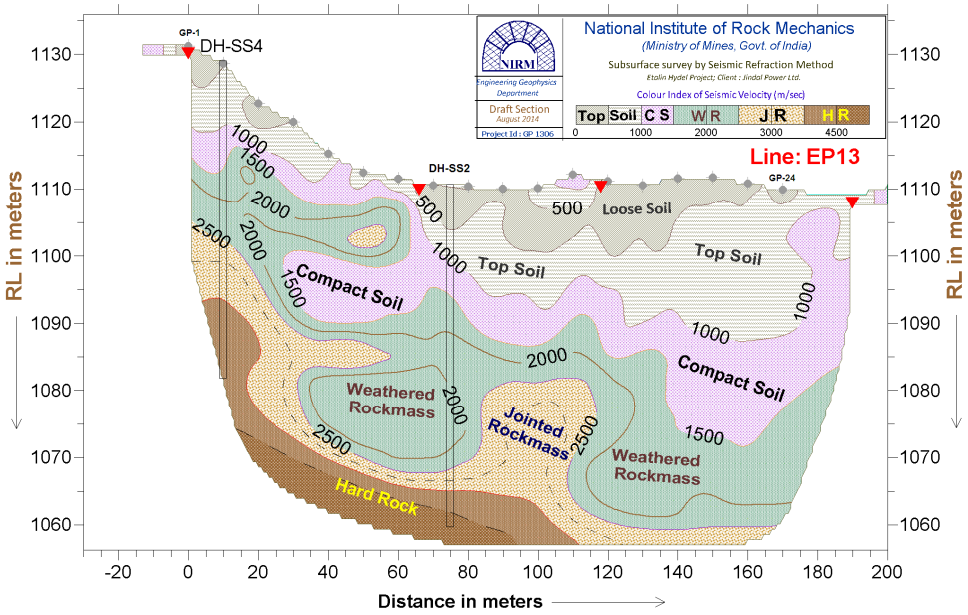

Fig. 2.2 Sample seismic velocity section along the ridge at surge shaft area of EHEPP

- M/s Soham Renewable Energy Private Limited (SREPL) proposed to construct a hydro power plant with a total installed capacity of 12.5 MW (4 x 3.125 MW) at Kumaradhara River near Nekkiladi village, Karnataka. The project site is close to the confluence of Kumaradhara River with Netravathi. The project envisages construction of a diversion barrage across Kumaradhara River to make use of a gross head of about 7.3 m. A power canal is proposed to draw water from the pond behind barrage to the powerhouse. The tail water is discharged back into the river through a short channel. Geophysical survey was carried out to ascertain the bed rock level and nature of rock mass across the river and around the proposed barrage alignment. The abutments on the left bank are being designed such that there is no over-flanking during floods. Therefore, soil profile is required on the left bank along the direction of river flow for the design of abutments and diversion structure. Similarly, soil profile is required on the right bank near the power house location. In view of these objectives, plan of geophysical survey is drawn as shown in fig. 2.3. Accordingly seismic refraction survey on the left and right bank abutments was carried out using hammer source and geophone spacing of 5 m. Seismic refraction survey across the river using Hydrophones with 2 m spacing was also carried out. The entire data was digitally processed and the seismic velocity sections for the respective lines were generated. Correlation of seismic sections with the available borehole sections showed that at most of the places both seismic and borehole sections matched well within the error limits of the data processing. The combination of on-land and water studies mapped the strata condition across the river from the right bank to left bank abutment. This study suggested that the river course was shifted towards right bank side. Based on survey results alternate suitable location was suggested for construction of barrage and rock line condition along the suggested barrage axis was also provided (Fig. 2.4).

In addition, it was recommended that the abutment on left bank should preferably go deep into the bank to ensure its foundation on the hard rock. The central portion may be grouted below the foundation till the hard rock level. This involves grouting up to a depth of 5-7 m. The final report was sent to SREPL incorporating all the comments and recommendations for the construction of barrage at Nekkiladi.

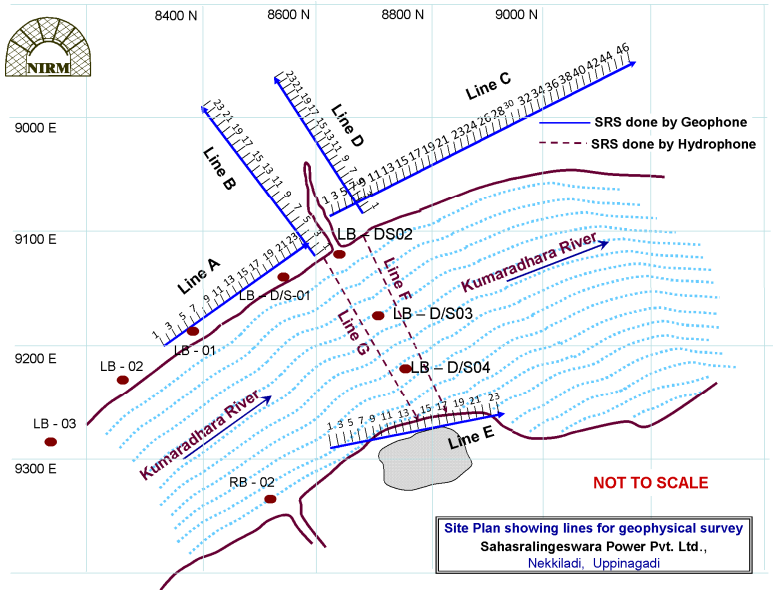

Fig. 2.3 Seismic Refraction lines (A to G) on left/right banks and across river at the site

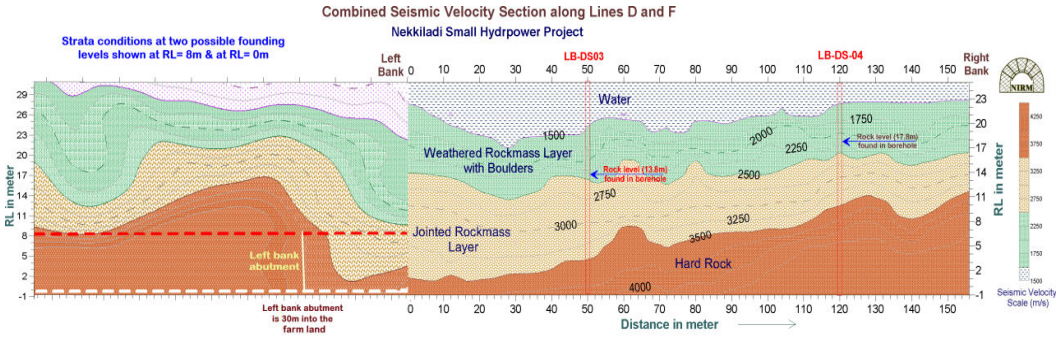

Fig. 2.4 Combined (across river and on the left bank) seismic velocity section showing the rock line in the study area

- A section of the Haldia-Maurigram-Raniganj-Barauni (HMRB) pipeline for transportation of crude oil from port city of Haldia in West Bengal to refinery at Barauni in Bihar passes through the Raniganj-Asansol coalfield area in West Bengal. In this stretch, there are several old and abandoned coal mines as well as some active coal mines. There had been instances of land subsidence proximate to and below the pipeline in this area leading to damage and leakage of oil from the pipeline. In our previous study it was reported that a deep seated cavity at around 50 m depth is present in the Kajora area at chainage 258.050 km. This was suspected to be a mining gallery which had induced subsidence whose effect had reached as close to 5 m depth

below the pipeline. Another vulnerable stretch was reported between chainage 257.730-257.930 km which was suspected either close to or over a mined out gallery. This location was close to the pipeline bend (Chainage 257.784 km). Both these features had potential of inducing a wider subsidence which might pose a threat to the pipeline. As per our recommendation, IOCL decided to go in for a repeat survey for finer details of subsurface condition. Accordingly again the geophysical survey was taken up for evaluating the stability of oil pipeline in Kajora area of West Bengal. The layout for the survey lines as per our earlier suggestions was a grid-like layout for high-resolution resistivity imaging (up to 15 m depth). The grid layout for detailed survey was suggested as 50 m x 50 m spacing and borehole locations for cross hole survey as shown in fig. 2.5. It was also requested to support for some additional seismic refraction survey to cross-confirm the result. In the present case, the electrical resistivity imaging was done by using dipole-dipole array with an electrode spacing of 3 m by using a 48-electrode imaging system. Data acquisition was done in the automatic mode with all parameters defined in a control file. The number of datum points to reach the desired depth of investigation was also defined in the control file. In total we have carried out 16 across ERI lines with a separation of 50 m and 3 along lines over the pipe and ±50 m. Similarly seismic refraction survey was carried out with the same fashion like ERI with a geophone spacing of 5 m and hammer source. The entire sets of data processed and subsurface sections were prepared. A sample section along line-11 showing results of both ERI and SRS surveys are shown in fig. 2.6 where an abnormal low resistivity and seismic velocity is observed below the pipeline. Going by the series of data analysis involving resistivity imaging and seismic velocity surveys, it was confirmed that the subsurface below the stretch of pipeline between chainage 258.200-258.450k m is prone to subsidence. Given the past history of subsidence close to the pipeline, the present survey only confirms that the zone of subsidence is now approaching below the pipeline between 258.050 - 258.450 m chainage. This subsidence, which is bound to happen, will be wide enough to sag the pipeline. Final report was forwarded to IOCL incorporating all the comments and recommendations for mitigating threat to the pipeline stability.

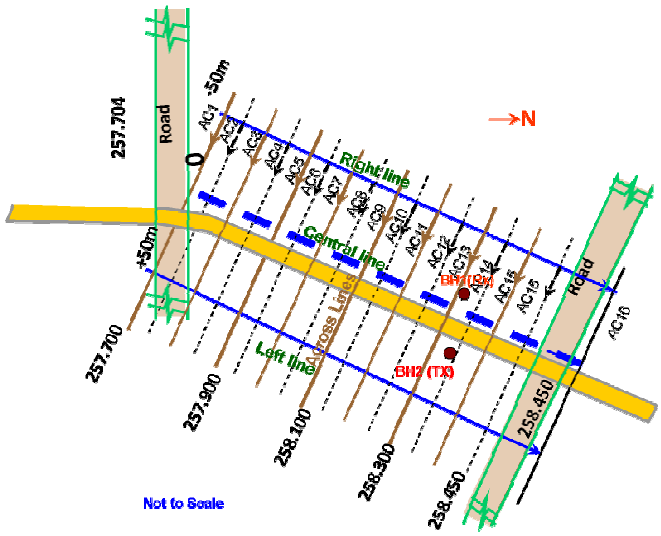

Fig. 2.5 Site Plan showing proposed lines of survey at Kajora area

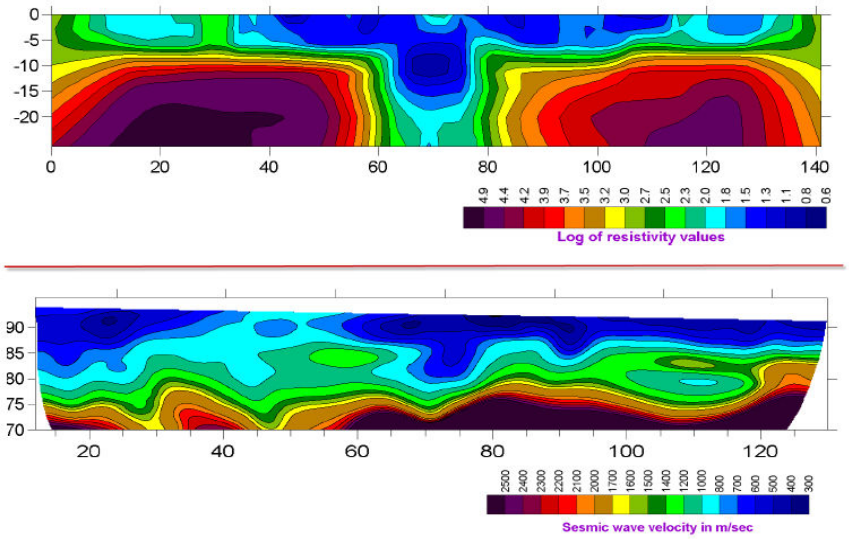

Fig. 2.6 Seismic velocity and ERI pseudo sections at across line 11 showing similar low velocity and low resistivity zone exactly below the pipeline.

- MOM sponsored S&T project entitled development of a viable technique for assessment of reclaimed land and for safety of structures under settling environment has the following objectives:
  1. In-situ geophysical measurements of P and S wave velocity for evaluating soil stiffness and other relevant parameters for assessing settlement potential
  2. Non-destructive testing of ground and structures based on integrated geophysical techniques
  3. Laboratory measurements on rock samples
  4. Qualitative and quantitative analysis of geophysical results
  5. Derive site-specific relationship between rock mass properties and measured parameters
  6. Formulation of a viable geophysical methodology for evaluating integrity of structure and stability of subsurface (ground, foundation etc.)

  In order to do so, integration geophysical techniques proposed are: (i) Multi-channel Spectral analysis of Surface Waves (MASW), (ii) Ground Penetrating Radar, (iii) Cross-hole seismic (CHS), (iv) Impact Echo (IE) and (v) Sonic measurements on samples (SM). Progress during the reporting period is discussed here. Earlier, we had carried out P and S wave studies for evaluating the soil stiffness at Shenoy Nagar area of Chennai Metro project. There we had developed a site specific relationship between static and dynamic parameters for a settling environment. This was the first objective of the S&T project. During this period, we carried out cross-hole survey in the Kajora area of IOCL pipeline 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 1m respectively. To carry out P-wave survey, borehole sparker source was used to generate compressional waves. 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. 12 channel hydrophone with a spacing of 2 m was used for receiving the signal. Both P- and S-wave velocities were plotted in the vertical section (Fig. 2.7). The survey result showed dome interesting pattern. While P and S wave velocities in general increase with depth, in this peculiar zone S-wave velocity decreased while there is increase in P-wave velocity between 10-16 m depth. 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 phenomenon was observed only under controlled experimentation in the laboratory, this was the first time 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".

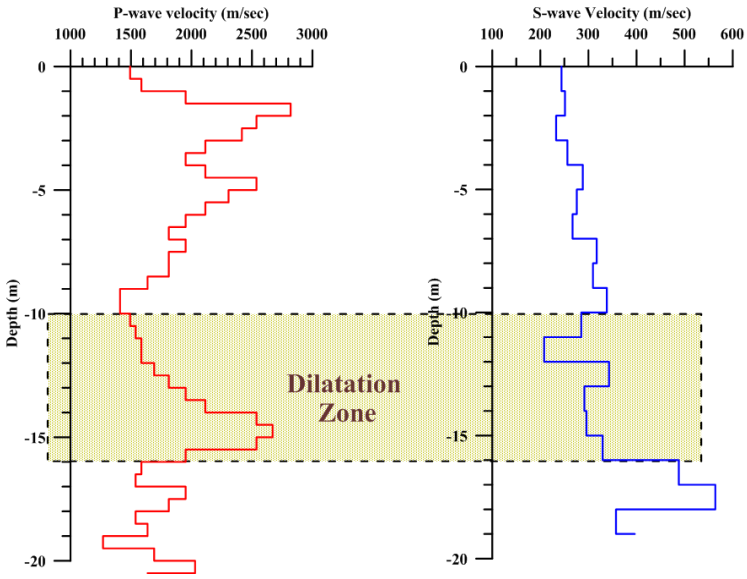

Fig. 2.7 Variation of seismic (P and S) wave velocity with depth showing plastic zone

- As part of multi storey Jayadeva hospital building construction at Mysore, the assessment of rock mass before excavation was required for the excavability of site. For this detailed investigation of geological, geophysical, point load and laboratory testing were carried out by the CTS department. As a supplementary investigation, seismic refraction survey was also done surrounding the four excavated pits with 13 refraction profile lines as per layout shown in fig. 2.8. All lines were surveyed with 3 m geophone spacing using hammer source. Based on the survey data, seismic velocity sections along all the lines were generated and correlated with the geological maps of the area. A sample seismic section is shown in fig. 2.9 in which hard soil and soft rock layers were indexed based on the velocity criteria. The volume of material to be excavated was also calculated. An integrated report was alter submitted by the CTS department with rock mass classification incorporating results of geological, geophysical, point load testing at site and laboratory testing of samples.

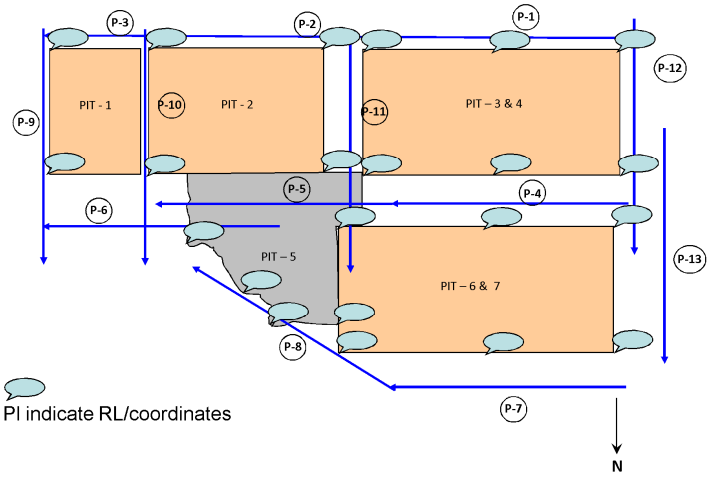

Fig. 2.8: Lay out of seismic refraction survey lines at Jayadeva hospital site

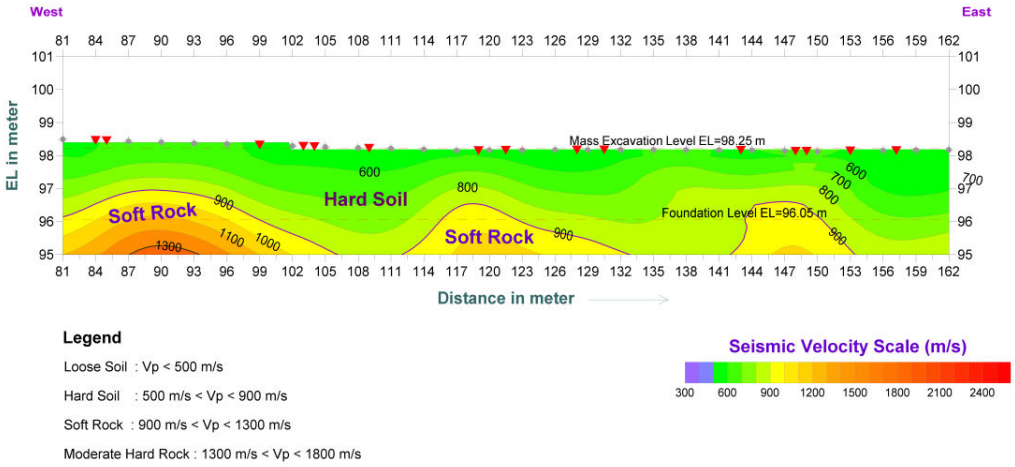

Fig. 2.9 Sample seismic velocity section along one of the survey lines

3. GEOTECHNICAL ENGINEERING INVESTIGATIONS

Geotechnical investigations are an essential and integral part for the design of any underground structure and super structure. In the design of underground and surface structures the decisions for geometry, shape, dimensioning, 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, layout, stope designing and sequencing of mining are dictated by geotechnical investigation results for safe and economical extraction of the mineral. Geotechnical Engineering 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 this period six industry sponsored projects and one S&T project sponsored by Ministry of Mines are completed. Two industry sponsored projects and one S&T project funded by Ministry of Coal are going on.

- Wangchhu Hydro Electric Project is located in Chukha district of western Bhutan. The project envisages construction of 134 m high concrete gravity dam and a surface powerhouse on the left bank to generate 570 MW of power. Based on the geological mapping it is assessed that bed rock on both the banks over which the concrete gravity dam to be founded consists of quartzite with occasional phyllite interbands of Shumar Formation. The scope of the work was to determine the in-situ stress, in-situ shear (Fig 3.1) and modulus of deformability parameters at proposed dam site. Results are showed c = 3.30 kg/cm^2 and ϕ = 37.60 for peak shear and c = 2.70 and ϕ = 37.2^o for residual shear for rock to concrete interface at right bank. For the same location rock to rock interface c = 3.40 kg/cm^2 and ϕ = 37.950 for peak shear and c = 3.1 and ϕ = 36.87^o for residual shear parameter. In the left bank area rock to concrete c = 3.05 kg/cm^2 and ϕ = 38^o for peak shear and c = 2.90 and ϕ = 36.9^o for residual shear and rock to rock interface c = 3.19 kg/cm^2 and ϕ = 38.30 for peak shear and c = 2.99 and ϕ = 38^o for residual shear are In-situ shear parameters. The modulus of elasticity (E_e) varied from 5.8 to 5.21 GPa for right bank, and 5.21 to 6. 51 GPa varied for left bank. The modulus of deformability of rock mass ranged from 4.7 to 5.39 GPa for right bank, from 5.06 to 5.09 GPa for leftbank.

- Nikachhu Hydropower project is located between the Nikachhu/Chhunabchhu and Nikachhu/Mangdechhu confluences in Trongsa District, and is approximately 3 km downstream from Chhunabchhu confluence. The project involves construction of 38 m high concrete gravity dam (from the deepest foundation level) across river Nikachhu and an underground powerhouse near the village Norbuodi. The project area lies in high Himalayan sequence and is surrounded by rocks belonging to Thimpu Gneissic Complex (TGC) and meta-sediments of Thimpu-Chekha Group. The scope of the work was to determine the in-situ stress, in-situ shear and modulus of deformability parameters at proposed underground powerhouse. The results of the investigations are σ_v = 8.66 MPa, σ_H = 12.24 ± 1.46 σ_h = 8.16 ± 0.9735 MPa and the recommended orientation of the underground powerhouse excavation is N 60^o. In the powerhouse area rock to concrete c = 3.8452 kg/cm^2 and ϕ = 41.3^o for peak shear and c = 3.4611

and ϕ = 41.2^o for residual shear and rock to rock interface c = 3.0557 kg/cm^2 and ϕ = 39^o for peak shear and c = 2.7622 and ϕ = 38.6^o for residual shear are In-situ shear parameters. The modulus of deformability of rock mass ranged from 7.5 to 9.26 GPa.

Fig. 3.1 Complete setup of direct Shear test equipment at Wangchhu HEP site

- 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, in-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 in-situ stress parameters at the vicinity of underground pumphouse of package-12 for its best orientation. The hydrofracture stress measurements were conducted in all the six zones from 26.00 m to 42.00 m depth (Fig 3.2). The shut-in pressure derived from the stress plot ranged from 1.10-2.24 MPa. The results of the investigations are σ_v = 1.11 MPa, σ_H = 1.84, σ_h = 1.24 ± 0.25 MPa and the recommended orientation of the underground excavation is N150^o.

- The Teesta-IV Hydroelectric Project is proposed along river Teesta in Sikkim. The project envisages construction of 108.5 m height concrete gravity dam and an underground powerhouse to house 4-units of turbines of 130 MW each to generate 520 MW of power. The main litho units exposed in and around Teesta–IV hydroelectric project include Daling Group of Meta-volcano Sedimentaries, Lingtse Granite Gneiss

and Central Crystalline Complex comprising high grade Central Crystalline (CCG), high grade Meta-sedimentary units and some calc-silicate gneisses rocks with impure marble. The scope of the work was to determine in-situ shear parameters by direct shear method and in-situ deformability of rock mass by plate load test for the proposed underground intake drift. Results showed in intake drift, rock-to-rock interface c = 2.50 kg/cm^2 and ϕ = 27.9^o for peak shear and c = 2.16 and ϕ = 27.5^o for residual shear are in-situ shear parameters. The modulus of deformability of rock mass 4.097 to 4.418 GPa at Intake drift.

Fig. 3.2 Straddle Packer System used for Hydrofracture test at Pranahitha Chevella Sujala Sravanthi Scheme Package-12

- The Teesta-IV Hydroelectric Project is proposed along river Teesta in Sikkim. The project envisages construction of 108.5 m height concrete gravity dam and an underground powerhouse to house 4 units of turbines of 130 MW each to generate 520 MW of power. The scope of the work was to determine in-situ shear parameters by direct shear method and in-situ deformability of rock mass by plate load test at different locations inside the proposed right abutment dam axis (Fig 3.3). The results of the investigations of dam axis rock-to-concrete c = 4.01 kg/cm^2 and ϕ = 41.3^o for peak shear and c = 3.37 and ϕ = 40.7^o for residual shear and the modulus of deformability of rock mass range from 5.450 to 6.451 GPa for dam axis.

- The proposed Etalin Hydroelectric Project is located in Dibang valley district of Arunachal Pradesh that shares its international boundary with China. The project envisages construction of 102 m and 81 m high diversion dams across the rivers Dri and Tangon respectively, two separate water conducting systems conveying the designed discharge to common underground powerhouse. Regionally, the area of the proposed project is located on the eastern limb of the Eastern Syntaxial Bend (ESB) in eastern part of Arunachal Pradesh that exposes rocks ranging in age from Proterozoic to Tertiary and Recent deposits. Trans Himalayan rocks belonging to Mishmi Group and Tidding Suture Zone, separated from each other by Lohit Thrust and delimited in the SW Tidding Thrust exposed in the northern part of the area. NIRM has carried out in-situ stress measurements of the proposed underground power house rock mass at different locations. The results of the investigations are σ_v = 8.29 MPa, σ_H = 12.97 ±

0.17, σ_h = 5.19 ± 0.07 MPa and the recommended orientation of the underground excavation is N50^o.

Fig. 3.3 Complete set up of Plate Load equipment at powerhouse cavern of Teesta-IV hydroelectric project

- S&T project sponsored by Ministry of Coal entitled development of state-of-the-art facilities for in-situ stress measurement by hydraulic fracture method in porous and fractured rock mass is going on. There are various methods to determine in-situ stress parameters, each having its own advantages and limitations. Among the methods available, the hydraulic fracturing method is the most commonly adopted method for in-situ stress measurements in the mining and hydroelectric projects because of its simplicity, reliability and economic viability. But the reliability and validity of this method becomes questionable in porous and fractured rocks encountered in underground tunnels and mines These limitations are experienced ever since the introduction of this method, especially in porous and fractured rocks. This is due to the fact that pressure cannot be developed if the rate of leakage in the formation is equal to or higher than the flow rate applied for fracture initiation. This problem of non-generation of water pressure can be tackled by (i) use of a high flow rate, and (ii) Use of a high viscosity fluid.

  The main objective of this research project is to develop a proper technique of hydraulic fracturing for stress measurement in porous and fractured rocks, found in some of the coal mines and some of the hydroelectric projects in the Himalaya. The first two sites were selected inside the proposed power house tunnel of one of the hydroelectric projects in the Himalaya and another two sites in underground coal mines where the rock formations are fractured and porous. Boreholes were drilled up to the depths of 10 to 30 m depending upon the requirement and site conditions. In-

situ stresses were measured inside these boreholes by hydraulic fracturing (Fig 3.4) method using either a (high) viscous fluid or (variable water) manipulation of flow rate or combination of both. The stress evaluation was made using latest software. Stress measurements were conducted by using different flow rates of water inside the fractured rocks. The stresses evaluated by this method was correlated with normal flow rate hydraulic fracturing method at the same locations where the rock mass was not fractured. Stress measurements were conducted by hydraulic fracturing method by using high viscous liquid in porous rocks. The stresses evaluated by this technique were correlated with stress measured by overcoring method. The stress measured by overcoring (Fig 3.5) method was used as bench-mark as this method does not suffer from the presence of porosity of the rock. The correction factor was introduced in the stress evaluation by hydraulic fracturing method in fractured and porous rocks. This new technique will be helpful in conducting the stress measurements in porous and fractured rocks, which will be highly beneficial to both mining and hydropower related excavation.

Fig. 3.4 Straddle packer & twin tube system

Fig. 3.5 Overcoring test at KTK-8 Incline

4. ENVIRONMENTAL AND EXPLORATION GEOPHYSICAL INVESTIGATIONS

Environmental and Exploration Geophysics Department works with an objective of research and application of near surface geophysical imaging techniques to addressing problems in our surrounding environment. Typical problems are like evaluation of urban construction, subsurface utilities imaging, environmental impact assessment and investigation of project sites for natural hazards like earthquake and landslide areas vis-à-vis major structures. Thus, as part of the efforts in site characterization exercise seismotectonic investigations are carried out for feasibility and design of crucial structures like nuclear establishments, dams and strategic underground structures, by combining geological, geophysical and geotechnical information of a site. The details of the project activities of the department are as follows:

- There are a few major and several minor lineaments in and around the site of Kudankulam Nuclear Power Project (KKNPP). Among them, surface signature of a suspected lineament, L2, could not be traced as part of the seismotectonic evaluation within 30 km radius around this site. Hence, Multi-channel Analysis of Surface Wave (MASW) was carried out in effort to explore for subsurface signatures at different locations of the alignment. The MASW survey was carried out in collaboration with Earth Sciences Department of the Indian Institute of Science (IISc), Bengaluru. For this purpose the lineament was marked on the ground, based on the coordinates from SEISAT map as well as with the help of GPS, and survey lines were fixed. The MASW data acquisition (Fig. 4.1) was carried out by IISc under the supervision of NIRM in and around known fault locations and an unidentified L2 lineament. 24-channel seismic array was designed for acquiring seismic data using Geode seismograph with sledgehammer as the source. Data processing results indicate contrast in shear wave velocity in the subsurface roughly aligning with the geological features observed previously at a known location (Fig. 4.2 and Fig. 4.3). Such contrast and the scale of velocity variation will be used for calibrating velocity section from the other locations. Correlation of velocity-sections with the geology of the area will be used to identify the locations for trenching investigations for identifying or delineating signatures related to the lineament.

Fig. 4.1 MASW survey carried out across L2 lineament

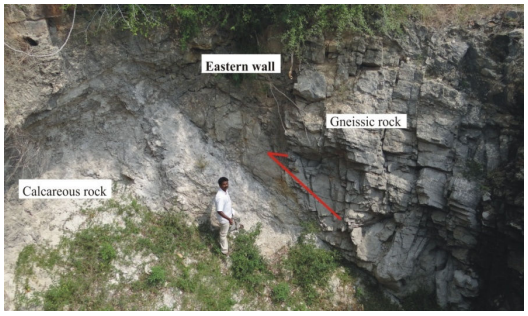

Fig. 4.2 MASW image across the fault at Thiruviruthanpuli

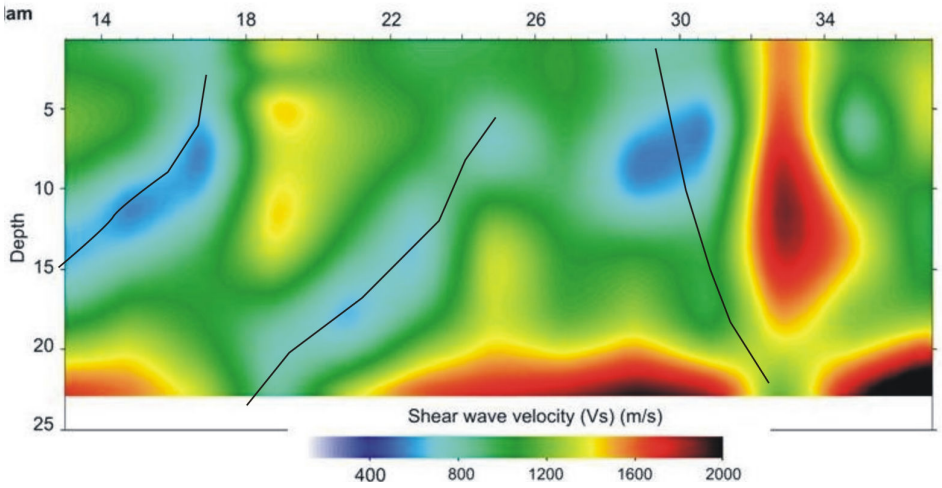

Fig. 4.3 View of the fault across which MASW survey conducted (MASW image shown in fig. 4.2)

- A lineament was identified within 5 km radius of the proposed Jaithapur Nuclear Power Project (JNPP) site (Fig. 4.4) during geological studies carried out by GSI. Subsequently a group of experts recommended geological investigations in trench for identifying the lineament and its related subsurface features up to rock level. Accordingly, NIRM was entrusted with the investigations. After preliminary geological, geomorphologic and literature surveys, the trace of the lineament was marked based on the geomorphic expression mentioned in the GSI Report, during a joint visit of NIRM, AMD and NPCIL. The study culminated in the design of 100 m (L) × 21 m (W) × 27 m (D) trench for the purpose, one of the largest trenches made for palaeoseismological studies in the world. To facilitate mapping at 1:20 scale, the trench was excavated with depth interval of 2-3 m in 10 stages. To maximise information collection from the trench, excavation was done in three parallel narrow trenches till stage 7 (Fig. 4.5), cleaned trench faces and floor for facilitating identification structural features and detailed mapping in 1 m × 1 m grids (Fig. 4.6 and Fig. 4.7). The trenching exposed 7-8 m thick laterite cap overlying laminated clay. Comprehensive organisation and analyses of various data, constituent analyses and dating rock and soil samples is in progress.

Fig. 4.4 View of light house lineament; the elevated portion is the scarp being studied through trench investigations

Fig. 4.5 View of three parallel Trenches at stage zero

Fig. 4.6 Cleaning of the trench walls to make it ready for mapping

Fig. 4.7 View of 1 m X 1 m grid for mapping fine geological details

- Seismotectonic evaluation in the 30-50 km radius of Kudankulam Nuclear Power Plant (KKNPP), Tamil Nadu was carried out. During this period geological investigations in the Mahendragiri forest area after obtaining necessary permission from the forest department were carried out. In the 50 km radius 103 lineaments were identified and categorized into three group based on the affinity and trend (Fig. 4.8). They are (i) those with no surface expression or seismic activity, (ii) those with no surface expression but associated with seismic activity and (iii) those with both surface expression and seismicity.

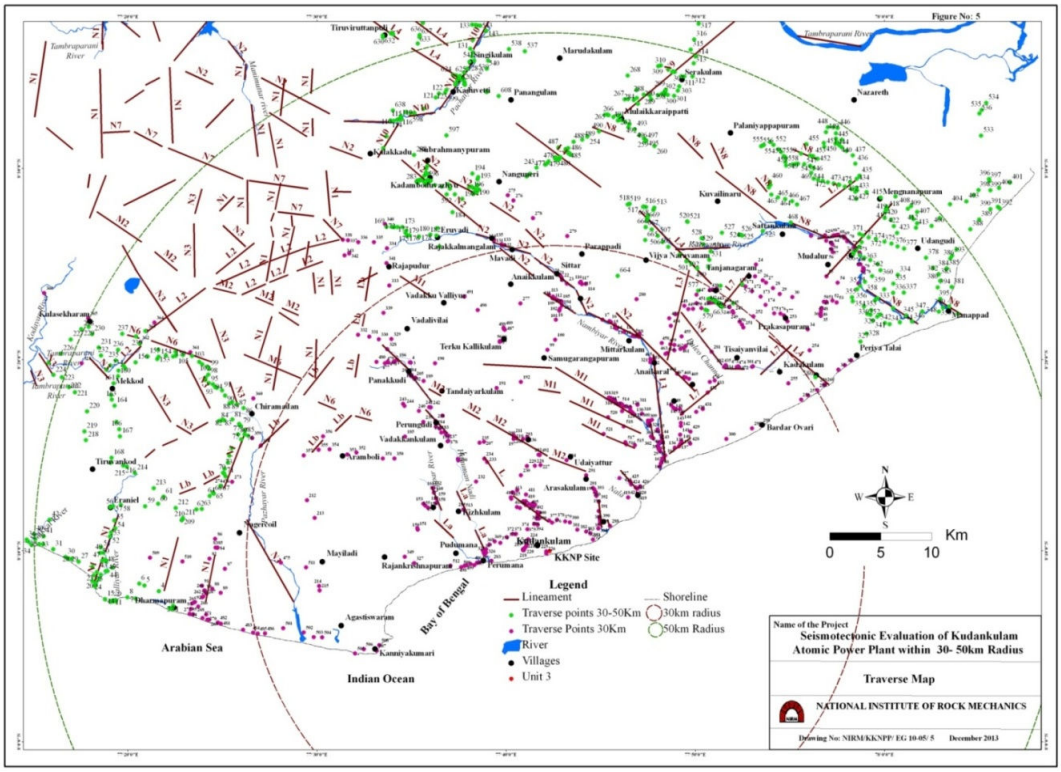

Fig. 4.8 Seismotectonic map of 300 km radius

The following are the classification of the lineament groups as per AERB and IAEA guidelines.

- 1st category - not significant as fault or for seismotectonic evaluation
- 2nd category - for consideration as capable fault
- 3rd category – as active faults (having surface signature of faulting and seismicity)

Among them, the lineaments L4 and N2 were identified as active faults. These two faults lie 11-12 km apart from each other. The L4 represent NW-SE trending Thenmalai fault and N2 parallel to it. These two faults are having regional affinity to Achankovil shear system. A maximum magnitude of 6 on Richter scale was suggested based on these two faults during the June-July 2014 AERB meeting in Mumbai and was agreed by experts.

- Geothermal studies at around Manappad and Kudankulam area was carried out. In order to evaluate the suspected geothermal activity in Manappad, 44 km NE of KKNPP, NPCIL approached NIRM for understanding and evaluate the incidence. Water samples collected at different times from the nearby wells were subjected to analyses at established national laboratories. Preliminary analyses of water from intra-fracture fills do not show any precipitation of secondary minerals. A few more studies at various locations along the lineament to collect mineral precipitate and other geological samples from the fracture zones are to be taken up in near future.

5. NUMERICAL MODELING, INSTRUMENTATION AND MONITORING

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.

- Tapovan Vishnugad Hydroelectric project is a 4x130 MW 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, by incorporating in-situ condition like joint sets, weak zone, shear zone and other geological materials. The model was based on the geological information given by NTPC prior to the excavation. Subsequent to substantial excavation activities in Tapovan-Vishnugad powerhouse complex, the work of "Back Analysis of Powerhouse Complex Behaviour using 3D Numerical Modeling at Tapovan-Vishnugad Hydroelectric Project" was taken up based on the instrumentation data provided by NTPC Ltd. Interim report was submitted to NTPC in May 2011. NTPC has recently submitted instrumentation data and analysis of the data is in progress and back analysis based on the instrumentation data will be carried out.

- The 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 meters and maximum height of 163 meters 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 with present height of 121.92 m. Due to the large reservoir capacity and height of the dam, it is 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). Location of the control points are shown in Fig 5.1. Points on the crest at different blocks were identified in consultation with SSNNL. Total of seven monitoring points were installed and seven sets of data has been collected till April 2015. Data reduction and interpretation is in progress to get required accuracy.

- 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 power house 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. The actual instrumentation section installed at Machine Hall Cavern and Desilting Chamber is shown in Fig 5.2.

Fig 5.1 Control points network at SSNNL Dam

Stability of Machine hall cavern was assessed based on the convergence observations of side walls, load on rock bolts and stress distribution along the length of instrumented bolts and piezometric observations. Based on the analysis of the instrumentation data

- 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 (2880 days) varied from 20 to 38 mm.
- Load on the rock bolts is increasing at some of the locations, particularly at 150 u/s at EL 506 (an increase of 9.22 tons during the operational period).
- During the last one year, there were no instances of high tensile stress recorded by the instrumented bolts. Currently some of the instrumented bolts show marginal increases in compressive stresses.
- The cavern is undergoing time dependent deformations and stress induced deformations due to its close proximity to the Main Central Thrust.
- The failure of rock bolts is still 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, 3 rock bolts have failed in Machine Hall and none in transformer hall. In 2014, 5 rock bolts have failed so far in Machine Hall and none in Transformer Hall.

- Back analysis study using 3D numerical modelling conducted by NIRM (Sripad et al. 2011) 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 microseismic monitoring will aid the assessment of the stability of the cavern in the near future.

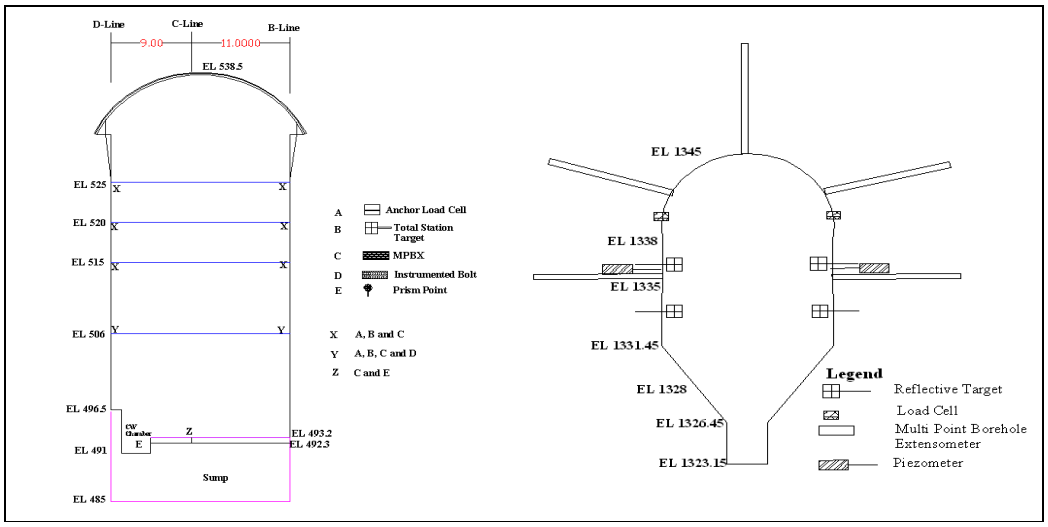

Fig. 5.2 Location of instruments in a section of machine hall cavern and desilting chamber

- The Mahamaya underground coal mine of Bhatgaon area in South Eastern Coal Fields Ltd. (SECL) intend to experiment with a special depillaring method called “Optimization of Panel Dimension System” proposed by Society for Mining Research Sustainable Development and Environment (SMRSDE). As per the method, the support requirements at the face are very minimum. The main objective of the NIRM study is to assess the support requirement for the proposed depillaring method for one panel. Site visits are completed. The mine management is yet to submit the required data for the analysis.

- The behavior of underground powerhouse of Sardar Sarovar project is being monitored by NIRM since the year 2000. During construction stages NIRM installed Magnetic Ring Multi Point Borehole Extensometer (MRMPBX) and total station targets on power house walls to monitor the deformations inside the cavern. During operational stage five no. of MR-MPBX were installed on surface center line of the powerhouse at a depth varied between 35-45 m to assess the roof deformations. The analysis of the instrumentation data for the period November 2013 to December 2014 indicated the following:

  - During Nov’13 to Dec’14 the maximum displacement measured was within 4 mm. The trend of displacement of almost all the MRMPBX’s at the underground powerhouse showed stable trend during the period.

- The displacements measured on the columns and beams are negligible and shows stabilizing trend.
- The surface MRMPBX data confirmed that the area between the crown and surface is stable and no movement is currently taking place.
- Instruments at critical chainages Ch 1516, Ch 1552 and Ch 1580 are showing stable trend.
- Monitoring needs to be continued to ascertain the stability as all the six units are under operation now.

➢ Sonshi Iron ore mine is the oldest operating mine of M/s Cosme Costa & Sons situated in North Goa. It is an open pit mine with fully mechanized mining unit. The current production level is around 3 MTpa. The waste from the mine is being dumped at Pissurlem village. The Pissurlem dump consists of two dumping areas, i.e., the old dumping area which has been stabilised as well as vegetated and new area which is currently being used as active dump site. The new dump covers an area of 45 hectares (Fig. 5.3). A detailed study was done with the results of laboratory test data of the samples and using limit equilibrium as well as numerical modelling techniques. The maximum dump height measured from toe is 83 m. However, the vertical height is 55 m at the centre as the original ground has higher elevation at the middle of the dump and gentle gradient towards the sides. The maximum height is observed only in southern part which is limited to about 200 m in length. The overall slope angle of the dump was found to be varying from 12^o to 20^o. The dump profile consisted of 10 m high benches with slope angle varying from 30^o to 32^o with berm width varying from 4 m to 10 m. NIRM carried out detailed geotechnical investigations at the Pissurlem dump and determined the physico-mechanical properties at the laboratory. Slope stability analysis has been carried out using limit equilibrium analysis and numerical analysis by means of FLAC Slope software. Eight cross sections and one longitudinal section were selected for the analysis. Each section is divided in to north-west and south-west sections. Thus 18 cross sections were analysed to arrive at the factor of safety (FOS). Figure 5.4 shows the Factor of Safety arrived using FLAC Slope software at one of the sections. The factor of safety calculated from both the analyses show FOS values above 1.84 and more or less the same at many locations. To improve the capacity of the dump, sections 2-2, 5-5 & 6-6 have been profiled with top EL. of 130 m, 130 m & 110 m respectively. The slopes are profiled with bench height of 10 m, slope angle of 45^o and berm width of 8 m. The stability analysis has been carried out for the above mentioned parameters of slope with geogrids placed at a height of every 10 m horizontally. Factor of safety calculated using both the approaches are found to be above 1.3, which indicates stability. Also, limit equilibrium analysis has been carried out with assumed water table at a depth of 10 m below the top surface of the dump. It was observed that the factor of safety values reduced in most of the sections due to the presence of water table. Hence proper drainage measures needs to be adopted in the field to reduce the build-up of pore water pressure. To further increase the stability of the dump material, the following additional recommendations are made:

- Toes of the individual benches should be covered with hard rock/boulders for toe protection.
- Weep holes or relief holes in the form of perforated pipes shall be drilled/installed/laid sufficiently deep in to the dump mass in the benches to reduce

the build-up of pore pressure in the dump mass, this will significantly improve the stability especially in the lower benches by draining out the infiltrated water from the benches.

- During rainfall, care should be taken to prevent any water stagnation in the drains provided on the berms. This would prevent seepage of runoff water in to the dump material.
- Lining of drains can also be done to prevent erosion of the dump material along the drains.
- Gullies at few places in the benches (especially lower benches) should be filled up and covered with hard rock boulders. Presence of gullies may cause instability problems and affect the overall stability of the dump material.
- The mouth of ERWMS pipes shall be covered with 40 mm screens which would prevent clogging of the pipes and facilitates maintenance during rainy season.
- Proper compaction of the mine waste after every 5 m dumping operation by use of rollers will also significantly improve the compaction.
- Bench marks/monitoring points may be installed at suitable locations on each bench and monitored using total station every day or at suitable time periods, during heavy rains and especially during the monsoon season, to find out the displacements occurring in the benches. Monitoring will definitely help forewarn about any major collapse or failures.
- The particle size distribution of the dump mass significantly influences the shear resistance and deformability of the mass. Well graded materials (with high uniformity coefficient, Cu) reach higher densities and distribute the particle stresses in a better manner, reaching higher shear resistance compared to materials of the same origin but which are poorly graded. Proper sampling in the field will help in achieving well graded dump material.
- Geogrids shall be placed at a height of 10 m in the horizontal direction and geotextile/jute mats shall be placed covering the slope face to increase the capacity and stability of the dump material.

Fig 5.3 View of Pissurlem dump

- The Nathpa Jhakri Hydroelectric Project of SJVNL is a 1500 MW project with underground powerhouse complex at Jhakri, Himachal Pradesh. It consists of the largest underground desilting complex of four numbers of 525 m long with a cross section of 27x17 m each separated by 46 m rock pillar located at Nathpa. Analysis of the instrumentation data of powerhouse and desilting complex supplied by SJVNL was conducted to evaluate the stability of the caverns during 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.

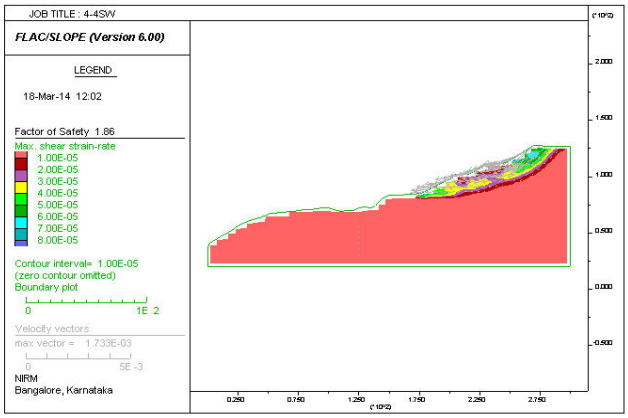

Fig. 5.4 Factor of Safety for section 4-4'SW

The analysis of instrumentation data at various components shows that:

Powerhouse Cavern

- The readings of both the anchors at RD 92 crown at Powerhouse Cavern are fluctuating. Excluding few peak values which may be due to instrumental errors (including the observed displacement of 30 to 40 mm during Jan –Oct 2013), the surface displacement vary in the range of 3-20 mm. Negligible relative displacement between 4 m and 6 m anchors indicate that, the displacement is taking place between surface and 4 m anchor.
- The displacements at RD 160, RD 123 and RD 41 at EL 1014 on the downstream wall shows stabilizing trend.
- At RD 184 EL 1022 right side of the crown, the 6 m anchor (surface displacement) showed erratic readings up to April 2012. However, for last two years, both 4 m and 6 m anchors show stable reading (-2 mm).
- At RD 80/EL 1014 - Drainage Gallery, there was a development of crack (16.98 mm) between 12 m–DG/7 m-MH and 8 m–DG/11 m-MH horizons between the period May 2007 and Jan 2011. During March 2011, the crack appeared to have closed but May 2011 onwards, 12 m–DG/7 m-MH anchor is showing similar trend as shown earlier and is currently at -10 mm. This may be an indication of possible opening and closure of the cracks.
- MPBX at RD 185, EL 1014 showed relative displacement between 8 m and 12 m anchors possibly due to development of crack of 2 to 3 mm width. During last 3 months, 12 m-DG/7 m-MH anchor shows displacement of 12 mm which needs to be confirmed with further monitoring.
- MPBX at RD 248/EL 1014 - Drainage Gallery shows increase in displacements at 12 m–DG/7 m-MH horizon. The displacements during last one year range from 1 to 5 mm.

Desilting Chambers

- At Chamber 4, RD 450 right wall, EL 1456.5 m, the displacement variations is in the range of -15 to +5 mm and no definite trend was available. The instrument head was replaced by NJHPS in Jan'10. The displacement data at 5 m depth was not available after Nov 2010. The surface displacement shows increasing trend

with an increase of 4 mm between the period Oct 2011 and Marc 2012. During the depletion of the chamber, the displacement varied between -11 to +3 mm. After March 2012, the instrument shows fluctuations in reading and is not considered for analysis.

- The reading at Chamber 4, RD 450 right wall, EL 1450 was resumed after changing the head in Jan 2010. However after the depletion period in chamber 4, the readings were erratic and surface and 5 m depth anchors stopped working after June 2010. The displacement at 10 m depth showed stabilising trend. After March 2012, the instrument shows fluctuations in reading and is not considered for analysis.
- At Chamber 4, RD 450 left wall at EL 1450, the displacements are less than 2 mm and showed stabilizing trend till April 2010. From April onwards, the readings were erratic and 5 m & 10 m anchors stopped working. The displacement data at 10 m depth is again available from June 2011. The displacements at 10 m and surface are showing stabilising trend since then.
- At Chamber 3, RD 450 right wall, EL 1450 (LB), the displacements at surface and 10 m depth vary from -7 mm to 4.0 mm. After March 2012, the instrument shows fluctuations in reading and is not considered for analysis. At RD 450 right wall, EL 1456.5, the displacements shown by MPBX exhibits stabilizing trend. The surface displacement varied between 5-7 mm since June 2011.
- At Chamber 2, the displacements at RD 450 left wall at EL – TB was less than 2 mm and showed stabilizing trend. The displacements at RD 450 right wall EL – TB shows stabilization trend. At RD 450 right wall at EL – MB, 5 m anchor is not responding and other anchors are showing stable trend with minor changes. At RD 450 Left Wall at EL MB, the displacements at surface and 10 m are 7.5 mm and 14 mm and vary within ± 5 mm and shows stabilising trend.
- The pore water pressure distribution is normal and varies as per the reservoir level. During the depletion of Chamber 4, the pore pressure at Chamber 4, RD 450 right wall at 1446.5 EL, was increased to 9.47 kg/cm^2. However, even after refilling, the pore water pressure did not drop and changes since then are within ± 1.0 kg/ cm^2 and currently shows pore water pressure of 9.76kg/cm^2. At 380 m left wall, the pore water pressure dropped to 0.54 kg/cm^2 after depletion and regained a pressure of 6.12 kg/cm^2 between May 2012 and Dec 2013 data was not available from this instrument. In January this instrument showed 7.39 kg/cm^2.
- The piezometer at RD 150 left wall did not record any changes in pore water pressure during the depletion period and is showing an average of 1.0 kg/cm^2 since the year 2006. However, it showed pore water pressure of 2.5 to 3.0 kg/cm^2 between the periods Jun- Sep- 2011.
- The pore water pressures in other chambers did not experience any appreciable changes during the depletion of any of the chambers.
- The analysis of the MPBX data at Desilting Chambers indicate that observations are fluctuating and many of the anchors are not functioning. This could be due to constant submergence of MPBX heads (Potentiometer type) and anchors in water. Hence, it is recommended to discontinue the monitoring of these MPBX Instruments. Installation of new MPBX instruments and remote monitoring is not possible at this stage. In this regard, it is recommended to carry out detail inspection of the walls of the chambers during the depletion of the chambers. The profile of the chambers may be taken many sections along the length of the

caverns with surveying instruments. The sections may be compared with the original sections for assessing any displacements during the operational period.

Access Galleries

- There was no significant convergence of the access galleries during last 7-8 years. However, it is observed that during the depletion period (21/07/2013 to 16/08/2013) of chamber-2, there was 14-16 mm divergence at lower access galleries and 7-10 mm divergence at upper access galleries. It may be noted that after the filling back of Chamber –2, it bounced back to the original stage.

TRT Outfall

- Pore water pressure measurements at 7 locations indicated that pore water pressure is less than 1.0 kg/cm2 and shows stable trend except at RD 7.5 (EL 1066) and RD 25 (EL 1066). At these locations pore water pressure is 2.64 kg/cm2 and 1.44 kg/cm2 respectively.
- NJHPS has installed many instruments during last one year and observations from these instruments will be discussed in subsequent reports.
- Many instruments are showing lot of fluctuation in readings. In this regard it is recommended to check the readout units with the suppliers and calibration of these units may be carried out to ensure correctness of the readings.

- Mangdechu Hydroelectric Project is a 720 MW (4x180 MW) power project under construction in Bhutan, It is run-of-the-river scheme on the Mangdechu 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. Geometrical and geological details were furnished by MHPA. The test results from field and laboratory were also provided by MHPA. 3D discontinuum model was prepared using 3DEC. Shear zones in the powerhouse area based on drill holes in the area were incorporated in the model. The model results show that supports in the form of rock bolts in the crown of powerhouse cavern are adequate with the additionally installed 12 m long rock bolts for further benching operations. The results also show that the thickness of SFRS of 250 mm is adequate for control of rock mass movement. At bus ducts, stitching with the cable anchors proved effective in functioning of the rock bolts and also to improve the factor of safety of the pillar in between powerhouse and transformer hall cavern. Excavation sequence studies with the 3D models indicate that entire bus ducts be excavated and supported before the commencement of TRT manifolds and penstocks. Instrumentation data available during the excavation up to 15th Jan 2015 are compared with the modelling results. Model results are compared between the excavation levels corresponding to the period of instrumentation data. (It may be noted that there is a difference between the actual excavation time and the time of installation of the instruments). The measured displacements are higher at few places than those predicted by 3D models for the same excavation period. This needs reassessment of geological features and variation in strength of rock mass at the places where the difference is high. However, the measured displacement does not show any alarming trend at any of the sections and the factor of safety except at the shear zone is more than 2.0.

- Mangdechu Hydroelectric Project is a 720 MW (4x180 MW) power project under construction in Bhutan, It is run-of-the-river scheme on the Mangdechu river in

Trongsa district. The scheme involves construction of 114 m high concrete gravity dam. Slope stability analysis of the dam abutments slopes in rock as well as in soil mass and to suggest suitable support system was taken up after making detailed site visit. 3D model was prepared incorporating all the geological and support details at the site (Fig 5.5). After initial analysis, the recommendations made are: (i) the failure of slopes and benches are not due to displacements, but due to the failure (strength) of rock mass and development of tensile zones at different regions along the slope and (ii) the following regions require additional attention besides installations of design supports:

Regions	Left Bank	Right Bank	Remarks
Section 1	EL 1680 to 1700	EL 1680 to 1690	Pre-stressed cable anchors (30-50 t) of 32 mm diameter and 25 m long.
Section 2	Bench at EL 1763	EL 1675 to 1685	Pre-stressed cable anchors (30-50 t) of 32 mm diameter and 25 m long. Provide 32 mm & 12-16 m rock bolts normal to the face of projected joints.
Section 3	EL 1675 to 1685	EL 1675 to 1685	Pre-stressed cable anchors (30-50 t) of 32 mm diameter and 25m long.
Section 4	----	----	----
Section 5	EL 1703 to 1715 Bench at EL 1750	Bench at EL 1747.5 EL 1770 to 1780	Pre-stressed cable anchors (30-50 t) of 32 mm diameter and 25 m long. Provide 32 mm & 12-16 m rock bolts normal to the face of projected joints.
Section 6	Bench at EL 1771	EL 1665 to 1690	Provide 32 mm & 12-16 m rock bolts normal to the face of projected joints. Combination of concrete retaining wall, grouting and Pre-stressed cable anchors on right bank.
Section 7	EL 1670-1685 EL 1700-1715 EL 1730-1745	EL1720-1750 EL 1670-1685	Combination of concrete retaining wall and grouting at lower slopes on both the abutments. Pre-stressed cable anchors (30-50 t) of 32 mm diameter and 25 m long in the slopes.
Section 8	EL 1760-1775	EL1670-1685	Pre-stressed cable anchors (30-50 t) of 32 mm diameter and 25 m long in the slopes. Combination of concrete retaining wall and grouting at lower slopes on both the abutments.

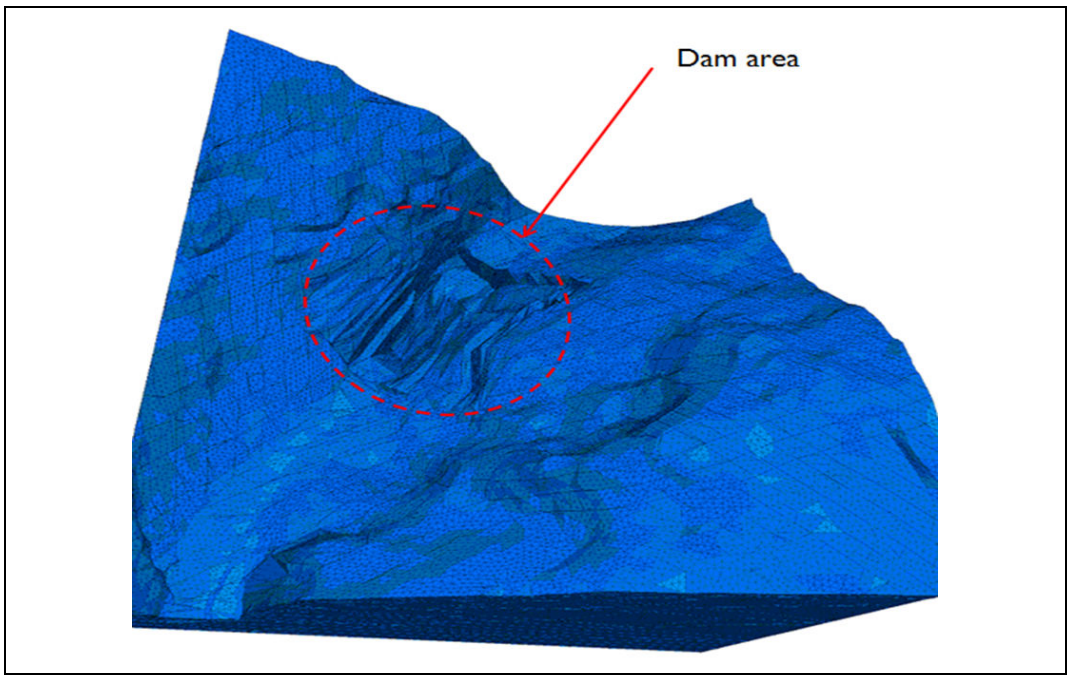

Fig. 5.5 Perspective view of the Three Dimensional Model

- 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). THDCIL have 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 is carried out using discontinuum and continuum methods. The following are the observations and recommendations for the support system for Tehri PSP.

  Powerhouse

  - Maximum crown displacement observed are as follows :
    - Centre of Crown : 189 mm at RD 47 m
    - Upstream Side of Crown : 215 mm at RD -23 m
    - Downstream Side of Crown : 172 mm at RD 57 m
  - Maximum wall displacement observed as follows:
    - Upstream Wall : 174.23 mm at RD -20.3m at EL 601.5 m
    - Downstream Wall: 148.71 mm at RD 55.6m at EL 600.5 m
    - Maximum Convergence : 227 mm at RD -38 EL 600 m
  - Percentage strain on the upstream wall and downstream wall were separately calculated using the half width of the cavern.
    - Maximum strain on upstream wall : 1.33% at RD -20.3 m at EL 601.5 m
    - Maximum strain on downstream wall: 1.13% at RD 55.6 m at EL 600.5 m

- On the upstream wall maximum strain in the unit bay area is 0.8% with maximum areas showing strain in the range of 0.3 to 0.5%. In the service bay area, the maximum strain observed is 1.33% and is concentrated in a limited area. In service bay area the percentage strain in most of the areas vary from 0.5 to 0.9%. Higher strain areas are mostly seen at the intersection of the shear joints at the wall.
- Out of the total displacement of crown for complete excavation, 87.57% displacement occurs after excavation of the crown. About 6.5% of the total crown displacement takes place after excavation of the first bench.
- Excavation of bench 2 and below has very less influence on the displacement at the crown. Each stage of excavation contributes in the range of 0.54 to 1.62% of total displacement.
- In case of upstream wall, out of total strain for complete excavation, 64.66% is seen after excavation of the crown and excavation of Bench 1 and Bench 2 adds 16.54% and 4.51% respectively. Subsequent excavation of the benches has added about 0.75 to 1.50% of total strain.
- In case of downstream wall, out of total strain for complete excavation, 45.13% is seen after excavation of the crown and excavation of Bench1 and Bench 2 adds 27.43% and 11.50% respectively. Subsequent excavation of the benches has added about 0.8 to 1.77% of total strain.
- It may be noted that excavation of busducts, transformer chambers etc. have added 3.76% of total strain on upstream wall and 3.27% on the downstream wall.
- Maximum strains on the crown and walls are influenced by excavation of crown, bench 1 and bench 2, after that excavation of lower benches have very less influence on the total strain.
- Shear joints have considerable influence on the displacement pattern of the crown and walls. Higher displacements are occurring either along the shear joints or at the intersections of the shear joints
- Yield zone on upstream is extending up to 20.10 m on upstream wall and 22.45 m on downstream wall. In general, extent of yield zone is more near the intersection of cavern with the bus ducts and other openings or in the areas where shear phyllites are present. Extent of yield zones has reduced due to the improved rock mass parameters away from the excavations. Strength to stress ratios in the yield zone is less than or closer to 1.
- Stress concentrations are mainly seen at the corners of powerhouse particularly near the floor and at some joint intersections in the rock mass.
- Although tensile stresses are developed in the relaxed zone around the cavern, the failure mode is predominately shear.
- At many sections considerable amount of floor heave (> 100 mm) is also observed.
- Distribution of axial force and shear forces in the rock bolts shows that at the intersection of the shear joints, the axial forces and shear forces have reached the limits. It may be noted that about 6.92% of the bolts on upstream wall, 8.85% on the downstream wall and 4.53% in the crown have reached limits of axial force and shear force specified for the bolts. Cable bolts in the upstream wall of the powerhouse helped in reducing the tensile stresses and also in reduction in nos. of bolts reaching the yield load.

Bus Ducts and other Tunnels

- At bus ducts also the more displacements are taking place along the shear joints or at its intersection.
- Near the junction, the displacement on the wall of the bus ducts vary from 50 to 70 mm. and in the crown, the displacements are around 50 mm. However, along the shear joint between Bus duct No. 2 & 3, displacement of about 100 mm is seen.
- At 2 m section, the displacement on the walls of bus ducts vary from 35 to 60 mm and in the crown it varies in the range of 35 – 55 mm. It may be noted from the figures that the displacements are reducing away from the junction along the length of the bus ducts. At a distance of 15 m and 20 m, the shear joints are cutting bus duct no. 3 and displacement of about 35 mm could be seen in the wall and floor of the bus ducts.
- At a distance of 5 m from the junction, the tensile stresses drastically reduce and further reduce along the length of bus ducts. This could be due to the presence of the cable bolts. Similarly the extent of yield zone also diminishes away from the bus duct junction.
- The failure mechanism is predominantly tensile at the bus duct junctions.
- Cable bolts in the vicinity of the bus ducts have greatly increased the stability of the bus ducts.

- Temporary and permanent support design of underground surge pool, pump house, draft tubes and delivery mains using 3-D Numerical Modelling of Pranahita Chevella Sujala Sravanthi Lift Irrigation Scheme Package 12 was carried out. A 3D discontinuum model was constructed with the actual geometry of the pump house, surge pool, draft tubes, bus shaft, delivery tunnels and intake tunnel. The boundaries are placed at sufficient distance away from the excavation in order to prevent the end constraint effect. The model was simulated till the ground level. The 3D model showing various components are shown in the Fig. 5.6. The support system estimated from IS code 15026-2002 are (i) 25mm diameter 5 m long bolt (Fe 415) in crown @ 2.3 m c/c spacing, (ii) 25 mm diameter 6 m long bolt (Fe 415) in walls @ 2.5m c/c spacing and (iii) 100 mm SFRS to be put in crown as well as in the walls. Numerical modelling was conducted to evaluate the efficacy of the proposed support system. The modelling result showed that the estimated support system is adequate for most of the places in surge shaft and pump house. However keeping in view of some localised failures and breaking of the bonds between SFRS and rock at few places recommendations made are (i) SFRS thickness may be increased to 60 mm in the walls of pump house between EL 485 m and EL 480 m, (ii) controlled blasting techniques may be adopted in order to minimise the damage in the immediate vicinity of the excavation, (iii) considerable floor heaving is expected to take place due to high horizontal stresses in the area. Rock bolts in the floor (6 m long 32 mm diameter bolts) may be put all along the floor of pump house and surge shaft. Provision of an invert can also be considered during construction and (iv) the analysis was based on estimated properties of the rock mass in the area. Any deviation from the estimated rock mass parameters may have influence on numerical modelling and support system estimation.

- The Mangdechhu Hydroelectric Project Authority (MHPA) management approached NIRM to conduct slope stability analysis of pothead yard slopes in rock with the planned support system and to suggest suitable support system if found inadequate. Draft report on the stability studies for pothead yard slopes of Mangdechhu

Hydroelectric project is submitted. Slope stability analysis has been carried out with two dimensional discontinuum numerical models using UDEC. Factor of safety and displacement contours at five identified cross sections at pothead yard site were analysed. Dynamic analysis has also been carried out for checking the overall behaviour of cut slopes under seismic loading condition.

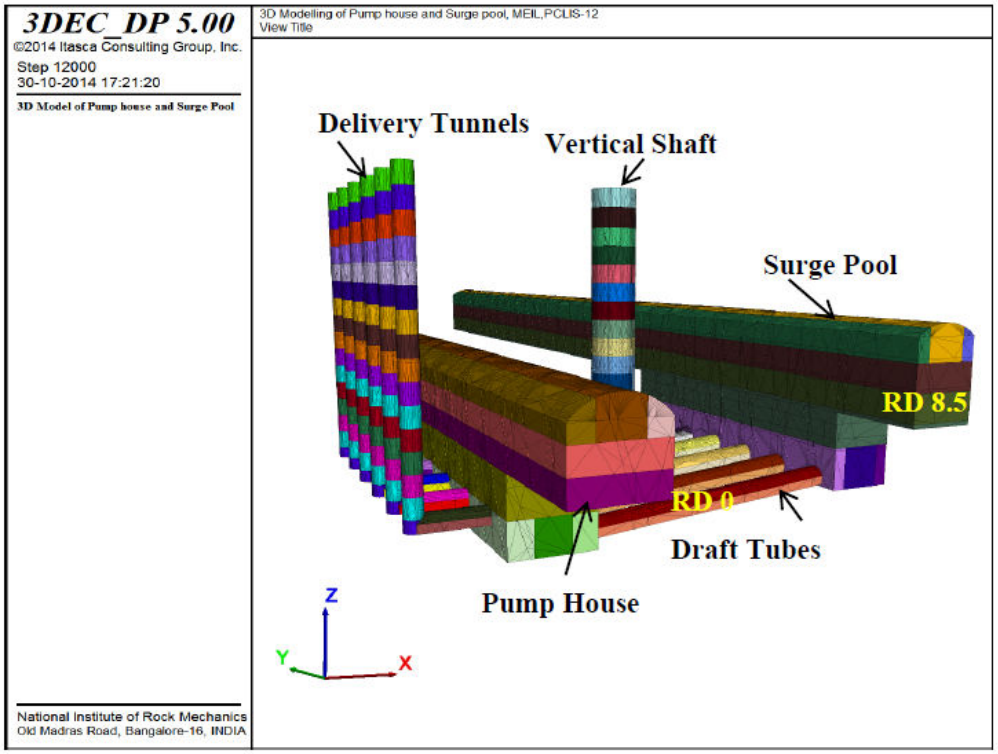

Fig. 5.6 3D view of the model showing pump house, surge pool and other components

After detail study recommendations are made (i) All the sections have factor of safety of more than 1.39. The maximum displacement value of 90 mm has been observed for section AA. For sections BB & EE the maximum displacement values varied between 70 to 80 mm. For sections CC & DD the maximum displacement values are in the range of 30 to 45 mm. (ii) The x-velocity and y-velocity values are approaching to zero for all the sections. From the history plots the stable nature of slope is observed due to the dynamic loading. (iii) The design support system is found to be adequate for supporting the excavated slopes at pothead yard location. (iv) It is recommended to have atleast three MPBX's installed in between berms i.e. for every 15 m height along the excavated periphery (along the bench) of pothead yard location for monitoring the movement of the rock mass. (v) Permanent target points needs to be installed in between individual benches for measuring convergence and continuous data has to be acquired for monitoring the stability of the excavated slopes. It is recommended to have atleast 30 target points installed in the pothead yard location. (vi) Instrument data at pothead yard location needs to be analysed regularly and compared with the estimated values, particularly displacement values for ensuring safety of excavated slopes and (vii) Wedge analysis needs to be carried out for excavated slopes to ensure stability against potential wedges, if any.

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 eleven industry sponsored projects, out of which five are completed and remaining six are in progress.

- Sangam Kalan limestone mine belonging to the India Cements Ltd. (ICL) is operating two pits in Tandur Mandal, Ranga Reddy district of Telangana State. The limestone is excavated by mechanised opencast method with shovel-dumper combination. The mine management approached the NIRM to monitor ground vibration twice in a year for a period of two years. Data monitored for all the blast were used for regression analysis. Site specific predictor equations for ground vibration and air overpressure were arrived and presented. The frequency of ground vibration was greater than 8 Hz. Based on DGMS guidelines, a safe ground vibration level of 10 mm/s was recommended for the structures of Sangam Kalan village. The recommended safe air overpressure level was 133 dB as per USBM and IS code. The recorded peak particle velocity was found to attenuate to below 10 mm/s at about 400 m and beyond, while beyond 800 m the vibration was found to be below 5 mm/s. The ground vibration recording carried at Sangam Kalan Village which is at about 2.7 km from the mine (Fig. 6.1) was below the instrument threshold level of 0.5 mm/s which implies that the structures are safe. A safe maximum charge per delay for different distances was presented so as to ensure vibration levels are within the recommended safe level.

- M/s Dalmia Cement (Bharat) Ltd. is operating Nawabpeta – Talamanchipatnam limestone mine and a cement plant of 4 MTPA capacity near Nawabpeta and Talamanchipatnam village, Mylavaram mandal, Kadapa district of Andhra Pradesh. Presently, the mine is working at west corner of lease area and advancing towards east and north direction. Two villages namely Nawabpeta and Talamanchipatnam are located in eastern and southern side of the lease area at distances of 1000 m from mine the lease boundary and 2200 m and 2000 m from the current working at the time of this study. As the villagers complained about the vibration due to blasting, the mine management approached NIRM to conduct ground vibration study and to furnish the findings as per DGMS guidelines. NIRM carried out field investigations during August 2014 and monitored 9 blasts. For all the blasts, ground vibration and air overpressure was monitored by deploying six seismographs positioned towards Nawabpeta and Talamanchipatnam villages (Fig. 6.2). The vibration data generated from all the blasts were regressed and a site specific equation was derived. The permissible level of ground vibration for frequencies greater than 8 Hz as per DGMS standard for

structures not belonging to the owner is 10 mm/s. However, considering a higher factor of safety, a safe permissible level of 5 mm/s is recommended for the structures in the villages of Talamanchipatnam and Nawabpeta. The safe maximum charge per delay (Q) for different distances is estimated and tabulated. The ground vibration waves attenuated to less than 1.0 mm/s beyond a distance of 725 m. As the villages are located beyond a distance of 1 km, the suggested maximum charge per delay will keep the vibration within permissible limit of 5 mm/s at the structures of these villages. The measured air overpressure levels were well within the suggested limits of 133 dB.

Fig. 6.1 Monitoring ground vibration and air overpressure at Sangam Kalan village in the presence of DDMS, Mine Officials and Locals

Fig. 6.2 Monitoring ground vibration near Middle School, Mandal Praja Parishat, Nawabpeta

- Kerala State Electricity Board (KSEB) had planned a Small Hydro Electric Project (SHEP) of 12 MW capacity by utilizing the water from the existing Periyar valley irrigation barrage at Boothathankettu. As the Bhoothathankettu barrage is located on the south side of excavation area at a distance of 200 m, KSEB is apprehensive about the ill effects of blasting on the barrage and on other structures belonging to state government. As per the request of KSEB, a Detailed Method Statement was submitted during August 2014. Subsequently, field investigation was carried out during September 2014 and twenty three blasts were designed and executed in different SHEP components. Ground vibration and air overpressure levels was monitored for all the blasts covering the critical structures (Fig. 6.3) by deploying six seismographs. The report presents the controlled blast designs with muffling to be adopted at the proposed SHEP site based on the field study. A safe permissible peak particle velocity limits of 50 mm/s for Bhoothathankettu barrage and 5 mm/s for surface structures was recommended.

- The Nuclear Power Corporation of India Limited (NPCIL) awarded the construction of cold water tunnel, hot water tunnel, Natural Draught Cooling Towers (NDCT) 7 & 8 package at Rajasthan Atomic Power Plant (RAPP), Rawatbhata, Rajasthan to the Gammon India Pvt. Ltd. As part of this work, about three lakh cubic meter of hard rock has to be excavated by drilling and blasting method. The excavation site is located at a closest distance of 10 m to the retaining wall under construction and other structures are located beyond a distance of 60 m from the construction site. Suitable blast design was suggested for different hole depths (2 m to 12 m) and field tested. Blast trials gave

good results and it was recommended to continue the same design. Fig. 4 shows the successful excavation of cut and cover tunnels close to the retaining wall. For all the blasts carried out during field investigation period, ground vibrations were measured at different critical locations. The recorded ground vibration data was used for regression analysis and a predictor equation at 95% confidence level was derived and submitted. Based on the frequency of ground vibration, the safe peak particle velocity for structures as per DGMS standard is 20 mm/s for industrial building and 10 mm/s for cement and brick structures. But the project authorities stipulated a safe peak particle velocity of 10 mm/s for all the industrial and cement and brick structures. The project authorities also stipulated 3 mm/s as the safe peak particle velocity for the structures housing electrical and electronic equipments. Similarly the safe peak particle velocity for hardening concrete was stipulated by the project authority depending on the curing time. Substituting the permissible levels of peak particle velocities for different structures and also for hardening concrete depending on its curing time (3 mm/s, 10 mm/s, and 15 mm/s), the safe maximum charge per delays for different distances were calculated and presented. It was recommended to use the lowest safe maximum charge per delay at the site during excavation.

Fig. 6.3 Monitoring ground vibration and air overpressure at Sangam Kalan village in the presence of DDMS, Mine Officials and Locals

Fig. 6.4 Photograph showing the excavated cut and cover tunnel close to the retaining wall.

- Deepak Fertilizers and Petrochemicals Company Limited (DFPCL) is the leading ammonium nitrate manufacturers in India. DFPCL wanted to introduce bulk ANFO in open cast mines. To start with the trials at OCP-I, RG III, SCCL, DFPCL desired to evaluate the performance of bulk ANFO by carrying out a scientific study and approached NIRM for measuring the velocity of detonation of ANFO in real time. NIRM had already conducted extensive real time VOD studies for different explosives at different open cast mines under an S&T project supported by SCCL and submitted the report entitled “Evaluation of explosives performance through in-the-hole detonation velocity measurement (MT/96/96, August 2001)”. DFPCL used a specially designed 10T truck for transporting ammonium nitrate prills in bulk along with a proportionate quantity of fuel oil carried in separate compartments. At the blasting site, the unit will mix the two materials together. Vertical augur takes prilled AN into the delivery augur. Pre-determined diesel is being injected at the inlet of the delivery augur for mixing with calibrated AN. Delivery augur can be rotated to deliver the product directly into the

bore hole mechanically convey the ANFO into a borehole. The VOD study for ANFO in real time was conducted at OCP I, RG III area of SCCL. The mine is fully mechanized operated in benches with the height varies from 10 m to 27 m. The 250 mm diameter holes are blasted using 634 series Site Mixed Slurry (SMS) explosive with shock tube initiation system or detonating cord and cord relays. Trials with ANFO in combination with non-electric shock tubes were conducted at different benches. The blasts were bottom initiated with down the hole detonators. The VOD was tested for both SMS and Site mixed ANFO. All the tests were carried out in sandstone benches of 10 to 14 m bench height. The continuous resistance wire method was used to measure the VOD using the probe cables of two different suppliers with known resistance per meter and two different VOD Monitors were used for the study. The VOD records were analysed using software provided along with the equipment. A total of 5 blasts were monitored measuring 11 holes out of which 4 blasts were successfully recorded and analysed for 6 holes. Fig. 6.5 illustrates the preparation of VOD monitoring and average VOD value for one of the blast. The report documented the highest and lowest recorded VOD value of ANFO as 4358 m/s and 4252 m/s respectively. Similarly for SMS 5305 m/s and 4467 m/s.

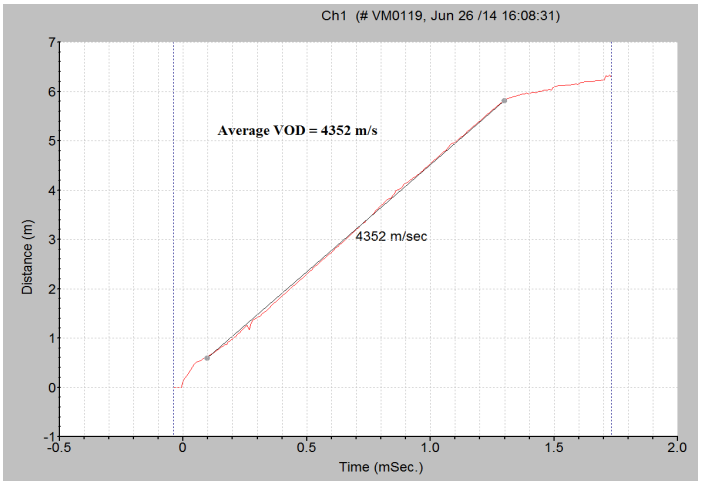

Fig. 6.5 Preparation of VOD monitoring and average VOD value for one of the blast

- Sardar Sarovar Narmada Nigam Limited (SSNNL) is constructing 118.6 km Morbi branch Canal which is taking off from Saurashtra Branch canal at 104.4 km near Surendernagar and tails in the Machhu II reservoir. The main purpose of this canal is to provide water security to Saurashtra and Kutch regions. The Morbi canal is passing through industrial area (ceramic industries zone) from chainage 109.3 to 115.6 km. These ceramic industries are falling very close to the edge of the proposed canal (10 to 75 m). At these regions the maximum cutting depth required for canal excavation is about 10 m in the rocky strata and therefore, rocks are required to be excavated by controlled blasting technique, so that the adverse impacts like flyrock, ground vibration and air overpressure are controlled within safe limits. NIRM carried out field investigation in three phases and during the investigation period a method statement and an interim report were submitted to SSNNL. The suggested method statement was incorporated in the tender document. This ensured that the suggested designs with safety requirement were implemented. To start with, trial blasts were carried out with both small and large diameter holes for establishing the attenuation characteristics of the ground vibrations. In order to do so, ground vibration and air overpressure level was measured by deploying six seismographs. Control of flyrock was achieved in small diameter holes by muffling with link mesh, sand bags and blasting rubber mats (Fig. 6.6), whereas for large hole diameter the blast was muffled with 20 mm thick plate fastened to old tyres. Based on the frequency of the monitored vibrations, a permissible limit of 20 mm/s as per DGMS norms were suggested. The safe maximum charge per delay for various distances was computed and presented for the prescribed limit from the site specific predictor equation. The air overpressure levels were restricted below 133 dB. Further, it was recommended that when the distance between the blast location and structure is 40 m and less, blasting shall be carried out with small hole diameter and if it is greater than 40 m blasting can be carried out using large diameter hole so as to adhere to the recommended maximum charge per delay. Blasts were designed for above mentioned two conditions.

Fig. 6.6 Photographs showing sequence of muffling

- Bagmane Estates Pvt. Ltd., Bangalore is constructing Bagmane Constellation Business Park in Outer Ring Road near Mahadevapura area of Bangalore. As a part of this project, it is proposed to construct two high raise towers called as Virgo and Carina. For construction of these towers, soil and hard rock had to be excavated to a depth of 10 m from the surface. The rock had to be excavated by drilling and blasting in close proximity to private structures. Keeping this in view, Bagmane Estates Pvt. Ltd. approached NIRM to technically guide in executing controlled blasting. NIRM carried out field investigation initially at Virgo area. Controlled blasts were designed and executed in close proximity to the private structures. The blast area was muffled sequentially covering with sand bags, link mesh and blasting rubber mats to restrict flyrock. Ground vibration was monitored at different locations, regression analysis was made and a predictor equation was derived. A safe peak particle velocity of 5 mm/s was recommended for the structures located near blasting area. Safe maximum charge per delay was computed and followed in all the blasts at Virgo area. By adhering to the recommendations made by NIRM, the rock was completely excavated at Virgo tower area and construction of civil structures is under progress (Fig. 6.7).

  Similar field investigations were carried out at Carina area (Fig. 6.8). For blasting beyond 10 m, blast designs, safe maximum charge per delay, muffling procedures were recommended. It was recommended that no blasting shall be carried out within a distance of 10 m from the existing structures. If hard rock had to be excavated within 10 m from the structures at Carina tower area, alternate methods to blasting were also recommended.

Fig. 6.7 Photograph showing post excavation & construction activity at Virgo tower area

Fig. 6.8 Close in structures located on south-western side of excavation Carina area

- Chennai Metro Rail Corporation Limited (CMRL) is constructing a metro rail link in the city of Chennai. The construction involves erection and excavation of various components like the elevated sections, tunnels and underground stations. One of the construction packages of this project is allotted to TT-AFCONS JV which includes construction of underground metro station at the Chennai city railway station. The construction of underground station involves removal of soil/rock to a depth of about 30 m. The width of the station is 30 m while the length is about 300 m. During the mechanical removal of the slot along the perimeter of the station area for erection of the diaphragm wall, it was found that the top soil is terminated at a depth of about 18 m below which the strata is comprised of hard granite rock. Considering the hard rock to be removed by controlled blasting and the proximity of the critical structures at the proposed Central station location, field study was conducted at an alternate site (a quarry near Chennai) during October 2012. This study indicated the probable vibration

levels that could be encountered during the actual blasting operations. The excavation method of the Central station is of top down method, which leads to a situation where in blasting is to be carried out under a RCC roof (partially confined conditions (Fig. 6.9). There were apprehensions with regard to the gas pressure that may be exerted on the concrete roof due to use of explosives. In order to assess this, experiments were carried out with open blasting in a prefabricated RCC structures. A load cell of 100 tons capacity, least count 50 kg was installed inside roof of the structure to monitor impact of load exerted by the blasting gas on the precast structure at an alternate site (Fig. 6.10).

Fig. 6.9 Photograph showing blasting to be carried out under an RCC roof

Fig. 6.10 Load cell mounted inside roof of the precast concrete structure at an alternate site to monitor load exerted by the explosive pressure

Response of the load cell for the blasts conducted (one side open) was plotted in Fig. 6.11. The study indicated that using up to 6 cartridges per blast (0.75 kg of explosive) there was no significant lift of the slabs of the prefabricated concrete structure of one side open. Using 7 cartridges (0.875 kg of explosive), the slab was lifted about 3 cm on three sides and 5 cm on back side of the prefabricated concrete structure (one side open). The vertical rod connecting the slab had given up. The back side slabs had fallen. Load cell reading was 1150 kg and this lower level may be due to the relative vertical lift of the slab and the load cell. The gas pressure might have escaped.

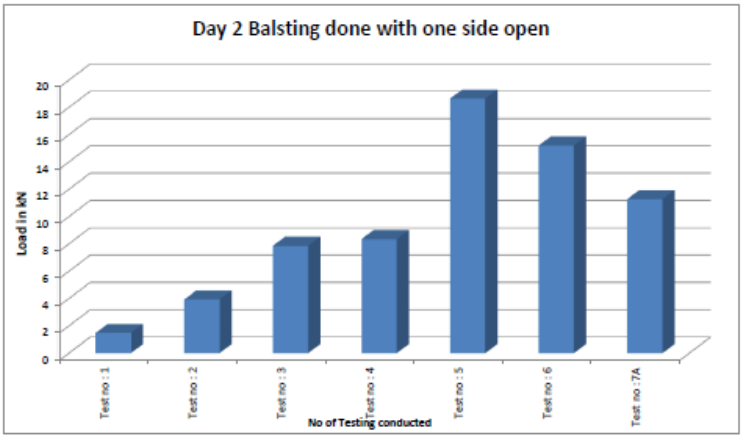

Fig. 6.11 Response of the load cell for the blasts conducted (one side open)

- Velmurugan Blue Metals and Velmuragan Stone Crusher are located side by side vide survey number 188 at Satrawada village, Nagari Mandal, Chittoor district of Andhra Pradesh. Both the quarries were working in common benches with top bench of 15 m high and a bottom bench of 24 m high. There was a proposal to split the second bench of 24 m into two benches of 12 m each. The rock in these quarries is excavated by drilling 115 mm diameter hole to a depth of 15 m and charging the drilled holes with cartridge emulsion explosives and initiated with shock tube initiation system (DTH and TLD). The burden and spacing practiced is 2.5 m x 3 m respectively. As there were complaints from the villagers of Adavikothur about ground vibration and air overpressure due to blasting at these quarries, the quarry managements approached NIRM to conduct a study on ground vibration and air overpressure jointly for both the quarries. All the private structures of the surrounding villages, reservoirs, etc. are located beyond a distance of 700 m from the working benches of the quarries (Fig. 6.12) except for lone house which is located at a distance of 480 m. The structures belonging to quarry owner like magazine, crusher and office are located within a radius of 500 m. Field investigations were carried out in two phases for both the quarries. Ground vibration and air overpressure was monitored at different locations for 10 blasts covering surrounding structures and nearby villages (Fig. 6.13). The post blast observation of boulder generation and frequency of secondary blast were noted. To reduce the boulders from the collar region a pocket charge was suggested in the stemming column. A site specific predictor equation for ground vibration was derived and presented. Based on the DGMS standard, for the recorded frequency range of >8 Hz, a permissible peak particle velocity of 10 mm/s could be recommended for domestic houses/structures in the villages which are not belonging to the owner. However, considering higher factor of safety, a peak particle velocity of 5 mm/s was recommended. It was observed that the ground vibration due to blasting attenuated below the recommended level of 5 mm/s at a distance of 400 m and fell below 1 mm/s beyond a distance of 700 m. Ready reckoner graphs were presented (i) to estimate the probable ground vibration for known maximum charge per delay and distance and (ii) to check whether the vibration could have exceeded the permissible level of ground vibration for known maximum charge per delay used and known distance between the blast and the structure.

Fig. 6.12 Photograph showing quarry site and villages

Fig. 6.13 Photograph showing vibration monitoring at a village

- Indian Railways is planning to eliminate level crossing gates across the country for ensuring the safety of the passers-by and safe running of the trains. Subways/Road-Under Bridge (*RUB*) is a solution for the elimination of level crossing. In this regard South Western Railway is planning to construct *RUB* at 14 different locations between Penukonda and Darmavaram Railway Stations in a stretch of 42 km. At all these 14 locations, railway authorities conducted geotechnical studies to categorise the soil and hard rock quantity. At four locations, hard rock strata are encountered at shallow depth which has to be excavated by drilling and blasting. The approximate size of excavation at all the four locations is 13 m long and 7.5 m wide with varying depths depending on the hard rock strata at these locations. The construction of RUB involves a sequence of operations including drilling and blasting; and the time allocated for this activity is 2 hrs 30 min only. Fig. 6.14 shows the location of these four RUBs at chainages 146/800-900,150/600-700, 154/200-300 and 171/000-100 km. Fig. 6.15 shows the location of LC No. 95. Generally, the construction of *RUB* involves a sequence of operations, starts with the removal of railway line along with sleepers (about 10 m in length), followed by the removal of the ballast and excavation of the soil to the desired depth. Subsequently the invert is laid with a precast concrete slab. The under pass is then assembled using eight numbers of pre-fabricated concrete segments. After which the sides and the top of the segments are filled with soil and ballast as per the design over which initially removed railway track is replaced and welded as per the standard procedure. The trains are allowed to use the tracks at a reduced speed till such time (may be 10 days) all other associated works are completed and tested for permitting the trains to run at the designated speeds. Keeping this in view, Hindupur Division of SW Railways, approached NIRM to furnish a method statement containing the feasibility of blasting at the proposed four locations of RUB. NIRM team visited the project sites and carried out a reconnaissance survey at the proposed four locations. Held detailed discussions with project authorities and collected the relevant details and plans for the preparation of report. After thorough study on feasibility of blasting and time requirement, a final report was submitted to SW Railways.

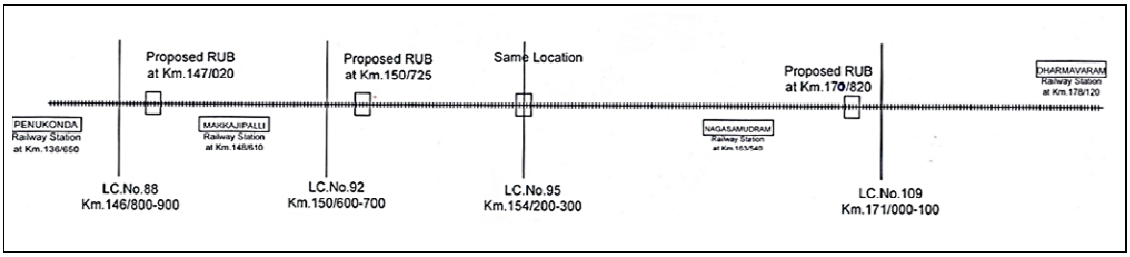

Fig. 6.14 Plan showing location of proposed RUB constructions with reference to existing LCs at four stations

- 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, spillway 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 spillway, 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. The project is unduly delayed due to bifurcation of the erstwhile state of Andhra Pradesh into two during 2014. Upon receiving the intimation from the project authorities field investigations shall be carried out.

Fig. 6.15 Location of level crossing no 95

- Waddera Sangam, Karimnagar District of AP operating fourteen quarries under Survey No. 493 and 497. At all these quarries rock is being excavated by drilling and blasting method. These quarries are located near some villages. In these quarries, blasting activities was stopped due to complaints from the locals. In this regard, quarry owners of Waddera Sangam approached the NIRM to conduct a scientific study on ground vibration, air overpressure and assessment of flyrock due to blasting operations at proposed quarries of Sy. No. 493 & 497. A preliminary visit was made during January 2014 at the proposed quarries. A meeting was attended at DGMS office, Hyderabad convened by Dy. DGMS along with quarry owners. During the meeting, the methodology for conducting the study was explained to the Dy. DGMS. The quarry owners initiated process for getting the permission from Dy. DGMS to conduct the study at the proposed quarries. The field work will be commenced upon getting the intimation from the client after getting the necessary permissions.

7. MINE DESIGN

For safe design of underground and opencast mining, NIRM carries out detailed rock mechanics and ground control investigations, and to validate the designs, it carries out systematic strata and support monitoring. The Institute is actively involved in rock mass characterization, support design, strata monitoring and design of safe and innovative mining methods. Investigations are undertaken to ensure safe extraction of coal and different minerals occurring under difficult ground conditions. Brief description of the projects undertaken during 2014-15 is given below.

- In Panel 38 Level East in Seam V at Churcha West Colliery, the depillaring panel is situated under a hill cover of about 465 m; the immediate roof is sandstone having an RMR of 61. The size of the pillars is 35 m x 35 m, size of the galleries 4.8 m x 3.0 m, size of spilts 4.8 m x 3.0 m, and size of slice 4.8 m x 3.0 m. The main fall generally takes place after an extraction area of 500 to 5100 m^2; and the periodic falls at every 200 to 4900 m^2. At the request of the mine management, the instrumentation and monitoring of this panel is being done to evaluate the ground conditions, for safe extraction during depillaring. Based on the monitoring data, suitable warning limits for stress and deformation will be suggested. Accordingly vibrating-wire type stress cells in four pillars, and convergence stations at every junction were installed. The instruments are being continuously monitored in all the three shifts during depillaring of the panel. From the strata monitoring observations, it was observed that the maximum convergence recorded in the panel was 50 mm at 38LE/16x, when the point was at goaf edge. In general, the deformations were less in the initial stages, but gradually increased as the extraction line reaches the point. The warning limit for this panel was 10 mm/day in rise pillars, 6 mm/day in dip pillars and 50 mm cumulative convergence. It was also seen that stress values were within normal range of 10 kg/cm^2. While the trend of change in stress over the pillars with respect to the line of extraction is as expected, the magnitude of change in stress observed is within safe limits. The depillaring of 38 level east panel was completed safely and the panel was sealed on 18th December 2014. After 38 LE panel, similar investigations have been taken up by NIRM in 15 Level East panel in V seam at Churcha mine, SECL (Fig. 7.1). Instrumentation and monitoring is being carried out in this panel also to evaluate the ground conditions, for safe extraction during depillaring. Based on the monitoring data, suitable warning limits for stress and deformation will be suggested.

- NIRM was requested by M/s UCIL to suggest the support plan and stoping parameters for the hangwall load, and to formulate the support plans for the crusher chamber of Tummalapalle underground mines in Kadapa district, AP. Accordingly, NIRM made the ground stability assessment and suggested the feasible methods of stoping at the mine, along with suggestions for working of the footwall lode and its support design. The mine authorities are continuing the development of the stopes as per the suggested design. Further, the mine management now proposes to work the hangwall lode also. Based on field and laboratory investigations, the red shale roof strata over the hangwall ore body (with its Q value 1.9 and RMR 39) had been classified as “Poor Rock Mass”. For these conditions the recommended support system was 1.8 m long,

25 mm diameter, full-column grouted roof bolts, at 1.0 m row spacing, four bolts in a row. In the junctions and in the loading points, additional 3 m long bolts/cables should be installed in between the bolts. The same support system was applicable for the 4.5 m wide strike drives also. It was suggested to extract the hangwall ore body forming 5 m wide rooms and leaving minimum 4.5 m x 4.5 m remnant pillars. The roof in the extracted rooms should also be supported with regular bolting at 1 m x 1 m spacing. With these parameters, the percentage of extraction by the room and pillar method would be more than 75%. Since the workings are shallow, crown pillars may not be necessary. However, rib pillars were required to protect the surface and the extraction areas in the adjacent panels. It was recommended to have rib pillars 7 m in width and 38.5 m in length (dip-rise direction) separating the different stoping panels along the strike.

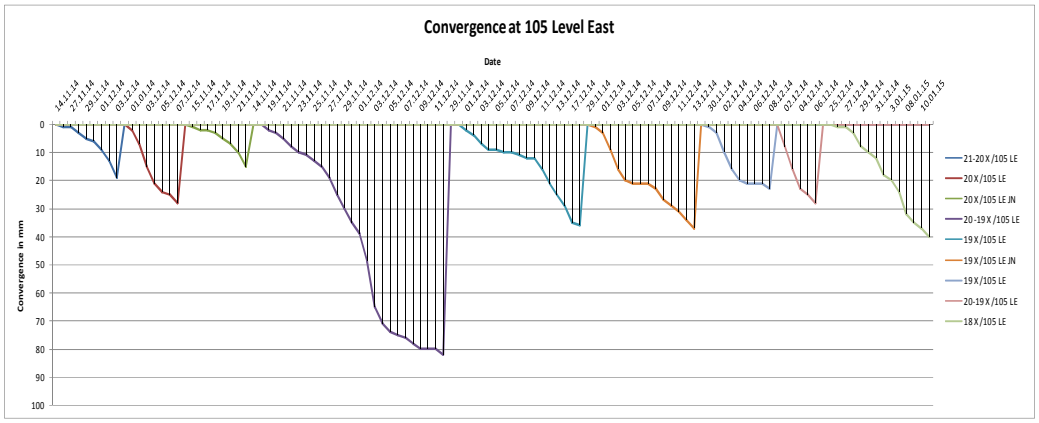

Fig. 7.1 Cumulative convergence recorded at 105 Level East of 15 LE panel, Churcha West mine, SECL

- MOIL Ltd operates 7 underground mines and 3 opencast mines. At Chikla underground mine, the mining method employed is horizontal cut & fill system. To optimize the stoping parameters for better safety and productivity at this mine, NIRM carried out 2D stress analysis of the area, and designed the stoping parameters, including support design, optimization of rib pillars, post pillars and barrier pillars. The major concern in an underground hard rock mine employing open stope methods such as cut and fill is safety of personnel, equipment and dilution of the ore due to failure of surrounding rock mass. The rock mass is of good category in case of ore body (Fig. 7.2). The stope width varies from 7 m to 15 m, for which the support requirements is systematic bolting at a spacing of 2 to 3 m (Fig. 7.3). However the 1.5 m rock bolt in between the cable bolt, as being practiced currently will not serve any purpose for the rock mass conditions present here and is not recommended for the proposed stope. The stability of the crown pillars was evaluated using empirical and numerical methods. Two empirical methods such as the Stability Graph Method of Potvin and Hadjigeorgiou and the Scaled Crown Pillar Span Concept of Carter (1992), were used to evaluate the crown pillar stability. It was observed that the present practice to leave 5 m thick crown pillar supported by cable bolts with 2 m spacing is adequate for these conditions. The requirement of crown pillar was worked out to be 2 m which means that the proposed crown pillar thickness is more than two times of the requirement. This estimated crown pillar requirement along with the post pillar and rib pillars and the

stability of the same was also evaluated by numerical modeling. As such there is a scope for further optimisation of rib and post pillars. However, it is highly recommended that the behaviour of the proposed crown and rib pillars need to be monitored by appropriate instrumentation program to ascertain the behaviour of the same during and post mining operations. This will enable us to understand the behaviour and performance of the pillars and also the support system.

Fig. 7.2 Banded texture (foliation) in ore zone, and lineation and bedding planes at Chikla mine, MOIL Ltd

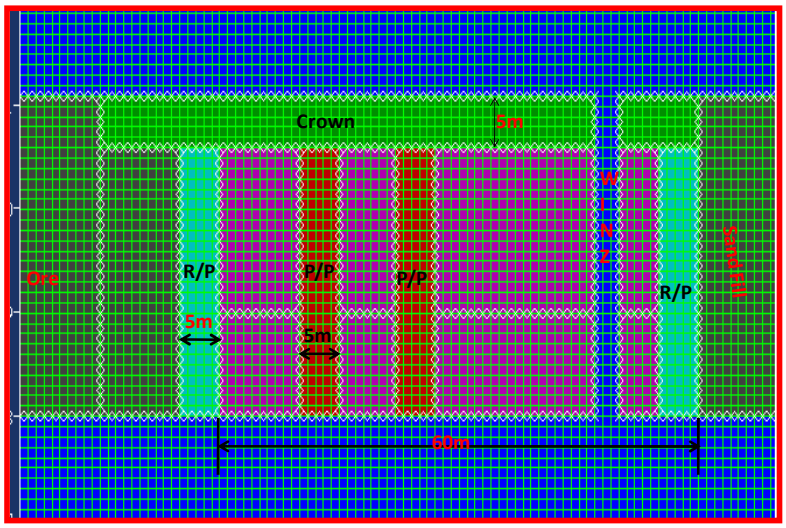

Fig. 7.3 Model geometry for Chikla mine stope design, MOIL Ltd

- At their chromite mines at Kaliapani, Odisha, M/s Balsore Alloys Limited Ltd intends to increase the dump storage capacity by constructing vertical walls and by stabilizing the slopes of the embankment. The expected height of the dump is 30 m (Fig. 7.4). The designing of the vertical wall for increasing the overburden dump capacity was awarded to M/s Engineering India Ltd, and M/s Balasore Alloys requested NIRM to verify the report and confirm the results and recommendations. NIRM has gone through the technical details presented in the report by M/s Engineering India Ltd., Pune, and also carried out independent verification analyses for the dump stability. M/s Engineering India have designed the vertical soil nail walls for increasing the overburden dumping capacity, designed vertical soil nail walls for permanent haulage

road embankments, and carried out stability analysis to check for technical viability. Reinforced shotcrete/ gunite facing soil nail wall and foam concrete block wall was designed to make the overburden vertical walls stable up to 30 m height. Soil nail wall is designed and analyzed for global stability, sliding stability, heave analysis and seismic stability, both in wet and dry conditions. NIRM Scientists visited the mine, and based on the field investigations, independently carried out and the stability analysis for 30 m high dump; the wall design was carried out using Slide 6.0 software for limit equilibrium analysis in the study area. It was seen that the soil nails, ground anchors and the foam concrete blocks supported by soldier beams – all have been designed adequately. The seismic analysis and the stability analysis in wet conditions were checked against established procedures, and they were found in order. The 30 m high retaining wall using foam concrete blocks supported by vertical soldier beams is appreciable; the design was checked and found adequate in all respects. The 30 m high wall was analysed by NIRM for a secondary check, with additional micro pile supports with a slope angle of 600. With this, the factor of safety obtained was 1.407 to 1.489 which is considered adequate for long term stability. The results of the analysis show that there is no failure taking place on the wall surface. Based on the study made by NIRM, and the Slide 2D analysis results, it is seen that the estimates made and the conclusions drawn in the report by M/s Engineering India appear to be in order for the conditions existing at the mine. The support measures and the drainage measures suggested are acceptable. The mine management was advised to go ahead with construction of the retaining wall as per the design, and implement the other recommendations.

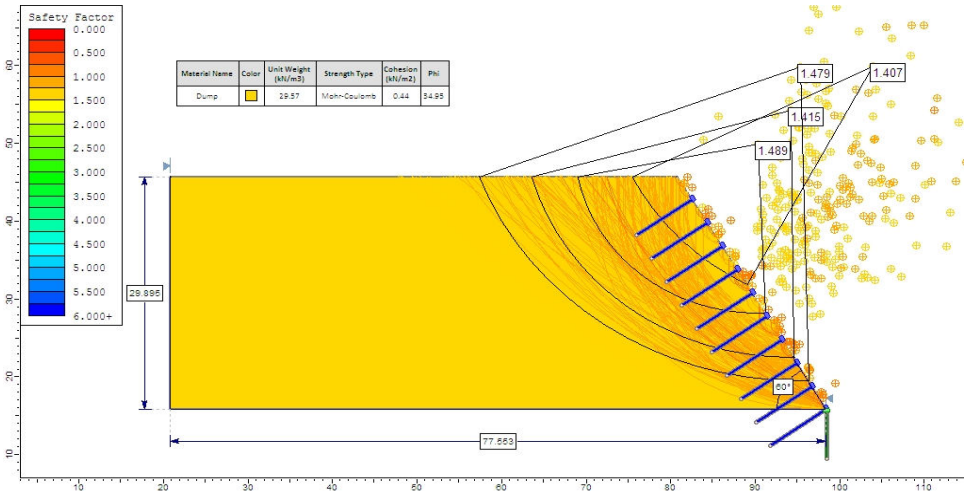

Fig. 7.4 Cross section of the 30 m high dump with supports and micropile, at the Kaliapani chromite mine, Odisha

- M/s Ramco Ltd are leading cement manufacturers in south India with 5 cement plants, 3 in the state of Tamilnadu. The RR Nagar plant is located in Virudhunagar District, south of Madurai in Tamilnadu. At present three limestone mines are operating to cater to their requirement. Pandalgudi limestone mine is one of them (Fig. 7.5). There is a dump yard on the footwall side and roads on either side, restricting deepening of the mines. In view of this, the mine management desired to carry out the slope stability studies. The basic philosophy behind the bench design in an open pit mine is that the

slopes should be flat enough to be stable and steep enough to allow economic mining operations. The overall slope angle is the line joining the crest of the top most bench and toe of the bottom most bench of the pit. For the purpose of this project, a minimum factor of safety of 1.3 is considered for long term stability. In limestone ore mines with hard strata, non circular failures in the benches are generally experienced. Keeping this in view, limit equilibrium method was used for the slope stability analysis, considering a number of path failure surfaces. The analysis was carried out using the software 'Slide 6.0', developed by Rocscience, Canada. This is comprehensive slope stability analysis software for analysis of soil and rock slopes. Using different material strength models such as Mohr-Coulomb, Anisotropic and Generalized Hoek-Brown Support types, the required support force for a given safety factor can be determined. The search algorithms available in the program enable one to find the critical slip surface with the lowest safety factor. The factor of safety of potential failure surface is computed for different sections, and the critical failure surface (the surface having the least factor of safety) is identified. In the limit equilibrium analysis since there is no sign of watery condition in and around the mine, only dry condition was considered to estimate the safety factor using Bishop's method of analysis. The analysis was carried out for the existing slope parameters to determine the optimum bench height and slope angle, and for the overall slopes to determine the ultimate pit slope angle. A factor of safety of 1.3 is considered for the long term stability. The slide analysis of the existing profile and the new profiles along the cross sections, ML 28 Left, ML 28 Right, so on till ML 33 Left & ML 33 right, was carried out and the minimum factor of safety was obtained for each section. The minimum factor of safety (FoS) of 1.3 is considered for the benches to be stable and safe over a longer period of time. The slide analysis of the existing profile and the new profile along the cross sections ML 28 Left, ML 28 Right, so on till ML 33 Left & ML 33 right, shows the minimum FoS ranging from 1.351 to 4.289. Based on the analysis, the proposed new dimensions suggested are: bench height 12 m (inclined length), bench width 2.5 m for two benches and 6 m for the third bench (safety bench), and individual bench angle 66^{o}. With the above parameters, the ultimate workable pit limit is 142.3 m with pit bottom width of around 40 m; an overall pit angle of 53^{o} is considered to be optimal safe workable angle for the pit 5 & 6 of Pandalgudi limestone mines. It is further suggested to use pre split blasting method to avoid over hangings in the benches.

Fig. 7.5 Overall view of the Pandalgudi mines

8. 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.

- Tapovan-Vishnugad hydroelectric power project at Joshimath is located within the tectonic block bounded by Main central Thrust in the south and Vaikrita thrust in the north with metamorphosed rocks exposed. The area is highly seismic active and falls in zone V. Among other components, this project has an underground power house near Helang for 520 MW (4 x 130 MW) of power generation under the spur between Animath Nala and Alaknanda river. During excavation of powerhouse, incidences of slabbing in roof strata and rockbursts type situation were encountered. In order to assess the stability of the powerhouse cavern and study the dynamic behaviour of the effect of stress re-distribution in the rock mass surrounding this cavern, NIRM had undertaken the real-time microseismic monitoring of the area around excavations

  Thirty geophone stations with sixty channel Nanoseismic sensor network was designed and installed the necessary DAQ system and enabled 12 channel data acquisition from MAT area, and expected to interface remaining channels to be interfaced shortly once the work at site is resumed after severe flood. The Data acquired from Feb 2013 to June 2013 was extracted from the system and found in good condition and data processing is in progress (Fig. 8.1, 8.2 & 8.3). Once the

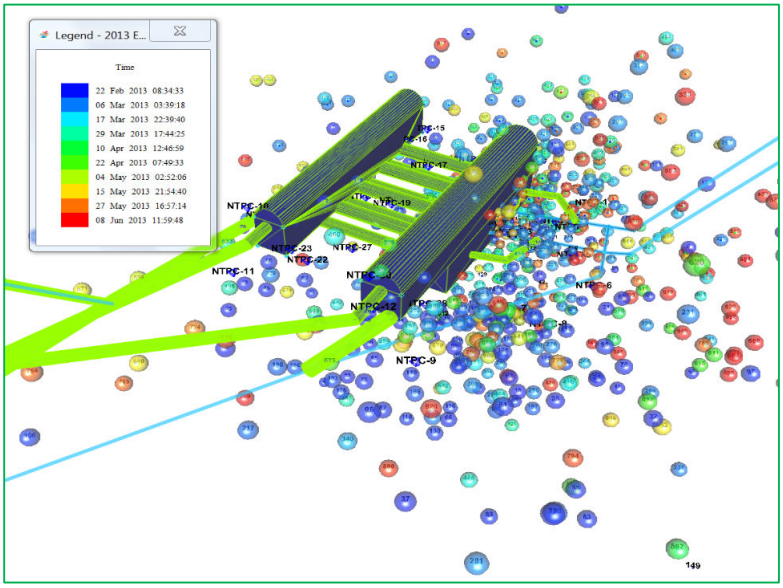

Fig. 8.1 Microseismic events recorded during March 2013 and June 2013, mapped on the TVHPP powerhouse caverns 3D Plan

power is available to the field stations, laboratory data acquisition will resume. Available data was processed for analysed for the system calibration and modifications. Remaining 18 sensor stations were also installed as soon as the boreholes were made available by NTPC during February 2015 and the same need to be interfaced to the central DAQ system. Real time monitoring is not yet enabled due the lack of dedicated data communication link. Examination of the recorded data was done and quality was found good and noise free. Data acquisition was initiated for the second year period of strata monitoring of the caverns.

Fig. 8.2 Installed nanoseismic instrumentation at TVHPP

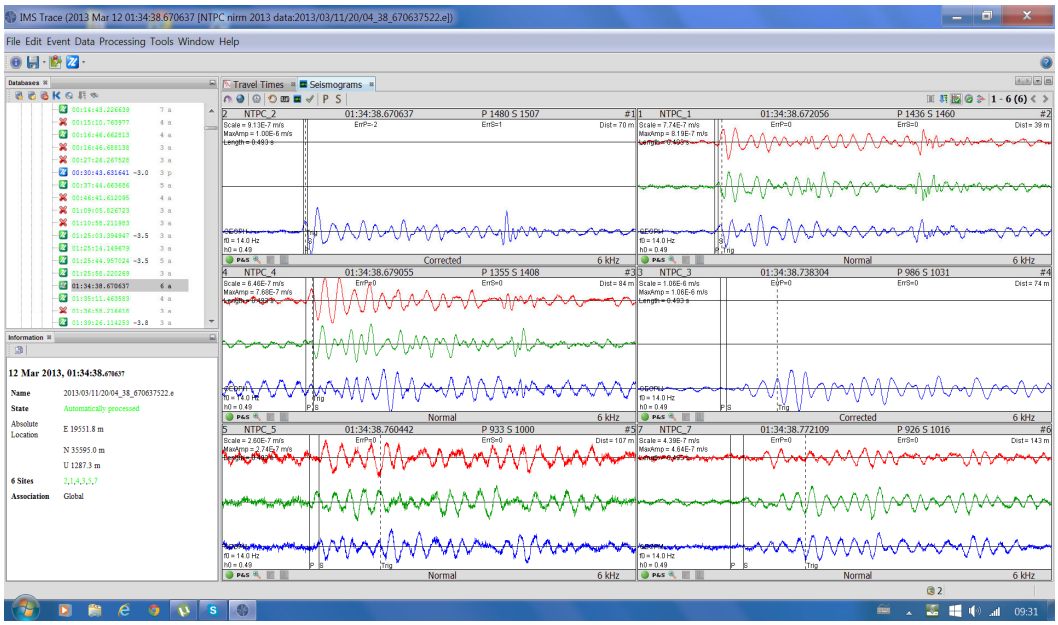

Fig. 8.3 Microseismic event recorded at TVHPP site in 12th March 2013

- The Tala Hydroelectric Project of Bhutan, which was commissioned in 2009 is facing problem of frequent rock bolt failure in the powerhouse cavern. So far more than 800 rock bolts have come out under severe stress conditions. This triggered a major concern to the project authorities on the stability of the powerhouse. In order to analyse the reason behind this phenomenon of expulsion of rock bolts, the NIRM and M/s DGPC, Bhutan entered in to an agreement for round-the-clock-monitoring of the area around powerhouse excavations by 30 station microseismic monitoring network.

NIRM agreed to provide logistic support for identifying the proper microseismic system for procurement by DGPC. It was also agreed that upon commissioning of the microseismic network, NIRM shall carry out the monitoring, data analysis work for three years during which DGPC personal will be trained to operate the system in future.

Thirty geophone station/sixty channel “Microseismic Monitoring System” installed at power house during Sep 2013 is functioning well and generating noise free high quality data without any interruption round the clock. The data acquired till March 2014 was used for calibration of the total system and put the system full pledged operation. Data acquisition and data processing work at NIRM Bangalore unit and at THP, Rinchentse is in progress in near real time to full fill the objective of real time monitoring. The data was analyzed and interpreted for the strata condition and correlated with the rock bolt failure. It was concluded that the strata condition is stable without any noticeable stress changes and the bolts failure with metal breakage is observed prior its physical ejection from rock (Fig. 8.4 to 8.8). The reason for failure is suspected because of high pre stressing. Daily we are interacting with site engineer and submitted the 1st annual report and half yearly report. Second year monitoring is being going on smoothly.

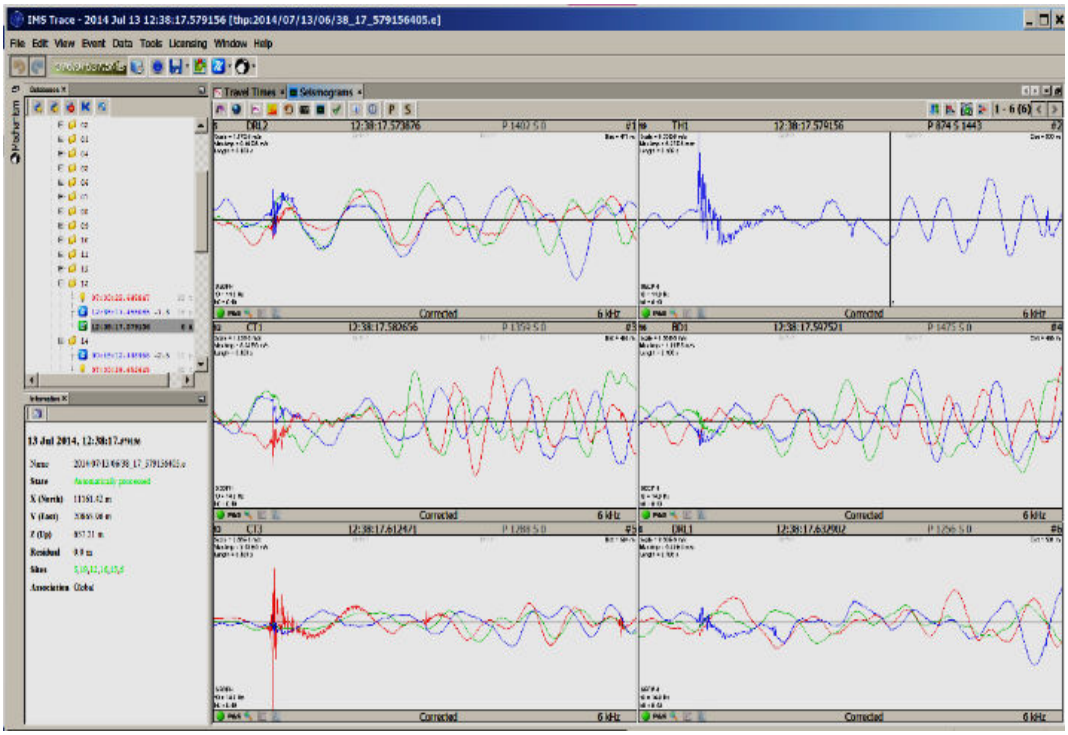

Fig. 8.4 Rock bolt metallic failure seismic signatures prior to the physical ejection from rock recorded at THPP, Bhutan

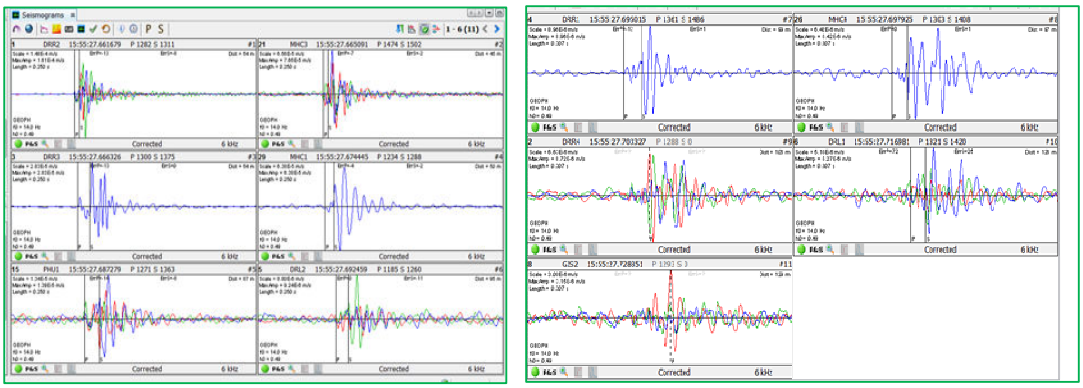

Fig. 8.5 Seismic signatures of the rock bolt physical ejection from rock

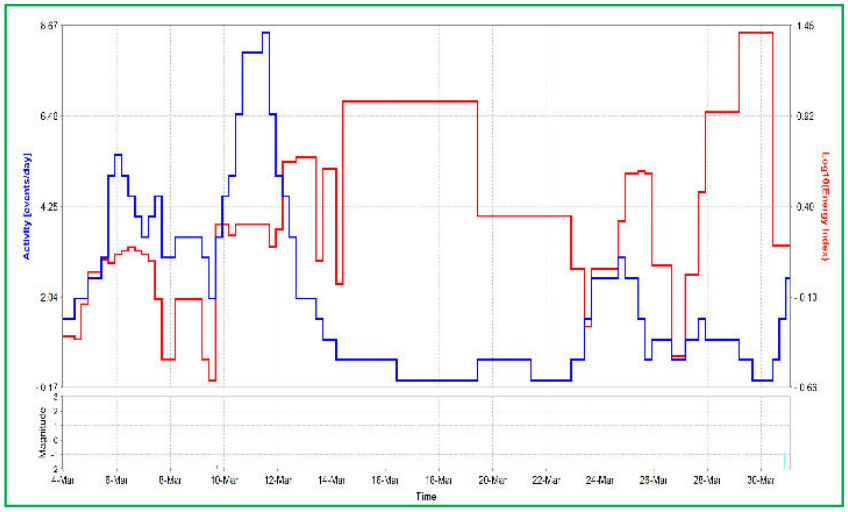

Fig. 8.6 Time history graph of activity rate vs CAV for March 2015 data

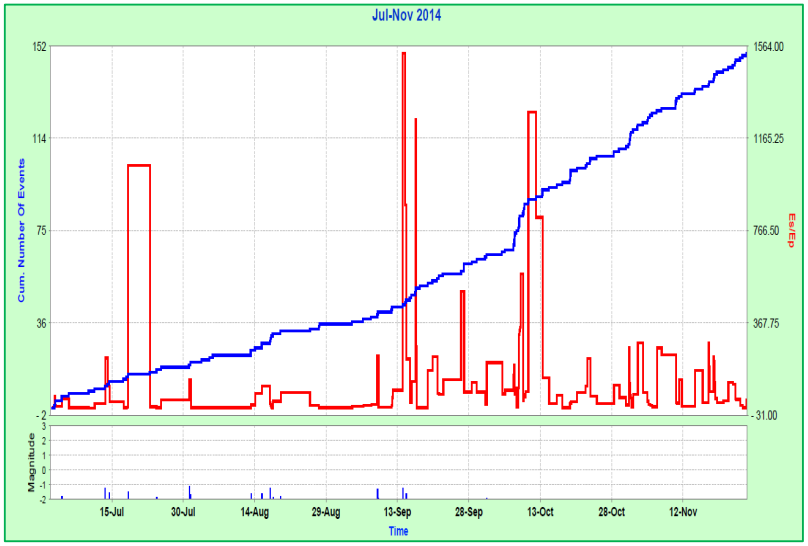

Fig. 8.7 Es/Ep vs. CAV time history for the data July-November 2014

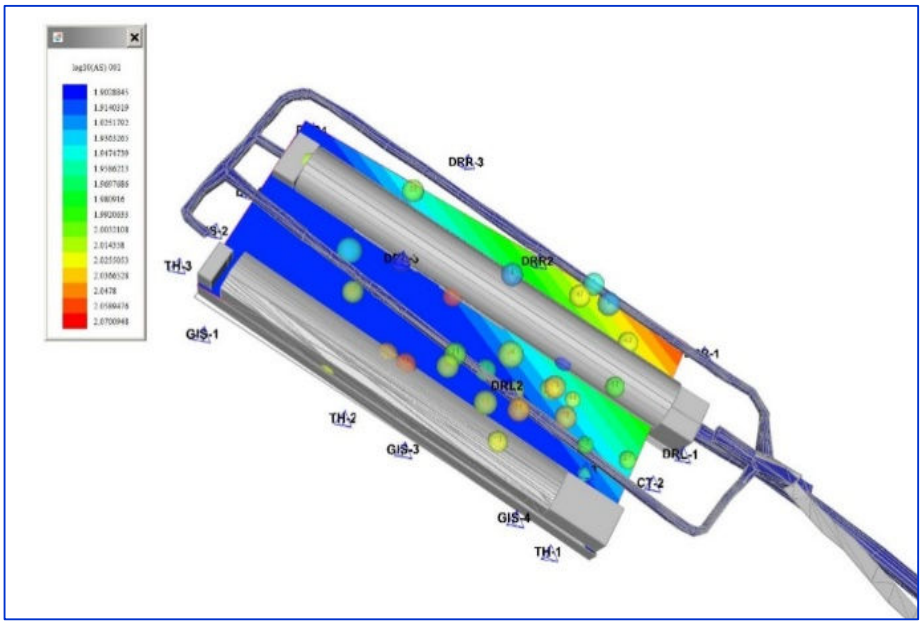

Fig. 8.8 Contours of apparent stress for data from July-Nov 2014 of strata seismic response

9. 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.

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 2014-15, destructive tests were carried out on 76 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	Shaft Sinkers Mauritius Ltd, Rampura Agucha Mines, Rajasthan.	UT, MPT and WRD
2	Hindustan Zinc Limited, Rajpura Dariba Mines, Rajasthan	UT, MPT and WRD
3	Singareni Collieries Company Limited, Coal Handling Plant, Kondapuram, Telangana.	UT, MPT, IR, VM, and UPV
4	Singareni Collieries Company Limited, NDT on 4 Man winding system, Telangana.	UT, MPT and WRD
5	China Coal No.5 Constructions Private Limited, SK Mines, Rajasthan	UT, MPT and WRD
6	Andhra Pradesh Heavy Machinery And Engineering Limited, Andhra Pradesh.	UT, MPT and PLT
7	Singareni Collieries Company Limited, NDT on GDK10 Man winding system, Telangana.	UT
8	Hindustan Zinc Limited, Rajpura Dariba Mines, Rajasthan	UT and WRD
9	Hindustan Zinc Limited, Zawar group of Mines, Rajasthan	UT, MPT and WRD

10	NALCO, Damanjodi, Odisha	WRD
11	Shriram EPC Limited	UT, MPT and PLT
12	Shaft Sinkers Mauritius Ltd, Rampura Agucha Mines, SVS, Rajasthan.	UT, MPT and WRD
13	Singareni Collieries Company Limited, NDT on 4 Man winding systems, Telangana.	UT, MPT and WRD
14	Shaft Sinkers Mauritius Ltd, Rampura Agucha Mines, Rajasthan	UT, MPT and WRD
15	Hindustan Zinc Limited, Rajpura Dariba Mines, Rajasthan	UT, MPT and WRD
16	Hindustan Zinc Limited, Zawar group of Mines, Rajasthan	UT, MPT and WRD
17	China Coal No.5 Constructions Private Limited, SK Mines, Rajasthan	UT, MPT and WRD
*UT – Ultrasonic Testing, MPT – Magnetic Particle Testing, WRD - Wire Rope Defectography, PLT – Proof Load Test, IR – Infrared Thermography, VM – Vibration Measurement, UPV – Ultrasonic Pulse Velocity		

- A MoU in vogue, signed between M/s Shaft Sinkers Mauritius Limited (SSML) and NIRM is for availing the technical services of NIRM for a period of three years w.e.f March 2013. As per MoU, it is required to conduct non-destructive tests (NDT) on winders, winch attachments/accessories, suspension gear parts and wire ropes once in six months period. Accordingly, three visits were made during October, November and December 2014. Using magnetic particle testing and ultrasonic flaw detector, all the associated vital components of the winder/winches and suspension gear parts were tested for surface, sub-surface and internal flaws (Fig. 9.1, 9.2a & 9.2b). Two ropes of kibble winder were tested in a usual manner, two ropes of stage winder and six ropes used in dymot winches were subjected to tests with special arrangements made at the site. All the tests were completed successfully and the results have been evaluated. It was found that the tested components were found to be free from surface, sub-surface and internal flaws.

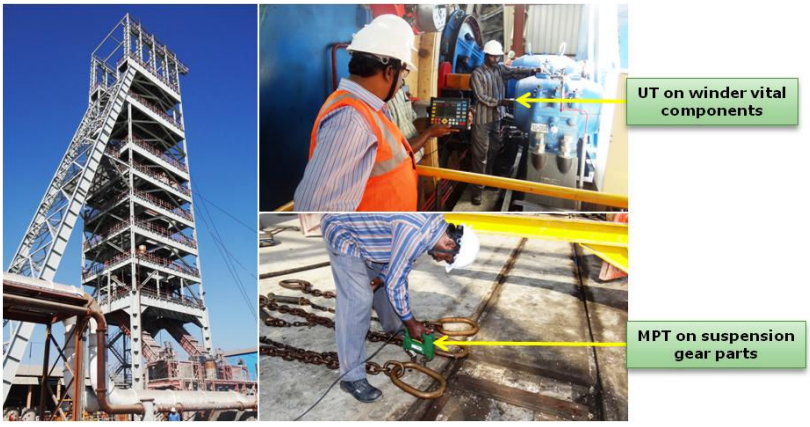

Fig. 9.1. NDT on winder vital components, suspension gear parts at Main Shaft

Fig. 9.2a Special arrangement made at the site for testing the winch ropes, South Ventilation Shaft

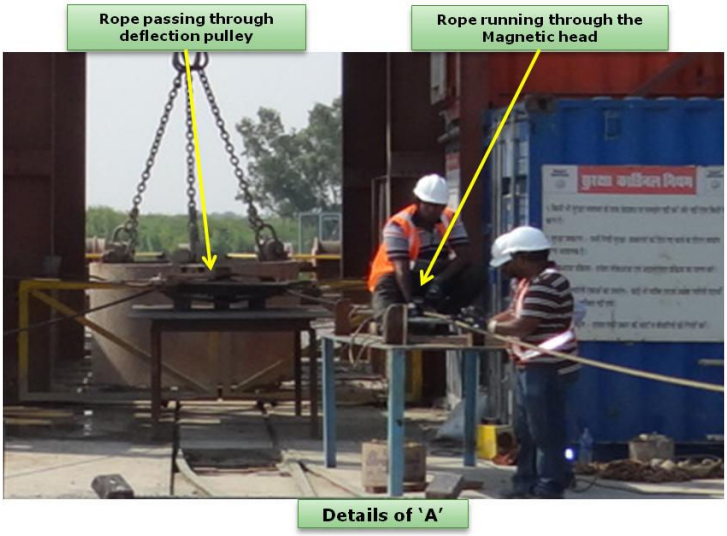

Fig. 9.2b Special arrangement made at the site for testing the winch ropes, South Ventilation Shaft

- Rajpura Dariba mine is a unit of Hindustan Zinc Limited located at Rajsamand District, Rajasthan. The operation at this mine is carried out by shafts run by winders. As per DGMS guidelines, the winders and all their associated vital components must be periodically evaluated for their fitness. Based on the service order, NIRM made two visits during February and August 2014 and one visit during February 2015. NDTs were carried out using MPT and UT on winder vital components and suspension gear parts of the winders i.e. (i) 225 kW Auxiliary shaft cage winder, (ii) 236 kW Main shaft cage winder and (iii) 740 kW Main shaft skip winder. The individual components tested at the site were drum shaft, disk brake pins, thruster brake system, drum connecting rods, sheave wheel shafts and all the suspension Gear Parts (Fig. 9.3).

  In addition, wire rope defectography was conducted on full locked coil wire ropes. (i) 18mm FLC ropes – 5 nos. of main shaft cage winder, (ii) 24 mm FLC ropes – 4 nos. of main shaft skip winder and (iii) 32 mm FLC ropes (cage and counter weight side) – 2 nos. of Auxiliary shaft winder. All the tests were completed successfully. Based on the NDT, it was recommended to replace cage side rope of Auxiliary shaft, two ropes of

skip winder at main shaft and one rope of cage winder at main shaft as they were found to have isolated fatigue cracks.

Fig. 9.3 NDT on winder vital components, suspension gear parts and wire rope inspection

- The steel structures of CHPs have to be periodically tested to assess their fitness to comply with safety standards as per DGMS guidelines. M/s. SCCL requested the NIRM to conduct NDT on steel structures of Kondapuram Coal Handling Plant. NIRM accordingly conducted the required tests on the steel structures at the project site in two phases. The study was conducted using NDT techniques such as visual inspection, ultrasonic testing, magnetic particle testing, infrared thermography and vibration analysis (Fig. 9.4). The results of visual inspection on the identified conveyor structures indicated significant deterioration of the roof sheets, bottom sheets and other structural members. The infrared thermography inspections on the identified structures C7, C8, C10, C11, C12, C14, C15, C20 and D-Belt structure do not indicate any significant thermal anomaly. 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 and falls under “Good Grade Concrete”. Vibration levels measured at the critical zones of C20, D-Belt structure, Pre weigh loading system and RLS I & II were found to be within the permissible limits. The recorded velocity did not exceed 1 mm/s in all the measured locations which is much below the permissible limits of 11.1 mm/s. The thickness measured at Bunker of Pre-weigh loading system is 10.2 mm and at Bunker of RLS-II is 12 mm respectively. The previously repaired segments of the bunkers are found to be damaged and needs replacement. The result of ultrasonic testing conducted on foundation bolts of RLS-II indicates that the scanned foundation bolts are free from internal flaws and their integrity is good. The result of magnetic particle testing conducted on the vital components of loading shutter system of RLS-II indicates that they were free from surface and sub-surface flaws and their integrity is good.

  The entire tests were completed successfully. However, it was recommended to replace deteriorated/corroded structural members such as roof sheets, chequered bottom walk way plates, worn out girders and gusset plates using suitable corrosive resistive steel. It was also suggested for conventional painting of gantry vertical beams, horizontal girders, bracing members, chequered bottom plates, gussets and other fasteners as per BS 5493.

Fig. 9.4 NDT on steel structures of Kondapuram Coal Handling Plant (CHP), Manuguru area

- M/s. Singareni Collieries Company Limited (SCCL) comprises of mines at different places. As per DGMS guidelines, the winder's vital components, suspension gear parts and wire ropes must be periodically tested for their fitness. NIRM conducted NDT on winders vital components, suspension gear parts and wire ropes in three visits during July, October and December 2014 (Fig. 9.5). Using MPT and UT, NDT was carried out on the winder vital components and suspension gear parts of the winders i.e. (i) 350 HP Cage winder at GDK-10 incline, Ramagundem Area, (ii) 285 kW Cage winder at PVK-5B, Kothagudem Area, (iii) 285 kW Cage winder at VK-7 incline, Kothagudem Area and (iv) 400HP Cage winder at 21 incline, Yellandu Area.

  Apart from the winder's vital components and suspension gear parts, wire rope inspection was also carried out on the four ropes (i) 32 mm FLC ropes – 2 nos. at GDK-10 incline, (ii) 32 mm FLC ropes – 2 nos. at PVK-5B, (iii) 32 mm FLC ropes – 2 Nos. at VK-7 and (iv) 32 mm FLC ropes – 2 nos. at 21 incline

  All the tests were completed successfully. Based on the tests conducted on suspension gear parts at VK-7 incline, two isolated cracks on the bridle chains were noticed on fixed drum side. The crack profile was analyzed and the direction of the crack propagation was studied. They were found to be cross-sectional with respect to the chain links. Since the defect was propagative linear type crack, it was recommended that the bridle chains identified with cracks to be replaced. As regards to NDT conducted on the wire ropes at VK-7 incline, isolated fatigue cracks were noticed on fixed drum side rope at six different places above cappel end. It was recommended that the rope may be cut up to a length of 100 m from cappel end and recapped.

Fig. 9.5 NDT on winder vital components, suspension gear parts and wire rope inspection of various mines

- M/s. China Coal No. 5 Construction India Pvt. Limited (CC5C) has taken up the shaft sinking operations for Hindustan Zinc Limited, Rajasthan. The shaft sinking operations have commenced with a Main winder and an Auxiliary winder, in addition to 15 winches placed on either sides of the head-gear. M/s China Coal requested NIRM to carry out NDT on winder vital components, suspension gear parts and wire ropes. NIRM made two visits during August 2014 and February 2015 and conducted the required NDT using MPT and UT on winder vital components and suspension gear parts of the two winders (i) 2000 kW main winder and (ii) 1250 kW auxiliary winder. In addition, wire rope defectography was conducted on multi strand wire ropes of ϕ 40 mm – 2 nos. All the tests were completed successfully (Fig. 9.6). Based on the test results, it was concluded that all the tested components on winders and suspension gear parts were free from surface, sub-surface and internal flaws. Based on the tests conducted on wire ropes, it is concluded that there were no anomalies. The wire ropes were free from Local faults (LF) such as pitting, corrosion and broken wires and also free from Loss of metallic cross-sectional area (LMA).

Fig. 9.6 NDT on winder vital components, suspension gear parts and wire rope inspection

- M/s Andhra Pradesh Heavy Machinery and Engineering Limited are manufacturing men transport trolleys used in underground mines. One such integrated part is 16 Bolt ham bone clamp. Before putting them to use, they have to be subjected to proof load test and NDT. M/s APHMEL requested NIRM to conduct proof load test and NDT on the components. Based on the service order, proof load test and NDT was carried out on 16 bolt ham bone clamps of 6 nos. at the NIRM laboratory (Fig. 9.7). All the tests were carried out successfully. Proof load test is conducted by applying a load three times the safe working load of the component on 200t Horizontal Universal Testing Machine. After the proof load test, the components were examined and it was observed that the tested components did not undergo any deformation. Subsequently the components were subjected to NDT (MPT and UT). The test results revealed that the components were free from surface, sub-surface and internal flaws.

Fig. 9.7 Proof load test and NDT on 16 bolt ham bone clamps

- 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, NIRM made two visits. NDT was carried out using MPT and UT on winder vital components and suspension gear parts of the four winders (i) 383HP cage winder at Balaria mine, (ii) 560 HP skip winder and 70HP cage winder at Zawar Mala mine, (iii) 236 HP cage winder at West Mochia mine and (iv) 400 HP skip winder and 200 HP cage winder at Central Mochia mine. In addition, wire rope defectography was conducted on the six ropes (i) 32 mm FLC ropes – 2 nos. at Balaria mine, (ii) 16 mm FLC ropes – 2 nos. at Zawar Mala mine, (iii) 30 mm FLC ropes – 2 nos. at Zawar Mala mine, (iv) 19 mm FLC ropes – 3 nos. at West Mochia mine, (v) 24 mm FLC ropes – 4 nos. at Central Mochia mine and (vi) 16 mm FLC ropes – 4 nos. at Central Mochia mine.

  All the tests were completed successfully (Fig. 9.8). Based on the NDT carried out on winder vital components and suspension gear parts, the results revealed that the tested components were free from surface, sub-surface and internal flaws. As regards to wire inspection, isolated fatigue cracks were observed at several locations on both the cage and counterweight side ropes at Balaria mine. The cracks were prominent on the cage side rope leading to deep wear. Therefore, it was recommended to replace both the ropes with priority for cage side rope.

Fig. 9.8 NDT on winder vital components, suspension gear parts and wire rope inspection

- M/s. National Aluminum Company Limited (NALCO) bauxite mine is located at Panchpatmali hills in Koraput District of Odisha. 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 & 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. 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 during August 2014 and the scanned strip charts were analyzed (Fig. 9.9). Based on the tests carried out on the cable belt drive system, it was concluded that the left side rope was found to be highly deteriorated and characterized with remarkable defects such as corrosion, pitting, and excessive deep wear and cluster broken wires. Apart from these defects, a large number of isolated broken wires along with other defects mentioned were also noticed. The percentage reduction in diameter of left side and right side rope was found to be 7.29% & 5.78% respectively. Since the reduction in diameter of both the ropes is well below 10% as per discard criteria, the ropes can be continued to be put to use. However, the left side rope is found to be deteriorating fast which is evidenced by the need for intermediate reinforcement through five new strands. In general, the left side rope has undergone excessive deep wear clubbed with isolated broken wires, cluster broken wires and dressed broken wires throughout its length. Continuous and careful monitoring of this rope was recommended.

Fig. 9.9 Inspection of cable belt drives

- M/s Shriram EPC Limited is undertaking pre-shaft sinking project at M/s HGML campus. The components used for pre-shaft sinking purpose must be periodically tested as per DGMS guidelines for their fitness. NDT and proof load tests were conducted on the components such as bucket bows, load carrying pins and D-shackles at the NIRM laboratory. Proof load test is conducted by applying three times the safe working load of the component on 200t Horizontal Universal Testing Machine. After the proof load test, the components were examined and it was observed that the tested components did not undergo any deformation. Subsequently the components were subjected to NDT (MPT and UT). The test results revealed that the components were free from surface, sub-surface and internal flaws.

Fig. 9.10. Proof load test and NDT on bucket bows, load carrying pins and D-shackles

- Investigations for the structural stability audit on head gears is going on. This project is sponsored by M/s Singareni Collieries Company Limited.

- Wire rope defectography investigations are being carried out. This project is sponsored by M/s National Aluminum Company Limited.

- NDT in Rajpura Dariba mines and Zawar group of mines are being carried out. This project is sponsored by M/s Hindustan Zinc Limited.

- NDT on man winding systems – 4 units are being carried out. This project is sponsored by M/s Singareni Collieries Company Limited.

B. Rock Sample Testing

- The Zeenath Transport Company (ZTC) is operating Ramgad Iron Ore Mine in Ramgad Village, Sandur Taluk of Bellary Dist. For the purpose of bench slope design of their operating mine, ZTC approached NIRM for determining the rock properties for the various formations of the mine. Accordingly rock samples in the form of blocks of different formations such as Latterite, iron ore, BHQ & shale /phyllite were received. Core samples of required sizes were obtained from the supplied blocks. The scope of work includes determination of the physical and mechanical properties like (i) density, (ii) uniaxial compressive strength (UCS), (iii) Young's modulus & Poisson's ratio and (iv) cohesion and friction angle from triaxial compression test (Multiple Failure Method). All the tests were carried out as per ISRM Standard on the prepared core specimens and the final report was submitted to the client.

- NHPC Ltd. is constructing a 520 MW Teesta-IV hydroelectric project on river Teesta and requested NIRM to carry out laboratory geotechnical investigations on rock samples from dam axis drift and intake/desilting chamber drift. The rock type in the dam axis drift is dominantly made up of quartz biotite gneiss (QBG) while at the intake desilting chamber drift, it is garnetiferous mica schist (GMS). The scope of work includes determination of the physical and mechanical properties such as, unit weight, porosity, tensile strength, uniaxial compressive strength, Young's modulus, Poisson's ratio, cohesion and friction angle. Samples were prepared and tested as per ISRM standards under both dry and saturated conditions using MTS servo hydraulic compression testing machine, electronic extensometers for measuring deformation and Hoek triaxial cell. The elastic constants were calculated between 20 to 60% of the failure stress of the samples tested under uniaxial compression test. Cohesion & friction angle was determined from Triaxial compression test data using Rock Data software. The important points concluded are: (i) density values of the intake/desilting drift are found to be higher than the values obtained for the dam axis drift, (ii) the porosity values are found to be lower for the intake/desilting drift as compared to the dam axis drift, (iii) tensile strength values of the dam axis drift are higher than the values for the intake/desilting drift, (iv) uniaxial compressive strength and elastic constants of the dam axis drift are higher than the values obtained for the intake/desilting drift and (v) cohesion and friction angles for the samples tested from dam axis drift are higher than the values obtained for the intake/desilting drift. The average test results of all the properties determined in the laboratory for dam axis drift and Intake/desilting drift are given below. The final report was submitted to the client with the results and graphs obtained from various tests.

Property	Dam axis drift		Intake/desilting drift	
	Dry	***Saturated***	***Dry***	***Saturated***
Density (kg/m^3)	2639	2648	2830	2836
Unit weight (kN/m^3)	25.89	25.98	27.55	27.63
Porosity (%)	0.91		0.62	
Tensile strength (MPa)	5.65	5.49	6.14	3.35
Compressive strength (MPa)	80.38	73.49	25.92	17.34
Young's Modulus (GPa)	20.49	18.18	15.32	8.34
Poisson's ratio	0.30	0.35	0.22	0.19
Cohesion (MPa)	19.40	19.95	10.64	9.69
Friction angle (degree)	47.47	43.85	25.34	20.34

- Sri Jayadeva Institute of Cardiovascular Sciences & Research (SJICR), Bangalore, is in the process of construction of a 350 bed hospital complex at Mysore. The work involves excavation of huge volumes of earth strata to facilitate foundation of various structures (Fig. 9.11). The contract provides for excavation of earthwork under the following broad soil/rock classifications for working out Bill of Quantities (BOQ) as per KPWD Specifications. They are: Ordinary or Soft Soil, Hard Soil, Soft rock by blasting, Soft rock without blasting, Hard rock by blasting. The excavation work is almost complete and most of the areas are exposed. In view of this the office of the SJICR, Bangalore approached NIRM, KGF to provide a procedure using scientific methods to

classify the strata at the site to differentiate and establish the classification of strata under the categories specified as “hard soil” and “soft rock”. Field investigations such as geological mapping, seismic refraction survey and geotechnical studies in the field and lab were carried out and analysed the data (Fig. 9.12). The draft report has been submitted. A view of a construction site in one of the excavated pits is shown in the figure below.

Fig. 9.11 View of the construction site

Fig. 9.12 Collection of geotechnical/geophysical data from the site

- 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, a subsidiary of ONGC, requested NIRM to carry out laboratory geotechnical investigations on core samples from thirteen wellbores namely B-12-17, of Tapti Daman area, Mumbai offshore, Khubal-1 (KH#1) and Khubal-2 (KH#2), Kunjaban-4 (KU#4) and Agartala Dome (AD#19) from Tripura Asset, Vazhakudi #1, Bhuvanagiri #6, Bhuvanagiri #2, Bhuvanagiri #11, Kali #4, Adambavur #1 Kuthalam #39 and Kuthalam #24 from Cauvery asset. The test results will form input parameters for geomechanical modelling of wellbore stability by IDT. The scope of work includes determination of the physical and mechanical properties like density, P-wave velocity, tensile strength, uniaxial compressive strength - vertical and horizontal, Young’s modulus and Poisson’s ratio, cohesion and friction angle from triaxial compression test (Multiple Failure Method). Samples were prepared in two directions (Vertical & Horizontal) and tested as per ISRM standards. Uniaxial and Triaxial tests were carried

out using MTS servo hydraulic compression testing machine, electronic extensometers for measuring deformation and Hoek triaxial cell. The elastic constants were calculated between 12 to 70% of the failure stress of the samples tested under uniaxial compression test. Cohesion & friction angle was determined from triaxial compression test data using Rock Data software. The details of work carried out in the laboratory including sample preparation, testing of various properties and their results are presented in the final report and submitted to the client.

- Rock core samples from Chikla mine, MOIL Ltd were collected for the determination of physic-mechanical properties. Specimens were prepared and tests were conducted on these core samples. The laboratory test values were used for designing the stoping parameters of Chikla mine.

- Rock core samples were collected from Pandalgudi Limestone Mine, Madurai for the determination of physic-mechanical properties. Laboratory investigations were carried out on the prepared test specimens as per ISRM standards. Properties like density, cohesion & friction angle were determined. The results were compiled in the form of a test certificate and submitted to the concerned department.

- Rock samples were received from surge pool and pump house area of Pranahita-Chevella Sujala Sravanthi Scheme, Medak District, AP. Laboratory investigations on these core samples were carried out to determine the physico-mechanical properties like density, uniaxial compressive strength with elastic constants, cohesion and friction angle from triaxial compression tests. The tests were carried out as per ISRM suggested methods.

10. TRAINING PROGRAMMES CONDUCTED

Training/Internship Programmes Conducted by NIRM

- Training Programme was conducted on "Tunnelling Technology" for 20 civil engineers of the Indian Railways (IRSE – Civil), for two-weeks at NIRM, Bengaluru and for 10-days at Norwegian Geotechnical Institute, Oslo between 19th May and 11th June 2014.

- Two Training Programmes were conducted on "Rock Mechanics and Tunnelling Technology" for L&T engineers – (a) for the first batch during 23rd to 27th June, 2014 at NIRM Bengaluru, and (b) for the second batch during 8th to 12th December, 2014 at NIRM, KGF, 20 engineers each.

- Four days training program for the Executives of Singareni Colleries Company Ltd. on "Kinematic Analysis of Discontinuities" was conducted from 9th to 12th December 2014 at Kothagudem and Ramagundam, Telangana State.

- Summer internship for four students of IV semester, B.Tech Mining Engineering, NIT Surathkal, was conducted for two weeks (2nd June to 13th June 2014) on various engineering geological aspects, by the Engineering Geology Department.

- Summer training and internship programme was conducted for 5 students of V semester, B.Tech Mining Engineering, NIT Surathkal for seven weeks between 1st June and 17th July 2014 on various aspects of Rock Mechanics.

- Vocational training programme was conducted for 10 students of Second Year B.Tech of Bapatla Engineering College, A.P. on Rock Mechanics Investigations Related to TBM, Operation and Working of TBM etc for three weeks i.e. from 5th to 25th May 2014.

ANNUAL ACCOUNTS
(2014-15)

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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, 2015, 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.

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

Basis for qualified opinion

i. *Non – detemination of liability towards gratuity and leave encashment through actuarial valuation and providing for such liabilities on an ad-hoc basis on 31-03-2015, the impact of which is unascertained.*
ii. *Non confirmation of balances by parties as described in item no.7 of Notes on Accounts to the financial statements, the impact of which is unascertained.*
iii. *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, 2015; 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.

Place: Bangalore
Date: 14/08/2015

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

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 2015.

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.

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 Benefits:

The Institute has made arrangement with Life Insurance Corporation of India for payment of gratuity under the Cash Accumulation Group Gratuity Scheme. Provision for the gratuity is accounted as per calculation made under Projected Unit Credit Method and intimated by the Insurance Company.

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. The Institute has requested LIC of India, who is managing the gratuity policy to indicate the additional liability towards gratuity and leave encashment. The Institute has not received any communication in this regard from LIC of India. Due to non-receipt of intimation of liability position as on 31-03-2015 from LIC of India, the Institute has made an ad-hoc provision of Rs.6,00,000/- towards gratuity liability and Rs.30,00,000/- towards leave encashment liability.

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.

6. Tax deducted at Source receivable, as mentioned in the schedule 12(a) to the balance sheet is subject to reconciliation and adjustments, if any.

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

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

14/8/15
(A.N.Nagarajan)
Registrar & Secretary

14.8.15
(V.Venkateswarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

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

GRSM & Associates Bangalore Chartered Accountants

Gopalkrishna Hegde
Partner
M.No: 208063

Place: Bangalore
Date: 14/08/2015

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS
CONSOLIDATED BALANCE SHEET AS AT 31ST MARCH 2015

Consolidated A/c

(Amount in Rs)

Liabilities	Sch No.	Balance as on 31-03-2015	Balance as on 31-03-2014	Assets	Sch No	Balance as on 31-03-2015	Balance as on 31-03-2014
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		1,68,267	2,25,729
				b) Cash at Bank		5,01,76,031	88,49,895
OTHER CAPITAL FUNDS	2			c) Stock - Stationery Items		1,54,009	1,24,005
a) Deferred Government Grant		5,04,48,246	1,00,000	**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
c) Income & Expenditure Account		(2,95,99,148)	(4,09,33,586)	a) Short term deposits against project advances received from clients		5,79,97,930	4,51,99,842
				Deposits	10	4,14,580	3,99,760
CURRENT LIABILITIES				**LOANS AND ADVANCES**			
a) Sundry creditors - pay roll deductions	3	5,29,068	-	a) Advances - Staff	11	12,65,096	14,01,489
b) Sundry Creditors - Staff	4	10,65,057	10,55,673	b) Advances - Suppliers	12	88,23,079	14,33,540
c) Sundry Creditors - Others	5	69,34,148	48,15,130				
d) Project Advacnes Received	6	15,52,34,082	13,32,40,158	Other Current Assets	13	3,25,24,459	2,23,58,570
e) Provisions	7	1,47,68,443	1,94,70,662	Expenses on Ongoing Projects	14	5,51,20,801	4,33,10,463
				FIXED ASSETS	15	2,10,22,391	2,27,31,491
TOTAL		**27,36,66,643**	**19,20,34,784**	**TOTAL**		**27,36,66,643**	**19,20,34,784**
						-	-

Notes forming part of the accounts -refer schedule 31

For National Institute of Rock Mechanics

14/8/15
(A. N. Nagarajan)
Registrar & Secretary

V. Venkateswarlu 14.8.15
(V. Venkateswarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

As per our Report of even date
For GRSM & Associates
Chartered Accountants

Gopalkrishna Hegde
Partner
M.No:208063

Place : Bangalore
Date: 14/08/2015

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

CONSOLIDATED INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2015

Consolidated A/c

(Amount in Rs)

Expenditure	Sch No	2014-15	2013-14	Income	Sch No	2014-15	2013-14
Administration Expenses	16	89,91,696	95,36,197	Grant-in-Aid received from Ministry of Mines	25	5,43,00,000	2,32,00,000
Pay & Allowances	17	7,57,24,516	5,89,57,529	Revenue from Completed Projects	26	6,44,96,688	14,22,26,249
Travelling Expenditure	18	3,37,093	5,48,432	Interest Received	27	1,25,47,821	63,89,935
Upkeep of Assets	19	7,02,843	8,91,797	Miscellaneous Income	28	7,49,478	1,69,707
Expenditure on Completed Projects	20	2,67,69,680	4,01,10,452	Withdrawal of Depreciation	29	1,51,754	10,58,405
Expenditure on Completed R&D Projects	21	-	3,07,68,145	Prior Period Income	30	12,07,985	1,06,78,189
Income Tax	22	-	1,20,03,745				
Depreciation on Fixed Assets	15	49,84,156	53,28,286				
Prior Period Expenses	23	3,71,941	8,025				
Provision for Income Tax	24	42,37,363	1,01,72,589				
Excess of Income over Expenditure		1,13,34,438	1,53,97,288				
Total:-		**13,34,53,726**	**18,37,22,485**	**Total:-**		**13,34,53,726**	**18,37,22,485**

Notes forming part of the accounts -refer schedule 31

14/8/15

(A. N. Nagarajan)
Registrar & Secretary
Place : Bangalore
Date: 14/08/2015

For National Institute of Rock Mechanics

V. Venkateshwarlu 14.8.15 WIS

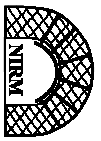
(V. Venkateshwarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

As per our Report of even date
For GRSM & Associates
Chartered Accountants

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 2015

Consolidated A/c

(Amount in Rs)

	Receipts	Amount	Amount		Payments	Amount	Amount
1	2	3	4	5	6	7	8
To	Opening Balance			By	Accurued Expenses		50,595
"	Cash	2,25,729		"	Undisbursed Payment to Employees		10,210
"	Bank	88,49,895	90,75,624	"	TDS Payable		1,25,100
"	Earnest Money & Sec. Deposit		3,00,000	"	Project Contingency (B)		2,99,641
"	Payroll Deductions - Income Tax		1,30,73,993	"	Staff Welfare		1,50,000
"	TDS by Clients		60,414	"	Service Tax Paid - Projects		78,74,897
"	Advance Received - R&D Projects		1,50,00,000	"	Service Tax Paid - Testings		3,71,562
"	Advance Received - Sponsored Projects		6,61,95,702	"	Honorarium/ Incentive (Projects / MTL)		87,44,459
"	Advance Received - Testing		27,46,100	"	Fixed Deposits		10,20,92,477
"	Service Tax Collected		82,69,403	"	Advances - Others		97,73,949
"	Fixed Deposits		8,92,94,389	"	Advances - Materials		3,49,796
"	Imprest		1,05,000	"	TDS Receivable		19,59,550
"	Travel Advance		49,750	"	Imprest		1,05,000
"	Security Deposits		5,21,872	"	Expenditure on R&D Running Projects		4,57,334
"	Income - Others		4,73,626	"	Expenditure on Completed Sponsored Projects		1,84,23,749
"	Income Penalty		85,679	"	Contigency Expenditure - Testing Servcies		8,59,044
"	Interest Received on Savings Bank		4,29,077	"	Stationery		4,37,767
"	Interest on IT Fefund		6,43,476	"	Expenditure on Completed Sponsored Projects		8,432
"	Interest on Term Deposits		41,52,262	"	Provision for Gratuity Payment		89,56,732
"	Institute-Project Adjustment Account		10,22,531	"	Provision for Income Tax		35,82,850
"	Govt. Grant-Capital		5,05,00,000	"	Sundry Creditors Pay Roll		1,40,83,964
"	Sundry Creditors - Staff		43,64,447	"	Sundry Creditors Others		54,57,769
"	Sundy Creditors - Others		1,74,111	"	Sundre Creditors Staff		42,64,853
"	Advances - Others		1,04,671	"	Purchase of Fixed Assets		23,47,974
"	Advances - Staff		21,66,244	"	Deposit with BESCOM - Bangalore		14,820

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

Consolidated Receipts and Payments Account for the year ending on 31st March 2015

Consolidated A/c

(Amount in Rs)

	Receipts	Amount	Amount		Payments	Amount	Amount
1	2	3	4	5	6	7	8
"	Accrued Grant in Aid		1,00,000	"	Advances - Staff		18,47,735
"	Grant in Aid (Non Plan)		5,43,00,000	"	Project Institute Adjustment Account		39,05,798
"	Income - Licence Fee		47,935	"	Pre Paid Expenses		49,738
"	Interest on Vehicle Advance		16,875	"	Prior Period Expenses		3,71,941
				"	Administration Expenses		80,53,395
				"	Salaries & Wages		6,66,94,798
				"	Travelling Expenses		3,03,101
				"	Up Keep of Assets		8,99,852
				"	Cash	1,68,267	
				"	Bank	5,01,76,032	5,03,44,299
	Total:-		32,32,73,181		Total:-		32,32,73,181

As per our Report of even date

For National Institute of Rock Mechanics

For GRSM & Associates

Chartered Accountants

(A. N. Nagarajan)
Registrar & Secretary

(V.Venkateswarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

Gopalkrishna Hegde
Partner
M.No:208063

Place : Bangalore
Date:14/08/2015

NATIONAL INSTITUTE OF ROCK MECHANICS
Champion Reefs Post, Kolar Gold Fields - 563 117.
CONSOLIDATED DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2015

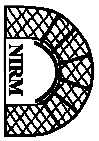
Schedule - 14

Consolidated A/c
(Amount in Rs)

		Gross Block						Depreciation				Net Block	
Name of the Assets	Rate of Depreciation %	Balance as on 01-04-14	Assets Written off/Trans-ferred	Purcchases up to 30.09.14	Purchases between 1.10.14 to 31.12.14	Purchases After 01.01.15	Total as on 31.03.15 (Total of Col 3 to Col 7)	Balance as on 01-04-15	Depreciation written off	Depreciation for the year	Total Depreciation as on 31-03-15 (Total of Col 9 to Col 11)	As on 31-3-15 (Col 8 - Col 12)	As on 31-3-14
1	2	3	4	5	6	7	8	9	10	11	12	13	13
Buildings	5	91,08,642	-	-	-	-	91,08,642	86,71,473	-	2,09,462	88,80,935	2,27,707	4,37,169
Plant & Machinery	7.5	3,22,25,642	-	6,94,592	-	-	3,29,20,234	3,16,65,932	-	1,28,218	3,17,94,150	11,26,084	5,59,710
Water Supply	5	3,28,926	-	-	-	-	3,28,926	2,97,453	-	12,060	3,09,513	19,413	31,473
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	23,47,231	-	1,93,269	25,40,500	20,25,756	22,19,025
Office Equipment	5	27,60,664	-	-	-	-	27,60,664	14,61,215	-	1,15,073	15,76,288	11,84,376	12,99,449
Vehicle	7.5	7,83,835	-	-	-	-	7,83,835	7,83,735	-	-	7,83,735	100	100
Laboratory Equipment	7.5	2,99,85,087	-	50,640	58,216	13,99,922	3,14,93,865	1,85,71,504	-	18,81,812	2,04,53,316	1,10,40,549	1,14,13,583
Technical Books	5	46,93,917	-	-	-	-	46,93,917	28,24,985	-	2,34,761	30,59,746	16,34,171	18,68,932
Computer Software	15	1,27,19,460	-	13,800	-	8,99,794	1,36,33,054	1,03,54,236	-	13,22,077	1,16,76,313	19,56,741	23,65,224
Computer Hardware	20	1,36,41,826	-	1,58,092	-	-	1,37,99,918	1,30,57,450	-	5,84,866	1,36,42,316	1,57,602	5,84,376
Conversion of Power line	5	17,99,459	-	-	-	-	17,99,459	11,54,465	-	89,973	12,44,438	5,55,021	6,44,994
Env Geo Tech Lab		21,13,409	-	-	-	-	21,13,409	12,99,020	-	1,52,068	14,51,088	6,62,321	8,14,389
PROJECT:													
Vehicle	7.5	8,06,889	-	-	-	-	8,06,889	3,13,922	-	60,517	3,74,439	4,32,450	4,92,967
Total:-		**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**
Advance for capital material purchase		-	-	-	-	-	-	-	-	-	-	-	-
(Previous year figures)		***11,59,55,210***	-	**40,732**	**-**	**41,504**	**11,60,37,446**	**8,79,77,669**	**-**	**53,28,286**	**9,33,05,955**	**2,27,31,491**	**2,79,77,541**

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

RSM & Associates Bangalore Chartered Accountants



NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS
BALANCE SHEET AS AT 31ST MARCH 2015

Institute A/c

(Amount in Rs.)

Particulars	Sch No.	Balance as on 31-03-2015	Balance as on 31-03-2014	Particulars	Sch No	Balance as on 31-03-2015	Balance as on 31-03-2014
		Rs.	Rs.			Rs.	Rs.
2	3	5	4	7	8	10	9
CAPITAL FUNDS	1						
a) Capital Reserve		32,44,334	32,44,334	**CURRENT ASSETS**	7		
b) Internal Capital Reserve		2,50,42,413	2,50,42,413	a) Cash in Hand		1,06,169	93,988
				b) Cash at Bank		(27,47,77,116)	(22,34,30,747)
OTHER CAPITAL FUNDS	2						
a) Deferred Government Grant		5,04,48,246	1,00,000				
b) Institute's Development Fund		4,60,00,000	4,60,00,000	**INVESTMENTS**	8		
c) Income & Expenditure Account		(24,06,45,748)	(20,97,57,125)	a) Fixed Deposit (IDF)		4,60,00,000	4,60,00,000
				b) Fixed Deposits - Short Term		4,69,92,153	
CURRENT LIABILITIES				**DEPOSITS**	9	4,14,580	3,99,760
a) Sundry creditors - Pay Roll Deductions	3	5,29,068	-	**LOANS AND ADVANCES**			
b) Sundry Creditors - Staff	4	10,64,436	9,64,842	a) Advances - Staff	10	1,84,931	4,71,790
c) Sundry Creditors - Others	5	63,17,679	50,88,551	b) Advances - Others	11	85,89,401	61,605
d) Provisions	6	1,47,68,443	1,94,70,662				
				Other Current Assets	12	97,26,479	22,67,585
				Project Account	13	4,89,42,333	4,20,51,172
				FIXED ASSETS	14	2,05,89,941	2,22,38,524
TOTAL		**(9,32,31,129)**	**(10,98,46,323)**	**TOTAL**		**(9,32,31,129)**	**(10,98,46,323)**
						-	-

For National Institute of Rock Mechanics

14/8/15

(A. N. Nagarajan)
Registrar & Secretary

(V Venkateswarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

Place : Bangalore
Date: 14/08/2015

As per our Report of even date
For GRSM & Associates
Chartered Accountants

GRSM & Associates Bangalore Chartered

Gopalkrishna Hegde
Partner
M.No:208063

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS
INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2015

Institute A/c

(Amount in Rs.)

EXPENDITURE				INCOME			
Sch No	Head of Account	2014-15	2013-14	Sch No	Head of Account	2014-15	2013-14
		Rs.	Rs.			Rs.	Rs.
1	2	3	4	5	6	7	8
1	Administation Expenses	89,91,696	95,36,197	6	Grant-in-Aid received from Ministry of Mines	5,43,00,000	2,32,00,000
2	Pay & Allowances	7,57,24,516	5,89,57,529	7	Miscellaneous Income	3,56,127	1,69,707
3	Travel Expenditure	3,37,093	5,48,432	8	Prior Period Income	54,868	1,06,78,189
4	Up Keep of Assets	7,02,843	8,91,797	9	Interest Received	95,37,719	43,56,256
5	Prior Period Expenses	3,71,941	8,025	10	Withdrawal of Depreciation	1,51,754	10,58,405
14	Depreciation on Fixed Assets	49,23,639	52,67,769		Excess of Expenditure over Income	3,08,88,623	4,59,19,781
	Provision for Income Tax	42,37,363	1,01,72,589				
	Total:-	**9,52,89,091**	**8,53,82,338**		**Total:-**	**9,52,89,091**	**8,53,82,338**

For National Institute of Rock Mechanics

14/8/15
(A. N. Nagarajan)
Registrar & Secretary

V.Venkateswarlu 14.8.2015
(V.Venkateswarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

As per our Report of even date

For GRSM & Associates

Chartered Accountants

GRSM & Associates * Bangalore * Chartered Accountants

Gopalkrishna Hegde

Partner

M.No:208063

Place : Bangalore

Date: 14 /08/2015

NATIONAL INSTITUTE OF ROCK MECHANICS

Champion Reefs Post, KOLAR GOLD FIELDS

Receipts and Payments Account for the year ending on 31st March 2015

Institute A/c

(Amount in Rs)

RECEIPT SIDE				PAYMENT SIDE			
1	Head of Account 2	Amount 3	Amount 4	5	Head of Account 6	Amount 7	Amount 8
To	Opening Balance			By	Provision for Gratuity Payment		89,56,732
"	Cash	93,988		"	Provision for Income Tax		35,82,850
"	Bank	(22,34,30,746)	(22,33,36,758)	"	Sundry Creditors Pay Roll		1,40,83,964
"	Govt. Grant-Capital		5,05,00,000	"	Sundry Creditors Others		54,57,769
"	Sundry Creditors - Staff		43,64,447	"	Sundre Creditors Staff		42,64,853
"	Sundry Creditors - Payroll Deductions		1,30,66,023	"	Purchase of Fixed Assets		23,47,974
"	Sundy Creditors - Others		1,74,111	"	Fixed Deposits - Short Term		7,66,03,232
"	Investments - Fixed Deposits		2,96,11,079	"	Imprest		55,000
"	Imprest		55,000	"	Deposit with BESCOM - Bangalore		14,820
"	Advances - Others		1,04,671	"	Advances - Others		95,19,549
"	Advances - Staff		21,66,244	"	Advances - Staff		18,47,735
"	Accrued Grant in Aid		1,00,000	"	Project Institute Adjustment Account		39,05,798
"	Project Institute Adjustment Account		5,000	"	Income Tax		64,686
"	Grant in Aid (Non Plan)		5,43,00,000	"	Pre Paid Expenses		49,738
"	Income - Licence Fee		47,935	"	Prior Period Expenses		3,71,941
"	Income - Others		3,02,655	"	Administration Expenses		80,53,395
"	Interest on Vehicle Advance		16,875	"	Salaries & Wages		6,66,94,798
"	Interest - Savings Bank Deposits		2,06,781	"	Travelling Expenses		3,03,101
"	Interest - Term Deposits		7,22,778	"	Up Keep of Assets		8,99,852
				"	Closing Balance		
				"	Cash	1,06,169	
				"	Bank Balance	(27,47,77,115)	(27,46,70,946)
	Total:-		**(6,75,93,159)**		**Total:-**		**(6,75,93,159)**

As per our Report of even date

For National Institute of Rock Mechanics

For GRSM & Associates

Chartered Accountants

14/8/15

(A. N. Nagarajan)
Registrar & Secretary

(V.Venkateswarlu)
Director

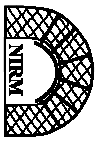
(A.Sundaramoorthy)
Member (Governing Body)

Gopalkrishna Hegde
Partner
M.No:208063

GRSM & Associates Bangalore Chartered Accountants

Place : Bangalore

Date: 14/08/2015



NATIONAL INSTITUTE OF ROCK MECHANICS
Champion Reefs Post, Kolar Gold Fields - 563 117.
DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2015

Institute A/c

Schedule - 14 (Amount in Rs)

		Gross Block						Depreciation					Net Block	
Name of the Assets	Rate of Depreciation %	Balance as on 01-04-14	Assets Written off/Trans-ferred	Purcchases up to 30.09.14	Purchases between 1.10.14 to 31.12.14	Purchases After 01.01.15	Total as on 31.03.15 (Total of Col 3 to Col 7)	Balance as on 01-04-15	Adjustment	Depreciation written off	Depreciation for the year	Total Depreciation as on 31-03-15 (Total of Col 9 to Col 11)	As on 31-3-15 (Col 8 - Col 12)	As on 31-3-14
1	2	3	4	5	6	7	8	9		10	11	12	13	13
Buildings	5	91,08,642	-	-	-	-	91,08,642	86,71,473	-	-	2,09,462	88,80,935	2,27,707	4,37,169
Plant & Machinery	7.5	3,22,25,642	-	6,94,592	-	-	3,29,20,234	3,16,65,932	-	-	1,28,218	3,17,94,150	11,26,084	5,59,710
Water Supply	5	3,28,926	-	-	-	-	3,28,926	2,97,453	-	-	12,060	3,09,513	19,413	31,473
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	23,47,231	-	-	1,93,269	25,40,500	20,25,756	22,19,025
Office Equipment	5	27,60,664	-	-	-	-	27,60,664	14,61,215	-	-	1,15,073	15,76,288	11,84,376	12,99,449
Vehicle	7.5	7,83,835	-	-	-	-	7,83,835	7,83,735	-	-	-	7,83,735	100	100
Laboratory Equipment	7.5	2,99,85,087	-	50,640	58,216	13,99,922	3,14,93,865	1,85,71,504	-	-	18,81,812	2,04,53,316	1,10,40,549	1,14,13,583
Technical Books	5	46,93,917	-	-	-	-	46,93,917	28,24,985	-	-	2,34,761	30,59,746	16,34,171	18,68,932
Computer Software	15	1,27,19,460	-	13,800	-	8,99,794	1,36,33,054	1,03,54,236	-	-	13,22,077	1,16,76,313	19,56,741	23,65,224
Computer Hardware	20	1,36,41,826	-	1,58,092	-	-	1,37,99,918	1,30,57,450	-	-	5,84,866	1,36,42,316	1,57,602	5,84,376
Conversion of Power line	5	17,99,459	-	-	-	-	17,99,459	11,54,465	-	-	89,973	12,44,438	5,55,021	6,44,994
Env Geo Tech Lab		21,13,409	-	-	-	-	21,13,409	12,99,020	-	-	1,52,068	14,51,088	6,62,321	8,14,389
Total:-		**11,52,30,557**	**-**	**9,17,124**	**58,216**	**22,99,716**	**11,85,05,613**	**9,29,92,033**	**-**	**-**	**49,23,639**	**9,79,15,672**	**2,05,89,941**	**2,22,38,524**
Advance for capital material purchase		-	-	-	-	-	-	-		-	-	-	-	-
(Previous year figures)		**11,51,48,321**	**-**	**46,332**	**-**	**-**	**11,51,01,988**	**8,24,46,372**	**-**	**-**	**52,77,892**	**87,72,42,464**	**2,74,24,056**	**2,74,24,056**

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

NATIONAL INSTITUTE OF ROCK MECHANICS
CHAMPION REEFS POST, KOLAR GOLD FIELDS
BALANCE SHEET AS AT 31ST March 2015

Project A/c

(Amount in Rs)

Liabilities	Sch No.	Balance as on 31-03-2015	Balance as on 31-03-2014	Assets	Sch No	Balance as on 31-03-2015	Balance as on 31-03-2014
OTHER CAPITAL FUNDS				**CURRENT ASSETS**			
Income & Expenditure Account	1	21,10,46,600	16,88,23,539	a) Cash in Hand	6	62,098	1,31,741
				b) Cash at Bank	7	32,49,53,147	23,22,80,640
CURRENT LIABILITIES				c) Stock - Stationery Items	8	1,54,009	1,24,005
a) Project Advances Received	2	15,52,34,082	13,32,40,158				
b) Sundry Creditors - Others	3	6,16,469	(2,73,423)	**INVESTMENTS**			
c) Sundry Creditors - Suppliers & Employees	4	621	90,831	a) Short Term Deposits against Project Advances received from clients	9	1,10,05,777	4,51,99,842
d) Institute Account	5	4,89,42,333	4,20,51,172				
				LOANS AND ADVANCES			
				a) Advances - Staff	10	10,80,165	9,29,699
				b) Advances - Suppliers	11	2,33,678	13,71,935
				Other Current Assets	12	2,27,97,980	2,00,90,985
				Expenses on Ongoing Projects	13	5,51,20,801	4,33,10,463
				Fixed Assets	14	4,32,450	4,92,967
TOTAL		**41,58,40,105**	**34,39,32,277**	**TOTAL**		**41,58,40,105**	**34,39,32,277**

14/8/15
(A. N. Nagarajan)
Registrar & Secretary

For National Institute of Rock Mechanics

14.8.15
(V.Venkateswarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

Place: Bangalore
Date: 14/08/2015

As per our Report of even date
For GRSM & Associates
Chartered Accountants

Gopalkrishna Hegde
Proprietor
M.No:208063

NATIONAL INSTITUTE OF ROCK MECHANICS

CHAMPION REEFS POST, KOLAR GOLD FIELDS

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31ST MARCH 2015

Project A/c

(Amount in Rs)

	Expenditure		2014-15	2013-14		Income		2014-15	2013-14
TO	Expenditure on Completed Sponsored Projects:	15	2,67,69,680	4,01,10,452	By	Amounts received against Sponsored Projects:	18	6,44,96,688	10,38,00,567
"	Expenditure on Completed R & D Projects:	16	-	3,07,68,145	"	Amounts received against R & D Projects:	19	-	3,84,25,682
"	Income Tax	17	-	1,20,03,745	"	Interest Received	20	23,66,626	20,33,679
"	Depreciation on Fixed Assets - Vehicle	14	60,517	60,517	"	Prior Period Income	21	11,53,117	-
"	Excess of Income over Expenditure		4,22,23,061	6,13,17,069	"	Other Incomes	22	10,36,827	-
	Total:-		**6,90,53,258**	**14,42,59,928**		**Total:-**		**6,90,53,258**	**14,42,59,928**

As per our Report of even date

For GRSM & Associates

Chartered Accountants

For National Institute of Rock Mechanics

14/8/15

(A. N. Nagarajan)

Registrar & Secretary

(V.Venkateswarlu)

Director

(A.Sundaramoorthy)

Member (Governing Body)

Gopalkrishna Hegde

Partner

M.No:208063

Place : Bangalore

Date: 14-08-2015

NATIONAL INSTITUTE OF ROCK MECHANICS

Champion Reefs Post, KOLAR GOLD FIELDS

Receipt and Payment Account for the year ending on 31st March 2015

Project A/c

(Amount in Rs)

	Receipts	Amount	Amount		Payments	Amount	Amount
TO	Opening Balance			By	Accurued Expenses		50,595
	Cash	1,31,741		"	Undisbursed Payment to Employees		10,210
	Bank	23,22,80,641	23,24,12,382	"	TDS Payable		60,414
"	Earnest Money & Sec. Deposit		3,00,000	"	Project Contingency (B)		2,99,641
"	Payroll Deductions - Income Tax		7,970	"	Staff Welfare		1,50,000
"	TDS by Clients		60,414	"	Service Tax Paid - Projects		78,74,897
"	Advance Received - R&D Projects		1,50,00,000	"	Service Tax Paid - Testings		3,71,562
"	Advance Received - Sponsored Projects		6,61,95,702	"	Honorarium/ Incentive (Projects / MTL)		87,44,459
"	Advance Received -Testing		27,46,100	"	Fixed Deposits		2,54,89,245
"	Service Tax Collected		82,69,403	"	Advances - Others		2,54,400
"	Fixed Deposits		5,96,83,310	"	Advances - Materials		3,49,796
"	Imprest		50,000	"	TDS Receivable		19,59,550
"	Travel Advance		49,750	"	Imprest		50,000
"	Security Deposits		5,21,872	"	Expenditure on R&D Running Projects		4,57,334
"	Income - Others		1,70,971	"	Expenditure on Completed Sponsored Projects		1,84,23,749
"	Income Penalty		85,679	"	Contigency Expenditure - Testing Servcies		8,59,044
"	Interest Received on Savings Bank		2,22,296	"	Stationery		4,37,767
"	Interest on IT Fefund		6,43,476	"	Expenditure on Completed Sponsored Projects		8,432
"	Interest on Term Deposits		34,29,484	"	Closing Balance		
"	Institute-Project Adjustment Account		10,17,531		Cash	62,098	
					Bank	32,49,53,147	32,50,15,245
	Total:-		**39,08,66,340**		**Total:-**		**39,08,66,340**

For National Institute of Rock Mechanics

14/8/15

(A. N. Nagarajan)
Registrar & Secretary
Place: Bangalore
Date:14/08/2015

V.Venkateswarlu 14.8.15

(V.Venkateswarlu)
Director

(A.Sundaramoorthy)
Member (Governing Body)

As per our Report of even date
For GRSM & Associates
Chartered Accountants

Gopalkrishna Hegde
Partner
M.No:208063

GRSM & Associates Bangalore Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS

Champion Reefs Post, Kolar Gold Fields - 563 117.

DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2015

Schedule - 11

Project A/c

(Amount in Rs)

		Gross Block						Depreciation				Net Block	
Name of the Assets	Rate of Depreciation %	Balance as on 01-04-14	Assets Written off/Transferred	Purcchases up to 30.09.14	Purchases between 1.10.14 to 31.12.14	Purchases After 01.01.14	Total as on 31.03.15	Balance as on 01-04-14	Depreciation written off	Depreciation for the year	Total Depreciation as on 31-03-15	As on 31-3-15	As on 31-03-14
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Vehicle	7.5	8,06,889	-	-	-	-	8,06,889	3,13,922	-	60,517	3,74,439	4,32,450	4,92,967
Total:-		**8,06,889**	**-**	**-**	**-**	**-**	**8,06,889**	**3,13,922**	**-**	**60,517**	**3,74,439**	**4,32,450**	**4,92,967**
Advance for capital material purchase		-	-	-	-	-	-	-	-	-	-	-	
(Previous year figures)		**8,06,889**					**8,06,889**	**1,92,888**	**-**	**60,517**	**2,53,405**	**5,53,484**	**6,14,015**

Note: 1. Items not put into use : NIL

2. Depreciation has been charged on Straight Line Method.

GRSM & Associates Bangalore Chartered Accountants

STATEMENT OF TOTAL INCOME AND TAX

NAME: NATIONAL INSTITUTE OF ROCK MECHANICS

STATUS:	AOP - MMR
WARD:	
ASST YEAR:	2015-16
PREVIOUS YEAR:	2014-15
PAN:	AAAAN1331N
DATE OF FORMATION:	23-07-1988

COMPUTATION OF TOTAL INCOME

A. INCOME FROM OTHER SOURCES

Net Profit as per Income & Expenditure	1,13,34,438	
Add:Project Staff Welfare	4,61,587	
Add: Project Contingency (A)	92,284	
Add: Project Contingency (B)	4,40,443	
Add: Depreciation as per Books	49,84,156	
Add: Provision for Income Tax	42,37,363	
Add: Provision for Gratuity Scheme	6,00,000	
Add: Provision for Group Leave Encashment Scheme	30,00,000	
Add: 30% of Aduit Fees of Rs. 61,798/-	18,539	
		2,51,68,810
Less: Depreciation as per IT Rule	30,23,690	
Less: Staff Welfare Expended	3,68,621	
Less: Gratutity Payment	89,56,732	
Less: Project Contingency (B)	3,53,269	
Less: Interest income considered separately	1,25,47,821	2,52,50,133
		(81,323)

Income from Other Sources		
Interest Incomes		1,25,47,821
Gross/Total Income		1,24,66,498
Taxable Income		1,24,66,500

COMPUTATION OF TAXES

Tax on Total Income		37,39,950
Add: Surcharge		3,73,995
		41,13,945
Education cess		1,23,418
		42,37,363
Less:		
Tax Deducted at Source		63,97,050
Balance Tax payable		(21,59,687)
Add: Interest under Section 234B	-	
Add: Interest under Section 234C	-	-
Tax Payable		**(21,59,687)**

[Secretary]

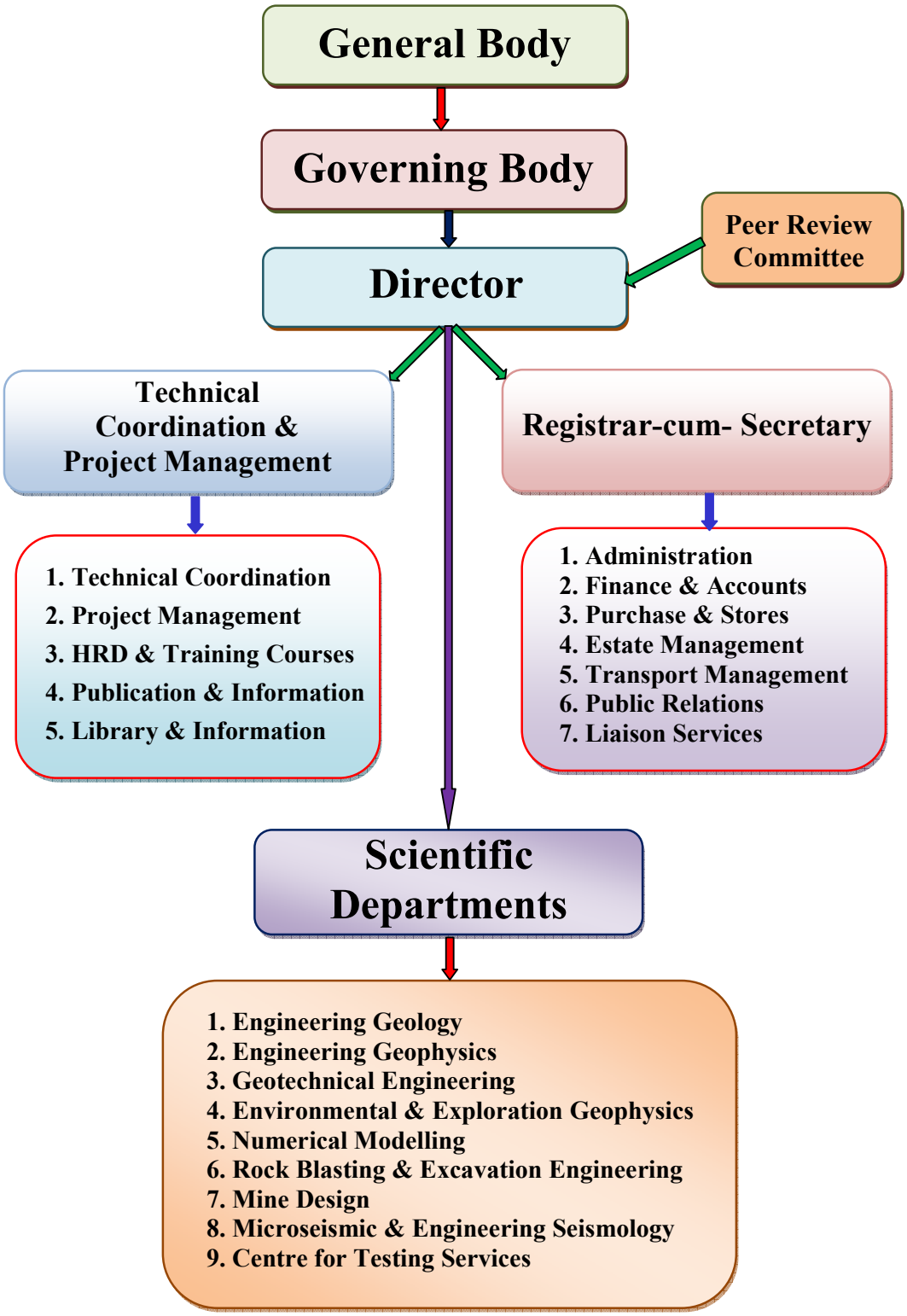
Place: Kolar Gold Fields

Date:

ANNEXURE

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
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

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

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

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

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

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

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

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

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

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

Member (D&R)
Central Water Commission
Room no. 401(S), Sewa Bhawan
RK Puram, New Delhi – 110 066

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

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 ORGANISATIONS & MAJOR CLIENTELE

Central Government Ministries & Departments

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)
Singareni Collieries Company Limited
Telangana State Power Generation Corporation (TSGENCO)

Public Sector Organisations

Atomic Minerals Directorate (AMD)
Chennai Metro Rail Corporation Limited (CMRL)
Engineers India Limited (EIL)
Hindustan Copper Limited. (HCL)
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.
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 Organisations

Druk Green Power Corporation Limited (DGPCL), Bhutan
Mangdechhu Hydroelectric Project Authority (MHPA), Bhutan

Annexure – 6

LIST OF PROJECTS

Sl. No	Title of Project	Persons involved	Status
1	Construction stage engineering geological investigations of surge pool and pump house (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme–II, Telangana State.	AK Naithani, LG Singh & Prasnna Jain	Completed
2	Geotechnical assessment of the plant water pump house (PWPH) of Rajasthan Atomic Power Project (RAPP) Units 7&8, Rawatbhata, Rajasthan.	AK Naithani	Completed
3	Engineering geological investigations of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (Package-6), Karimnagar District (Phase-II), Telangana State.	AK Naithani & Devendra Singh Rawat	Completed
4	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 (Package-12), Siddipet, Telangana State.	AK Naithani, LG Singh & Prasnna Jain	Ongoing
5	Engineering geological investigation of Pulichintala Hydroelectric Scheme (4 x 30 MW), Guntur District, Andhra Pradesh.	AK Naithani, LG Singh & Prasnna Jain	Ongoing
6	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	Ongoing
7	Geotechnical Assessment of the Foundation of 1.5 MLD Capacity Over Head Tank at NR Park, Bellary, Karnataka.	AK Naithani, LG Singh & Prasnna Jain	Ongoing
8	Engineering geological investigations of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme (Package-6), Karimnagar District (Phase-III), Telangana State.	AK Naithani & Devendra Singh Rawat	Ongoing
9	Seismic refraction survey along the proposed tunnel alignment of package-24 of PCSS Lift Irrigation, Andhra Pradesh.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Completed
10	Seismic refraction survey at the Etalin Hydro Power Project, Arunachal Pradesh.	PC Jha, N Sandeep, YV Sivaram, B Butchi Babu & LG Singh	Completed

Sl. No	Title of Project	Persons involved	Status
11	Geophysical survey for estimating the rock line along proposed barrage alignment of Nekkiladi Hydropower Project.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Completed
12	Geophysical survey for evaluating the stability of oil pipeline in Kajora area, West Bengal.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Completed
13	Development of a viable technique for assessment of reclaimed land and for safety of structures under settling environment.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Ongoing
14	Rock mass classification using seismic refraction survey of Jayadeva construction site at Mysore.	PC Jha, N Sandeep, YV Sivaram & B Butchi Babu	Ongoing
15	Determination of in-situ shear and deformability parameters at the proposed dam site of Wangchhu H.E. Project, Bhutan.	DS Subrahmanyam, G Shyam, K Vamshidhar & A Sudhakara Rao	Completed
16	Determination of in-situ stress, deformability and shear parameters at the proposed underground powerhouse of Nikkachhu Hydroelectric Project, Bhutan.	DS Subrahmanyam, G Shyam, K Vamshidha & A Sudhakara Rao	Completed
17	Determination of in-situ stress at the proposed underground pump house of Dr. B.R. Ambedkar Pranahita Chevella Sujala Sravanthi Project, Package No.12.	DS Subrahmanyam, RK Sinha, G Shyam, A Sudhakara Rao & TY Moses Immanuel	Completed
18	Determination of in-situ shear and deformability parameters at the proposed intake drift of Teesta stage-IV H.E. Project, Sikkim.	D.S. Subrahmanyam, G. Shyam & A. Sudhakara Rao	Completed
19	Determination of in-situ shear and deformability for the proposed right abutment of the Teesta IV hydroelectric project, Sikkim.	D.S. Subrahmanyam, G. Shyam & A. Sudhakara Rao	Completed
20	Determination of in-situ stress parameters at the proposed underground powerhouse of Etalin hydroelectric project, Arunachal Pradesh.	DS Subrahmanyam, RK Sinha, G Shyam & K Vamshidhar	Completed
21	Development of State-of-the-art facilities for in-situ stress measurement by hydraulic fracture method in porous and fractured rock mass.	DS Subrahmanyam, S Sengupta, G Shyam & K Vamshidhar	Completed
22	Identification of L2 lineament in the vicinity of KKNPP through geophysical and geological investigations.	Biju John, V.R. Balasubramaniam, Yogendra Singh, Goverdhan Kantepudi & K.S. Divyalakshmi	Ongoing

23	Evaluation of light house lineament related with Jaithapur Nuclear Power Plant, through trench studies, Ratnagiri, Maharashtra	Biju John, Yogendra Singh, K.S. Divyalakshmi, Akhil T. & V.R. Balasubramaniam	Ongoing
24	Seismotectonic evaluation in the 30-50 km radius of Kudankulam Nuclear Power Plant (KKNPP), Tamil Nadu.	Biju John, D.T Rao, Yogendra Singh, K.S. Divyalakshmi, C. Srinivasan & V.R. Balasubramaniam	Ongoing
25	Geothermal studies at around Manappad and Kudankulam area.	Biju John, Yogendra Singh, Srinivasan C and V.R. Balasubramaniam	Ongoing
26	Back analysis of powerhouse complex behavior using 3D numerical modeling at Tapovan Vishnugad Hydroelectric Project.	Sripad R Naik, Roshan Nair & K. Sudhakar	Ongoing
27	Geodetic monitoring of Sardar Sarovar Dam, SSNNL, Kevedia, Gujarat.	Sripad R Naik, K Sudhakar, Rabi Bhushan & BH Vijay Sekar	Ongoing
28	Instrumentation, monitoring and data analysis at powerhouse complex Tala Hydro Power Plant, Bhutan.	Sripad R Naik, K Sudhakar, Roshan Nair, Rabi Bhusan & BH Vijay Sekar	Completed and Ongoing
29	Surface subsidence prediction and review of support system at Mahamaya U/G mine, Bhatgaon area, SECL, Chattisgarh.	Sripad R Naik, Dr. Ritesh Lokhande & K Sudhakar	Ongoing
30	Deformation monitoring of underground powerhouse cavern of Sardar Sarovar Project, Gujarat.	Sripad R Naik, K. Sudhakar, Rabi Bhusan & BH Vijay Sekar	Completed and Ongoing
31	Investigation into stability of Pirsurlem waste dump slopes at Sonshi Iron Ore Mine, Goa	Sripad R Naik, A Renaldy, BH Vijay Sekar & K Sudhakar	Completed
32	Analysis of instrumentation data of dam, desilting complex, power house complex, of NJHPS, SJVNL, Shimla.	Sripad R Naik, K Sudhakar, Rabi Bhusan & BH Vijay Sekar	Completed and Ongoing
33	3D analysis of underground powerhouse complex of Mangdechu Hydroelectric Project, Bhutan.	Sripad R Naik, BH Vijay Sekar, K Sudhakar & Rabi Bhusan	Ongoing
34	Slope **s**tability analysis of abutment cut slopes for concrete gravity dam at Mangdechu Hydroelectric Project, Bhutan**.**	Sripad R Naik, BH Vijay Sekar, Rabi Bhusan & K Sudhakar	Ongoing
35	3D stress analysis of underground caverns of powerhouse complex with bus bar tunnels and penstock entry for at Tehri PSP**.**	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Ongoing
36	Temporary and permanent support design of underground surge pool, pump house draft tubes and delivery mains using 3-D numerical modelling – package 12 of PCSS Lift Irrigation Scheme.	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Completed

37	Stability analysis of rock slopes for pothead yard location at Mangdechhu Hydroelectric Project, Bhutan.	Sripad R Naik, Rabi Bhusan, BH Bijay Sekar & K. Sudhakar	Ongoing
38	Monitoring of ground vibration and air overpressure at Sangam Kalan limestone Mine, Phase-IV, ICL, Tandur Mandal, Andhra Pradesh.	G Gopinath, AI Theresraj, R Balachander, GC Naveen & HS Venkatesh	Completed
39	Ground vibration and air overpressure studies at Nawabpeta-Talamanchipatnam limestone mines, AP.	AI Theresraj, GC Naveen, G Gopinath, R Balachander & HS Venkatesh	Completed
40	Suggesting suitable controlled blasting methods and monitoring ground vibration and air overpressure produced from blasting at Bhoothathankettu SHE Project (24 MW), KSEB.	AI Theresraj, GC Naveen, G Gopinath, R Balachander & HS Venkatesh	Completed
41	Design for the hot and cold water tunnels and ground vibration measurement near operating units of 5 and 6 Nuclear Plant, RAPP, Rawatbhata.	G Gopinath, AI Theresraj, GC Naveen, R Balachander & HS Venkatesh	Completed
42	Study on velocity of detonation of ANFO and bulk explosives in real-time at Singareni Collieries Company Ltd, Ramagundam area.	G Gopinath, AI Theresraj, GC Naveen, R Balachander & HS Venkatesh	Completed
43	Technical guidance on controlled blasting and monitoring of blast vibration at Morbi Branch Canal Project, Morbi, SSNNL, Gujarat.	G Gopinath, AI Theresraj, R Balachander, GC Naveen & HS Venkatesh	Completed
44	Technical guidance on controlled blasting and monitoring blast vibration at Bagmane Constellation Business Park, Outer Ring Road, Bangalore	R Balachander, GC Naveen, AI Theresraj, G Gopinath & HS Venkatesh	Completed
45	Study on feasibility of blasting for hard rock excavation in Top Down method, TT-AFCONS Jv., CMRL Site, Chennai.	G Gopinath, AI Theresraj, R Balachander, GC Naveen & HS Venkatesh	Completed
46	Study on ground vibration and optimization of blast design parameters for Velmurugan Blue Metals and Stone crusher (Sy.No.188)	G Gopinath, R Balachander, AI Theresraj, GC Naveen & HS Venkatesh	Completed
47	Pre-construction report on application of blasting techniques for excavation of hard rock strata for construction of road under bridges from Penukonda to Darmavaram railway stations, South Western Railway, A.P.	GC Naveen, G Gopinath, R Balachander, AI Theresraj & 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, A.P.	G Gopinath, AI Theresraj, R Balachander, GC Naveen & HS Venkatesh	Ongoing

49	Study on ground vibration and assessment of flyrock at quarries of Sy. No. 493 & 497, Waddera Sangam, Karimnagar District, A.P.	Al Theresraj, G Gopinath, R Balachander, GC Naveen & HS Venkatesh	Ongoing
50	Rock mechanics investigations to evaluate the requirement of support pillars in LDBH stopes at Kathpal & Boula Chromite mines, FACOR, Odisha.	Roshan Nair, S Kumar Reddy & Manoj kumar	Completed
51	Strata control investigation in panel no. 38 Level East in V seam at Churcha Mine, SECL.	C Nagaraj, Amrith T Renaldy & K Vamshidhar	Completed
52	Design of support system for crusher chamber and for hangwall lode, UCIL.	V Venkateswarlu & C Nagaraj	Completed
53	Analysis of dump stability and design of vertical walls for Kaliapani Chromite Mine, Odisha	Amrith T Renaldy	Completed
54	Design of stoping parameters for Chikla Mine of MOIL Ltd.	GD Raju, Prasnna Jain & V Venkateswarlu	Ongoing
55	Strata control investigations in 15 East Panel, V Seam at East Block of Churcha Mine, SECL.	C Nagaraj, Amrith T Renaldy & V Venkateswarlu	Ongoing
56	Slope stability study for pit nos. 5 and 6 at Pandalgudi Limestone Mine, Virudhunagar District, Tamilnadu.	T Amrith Renaldy & Prasnna Jain	Ongoing
57	Powerhouse caverns monitoring at Taphovan-Vishnugargh Hydropower Project, Utharakhand using Nanoseismics.	Sivakumar Cherukuri & Vikalpkumar)	Ongoing
58	Microseismic monitoring of powerhouse cavern of THPP, DGPC, Bhutan).	Sivakumar Cherukuri	Ongoing
59	In-situ non-destructive testing for M/s Shaft Sinkers Mauritius Limited.	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
60	In-situ non-destructive testing for M/s Hindustan Zinc Limited – Rajpura Dariba Mines.	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 on steel structures of Kondapuram Coal Handling Plant, Manuguru Area, M/s Singareni Collieries Company Limited.	M Victor, A Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D	Completed

		Prashanth Kumar, S.Thobias, Y Naveen Anandan, S Babu & S Arvind Kumar	
62	In-situ non-destructive testing for M/s Singareni Collieries Company Limited.	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 China Coal No.5 Constructions Private Limited, SK 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
64	Proof load test and non-destructive testing for M/s Andhra Pradesh Heavy Machinery and Engineering Limited, Andhra Pradesh.	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
65	In-situ non-destructive testing for M/s Hindustan Zinc Limited – Zawar Group of Mines.	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
66	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
67	Proof load test and non-destructive testing for M/s Shriram EPC Limited.	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

68	Structural stability audit on head gears for M/s Singareni Collieries Company Limited.	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	Ongoing
69	Wire rope defectography study for M/s National Aluminum Company Limited.	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	Ongoing
70	NDT in Rajpura Dariba mines and Zawar group of mines for M/s Hindustan Zinc Limited.	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	Ongoing
71	NDT on man winding systems – 4 units for M/s Singareni Collieries Company Limited	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	Ongoing
72	Laboratory Testing on rock core samples of iron ore mine for Zeenath Transport Company, Bellary	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
73	Laboratory geotechnical investigations on rock samples from dam axis drift and intake/desilting chamber drift of Teesta-IV HE Project.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
74	Assessment and expert advice on rock strata classification for the excavations related to the construction of 350 bed hospital complex for Sri Jayadeva Institute of Cardiovascular Sciences & Research, Mysore.	A Rajan Babu, GD Raju, S Udaya Kumar & Rabi Bhushan	Completed
75	Laboratory geotechnical investigations on shale samples from wellbores B12-17, KH#1, KH#2, KU#4, AD#19, VZK#1, BV#6, V#2,BV#11, KI#4, ADB#1, KA#39, & KA#24- ONGC.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
76	Determination of physico-mechanical properties of rocks, Chikla Mine of MOIL Ltd.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed

77	Determination of shear properties and unit weight for rock samples from Pandalgudi Limestone Mines, Ramco cements, Madurai.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed
78	Determination of physico-mechanical properties of rock core samples from surge pool and pump house area of Pranahita-Chevella Sujala Sravanthi Scheme, Medak District.	S Udaya Kumar, A Rajan Babu, GD Raju & D Joseph	Completed

Annexure – 7

LIST OF PUBLICATIONS

1. AK Naithani, PC Nawani, LG Singh and DS Rawat, 2014: 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.

2. AK Naithani, 2014: Engineering geological investigations for preparation of DPRs of hydroelectric projects – State-of-the-Art. In NIRM Silver Jubilee Commemorative Volume, (D.S. Subrahmanyam and A.K. Naithani eds.), Publ. by NIRM, pp 162-172.

3. AK Naithani, LG Singh, DS Rawat and Prasnna Jain, 2014: Engineering geological assessment of the north wall of surge pool and rock ledge between surge pool and pump house of Mahatma Gandhi Kalwakurthi lift irrigation scheme-II (5x30 MW), Mahaboobnagar District, Telangana State, India. Proc. of International Symposium ROCK INDIA 2014 – Present Technology and Future Challenges and Workshop on Open Pit Mining, Organized by ISRM (India) and CBIP, 20-22 August 2014, New Delhi, pp 103-112.

4. Biju John, 2014: Significance of brittle fault evaluation in site characterization studies for major engineering projects: An update. National seminar on Engineering Geology Geotechniques and geohatards- A Quest for Excellence. Held at Kolkata during 10-11 July 2014.

5. Biju John, 2014: Some observations on fluid associated brittle faulting from Peninsular India. Third Conference on Rock Deformation and Structures (RDS-III) (October 29-31, 2014).

6. Biju John, Rajendran CP and Yogendra Singh, 2014: Characteristics of earthquake related Surface rupture: Two examples from Peninsular India. 5th International INQUA Meeting Paleoseismology, Active Tectonics and Archeoseismology, 21-27 September 2014 at Busan, Korea.

7. Butchi Babu B, PC Jha, YV Sivaram and PK Khan, 2014: Foundation evaluation of structures using correlation between SPT- N value and seismic wave velocity, communicated.

8. CP Rajendran, Biju John and K Rajendran, 2015: Medieval pulse of great earthquakes in the central Himalaya: Viewing past activities on the frontal Belt. JGR doi:10.1002/2014JB011015.

9. Divyalakshmi KS, V Ram Mohan and J Sriganesh, 2015: Characteristics of Indian Ocean tsunami from Numerical Modeling in Palk Bay coast south India. Recent Advances in Environmental Geology, 21–22 March 2015.

10. Divyalakshmi KS, J Sriganesh and V Ram Mohan and RS Kankara, 2014: April Sensitivity analysis for fault direction in Tsunami propagation and modeling for Kovalam to Mamallapuram coast, Tamil Nadu. Envirogeochimica Acta, vol. 2, pp 118-130.

11. Divyalakshmi KS, J Sriganesh, MV Ramana Murthy and V Ram Mohan, 2014: Influence of earthquake parameters on Tsunami wave height and Inundation., AGU fall meeting , December 2014.

12. DS Rawat, AK Naithani and G Srinivasa Rao, 2014: Construction stage geological problems and advantage of twin tunnels for the identification of problematic zones - a case study. Proc. of INDOROCK 2014, 5th Indian Rock Conference on Underground Construction for Hydropower, Mining and Infrastructure, (Rajbal Singh and Hari Dev eds.), Pub. by ISRMTT, pp 390-397.

13. DS Subrahmanyam, 2014: Influence of local perturbation on regional stress and its impact on the design of major underground structure in H.E. Projects. International Journal of Geology, Earth & Environmental Sciences, ISSN 2277-2081, vol. 4, no. 2, pp 6-11.

14. DS Subrahmanyam, 2014: A study on the deformability modulus of rock mass at different classes of rocks encountered at different sections for the design of head race tunnel in one of the hydroelectric projects, Journal of International Academic Research for Multidisciplinary ISSN: 2320-5083, vol. 2, no. 6, pp 584-592.

15. HS Venkatesh and V Venkateswarlu, 2014: Role of R & D with reference to Safe and sustainable Mining" 26th National convention of Mining Engineers & National Seminar on Safe and Sustainable Mining in the current Economic Scenario, 5 – 6 December 2014, Bangalore pp. 40–48.

16. HS Venkatesh, Al Theresraj and R Balachander, 2015: Mitigating of adverse impacts due to blasting in stone quarries. Workshop on Explosives for Mines – Safety Issues, SOUVENIR 2015, 24th March 2015, DGMS (Sothern Zone) & Explosives Manufacturers, Hyderabad, pp 47-55.

17. J Sriganesh, V Ram Mohan and Divyalakshmi KS, Tune Usha and MV Ramana Murthy, 2014: Tsunami threat assessment due to earthquakes with different magnitude and source, for Cuddalore coast Tamil Nadu India, IO Tsunami 2014, 10-13 December 2014.

18. Kumar Reddy S, 2014: Sustainable development of Pulivendula barite deposit adopting suitable stoping method. Proc Seminar on Sustainable Development in Mineral and Earth Resources. 21-22 June 2014, New Delhi.

19. MP Jonathan, Divyalakshmi, KS and V Ram Mohan, 2014: Village level threat maps for Tamil Nadu, SE coast of India- Numerical Modelling Techniques., AGU fall meeting , December 2014.

20. PC Jha, VR Balasubramaniam, N Sandeep, Butchi Babu B and YV Sivaram, 2014: Application of GPR in assessing the stability of oil pipeline, 15th international conference on ground penetrating radar (GPR 2014), Brussels, Belgium, from June 30 to July 4, 2014. pp 456 – 461.

21. PC Jha, VR Balasubramaniam, N Sandeep, Butchi Babu B and YV Sivaram: Application of GPR in assessing the stability of oil pipeline. Accepted to Publish in IEEE Journal, in Dec 2015.

22. PC Nawani, Sripad R Naik, R Nair, Massive varunavat hill landslide overlooking Uttarakashi Town in Uttarakhand Himalaya Its treatment vis a vis Stability Analysis.

Mountain Hazards and Disaster Risk Reduction, Monograph Series-Disaster, Risk Reduction, Approaches and Practices, Springer 2015 pp 13-31 Ed: Rajib Shaw & H K Nibanupudi ISBN 978-4-431-55241-3.

23. Shivakumar Cherukuri, 2015: Real-time stability evaluation of large underground powerhouse caverns - application of microseismics (ARMA-15/333) is accepted for the international symposium by American Rock Mechanics Association (ARMA) for presentation.

24. Rajan Babu, A and Biju John, 2014: Strata classification: Some intriguing annotations from a Piedmont area from South India, Conference on Computational Mechanics. May 16-18, 2014, Suzhou, China.

25. RD Lokhande, VMSR Murthy, V Venkateswarlu and KB Singh, 2015: Assessment of pot-hole subsidence risk for Indian coal mines. International Journal of Mining Science & Technology, On-line : http://dx.doi.org/10.1016/j.ijmst.2015.02.004

26. S Sengupta, DS Subrahmanyam and RK Sinha, 2014: State of ground stress its use and measurement in rock engineering with special reference to weak rocks. ISRM (India) International Journal ISSN: 2277-131X, vol. 2, no.3. pp 11-39.

27. Sripad R Naik and Sastry VR, 2014: Behaviour of large underground cavern during construction in Himalayas - A case study. International Journal of Earth Sciences and Engineering, vol. 7, no.4, pp 1601–1610.

28. Sripad R Naik and Sastry VR, 2014: Behaviour of cross tunnels in large underground cavern- A case study. International Symposium Rock Mechanics 2014 - Present Technology and Future Challenges 20-22 August 2014, New Delhi.

29. W Abdellah, D Raju, HS Mitri and D Thibodeau, 2014: Stability of underground mine development intersections during the life of a mine plan. International Journal of Rock Mechanics and Mining Sciences (IJRMMS), vol. 72, pp 173–181.

30. Yogendra Singh, Biju John, GP Ganapathy and Divyalakshmi KS, 2014: Geological indicators of a suspected seismic source from Peninsular India Geophysical Research EGU General Assembly Abstracts, vol. 16, EGU2014-798.

Annexure-8

NEWS LETTER

- The Foundation Day Lecture was delivered by Professor TG Sitaram of IISc, Bengaluru, on 14th August, 2014. The title of his lecture was "Practical Equivalent Continuum Analysis of Jointed Rock Mass – Field Case Studies in Infrastructure and Mining Projects".

- Dr V Venkateswarlu (Director) delivered an invited Keynote Lecture on "Application of geosynthetics for slope protection", in the Global Geosynthetics Summit organized by Chamber of Indian Industries at Ahmadabad on 5th September, 2014.

- Dr V Venkateswarlu (Director) delivered a lecture on "Developments in Rock Mechanics" to the Indian Association of Petroleum Geologists, at Shell Technology Centre, RMZ Towers, Bengaluru, on 17th October, 2014.

- Dr V Venkateswarlu (Director) attended the Indian Geotechnical Conference (IGC-2014) at Kakinada during 18-19 December, 2014.

- Dr V Venkateswarlu (Director), Mr Sripad R Naik, Dr AK Naithani and Mr T Amrith Renaldy attended the International Symposium on Rock Mechanics, Rock India-2014, and Workshop on Open Pit Mining, at CBIP, New Delhi on 20-22 August, 2014. Dr AK Naithani was a member of Technical Committee.

- Dr DS Rawat attended the Indorock–2014 conference on underground construction for hydropower, mining and infrastructure, organized by Indian Society for Rock Mechanics and Tunneling Technology in association with Central Water Commission and Central Soil and Material Research Station at New Delhi from 12 to 14 November 204 and presented a research paper.

- Dr Rabi Bhusan attended the Conference on "Challenges and Barrieres in Hydropower development" at Shimla during 18th to 19th September 2014 organised by CBIP, New Delhi.

- Dr HS Venkatesh, was a member of the Expert Committee for the construction of Hydel Projects in the Himalaya, constituted by Ministry of Environment and Forest. He participated in the final report preparations and submitted NIRM observation with respect to TOR. Final submission was made to MOEF during April 2014.

- Mr Butchi Babu B presented a paper at International Conference on Ground penetrating Radar (GPR-2014) during June 30-July 4, 2014, Brussels, Belgium. This tour was funded by DST, Govt. of India.

- Dr AK Naithani attended the Doctoral Committee Meetings at Centre for Disaster Mitigation and Management, VIT University, Vellore, Tamil Nadu.

- Dr Biju john attended doctoral committee meetings at VIT University, Vellore on 28th November 2014 and 18th February 2015.

- Mr G Gopinath delivered lectures for the field engineers on various topics like blasting in tunnels and underground metalliferous mines, advances and practices in blast initiation system, use of electronic delay detonator technology and controlled blasting techniques for infra structures application organised at ESCI, Hyderabad during July 2014.

- Dr HS Venkatesh is nominated as a Member Editorial Board of Visfotak Journal from September 2014.

- Dr HS Venkatesh delivered two lectures on Introduction to explosives, initiation system and Optimisation on underground blasting at Technology Exchange Program on Rock Blasting organised at NITK on 18th September 2014 at Surathkal.

- Dr HS Venkatesh was nominated as Member, Organising Committee, 26th National Convention of Mining Engineers & National Seminar on Safe And Sustainable Mining in the Current Economic Scenario, 5-6 December 2014, Institution of Engineers, Bangalore.

- Dr HS Venkatesh delivered lectures on blasting with reference to Hydel/construction to the HCC officers at Mumbai on 18th December 2014.

- Dr HS Venkatesh presented an invited paper entitled “Mitigating of Adverse Impacts due to Blasting in Stone Quarries” at Workshop on Explosives For Mines - Safety Issues, on 24th March 2015, organized by DGMS (Sothern Zone), Hyderabad.

- Mr T Amrith Renaldy and Mr S Kumar Reddy guided the students of Dr TTIT, KGF, for their one-month internship training programme and also guided the projects for the final year BE (Mining) students.

- Mr T Amrith Renaldy and Mr S Kumar Reddy were the examiners and paper setters for the BE (Mining) examination of VTU, Belgaum.

Degree Awarded

- Ph.D. Degree was awarded to Mr. Saneep Nelliat by Indian School of Mines Dhanbad under the joint supervision of Prof. P.R. Mohanty (ISM) and Dr. P.C. Jha (NIRM). The title of his Ph.D. thesis is “Geophysical studies to resolve some of the geological problems related to hydropower development in India and Bhutan”.

- Ph.D. Degree was awarded to Mr. Prasnna Jain by IIT Bombay under the joint supervision of Prof. T.N. Singh (IIT Bombay) and Dr. A.K. Naithani (NIRM). The title of his Ph.D. thesis is “Evaluation of engineering geological and geotechnical properties for the performance of a tunnel boring machine (TBM) in Deccan Trap rocks – a case study from Mumbai, India”

Training Programmes Attended

- Dr AK Naithani and Mr G Gopinath attended the training programme on Managerial Effectiveness Enhancement, organised by the Institute of Management Training & Research, Goa and sponsored by Department of Science & Technology at IMTR, Goa during 19-23 January 2015.

- Mr. Butchi Babu B attended DST sponsored training programme on Basic Geophysical Techniques at Indian School of Mines, Dhanbad during Jan 18-25, 2015. He received 'Best Performer' award with a Memento and cash prize for his all-round performance at the training programme.

- Dr VR Balasubramaniam attended training on Detection and Mapping of Underground Utilities held during August 22-23 at Aqua Foundation Academy, New Delhi.

Annexure - 9

STAFF ON ROLL

(as on 01.04.2015)

Director
Dr V Venkateswarlu

Departments & Regular Staff

Engineering Geology
- Dr AK Naithani
- Dr Devendra Singh Rawat
- Dr L Gopeshwor Singh
- Dr Prasnna Jain

Geotechnical Engineering
- Dr DS Subrahmanyam
- Mr G Shyam
- Mr K Vamshidhar
- Mr Vikram S

Numerical Modelling
- Mr Sripad R Naik
- Dr Rabi Bhusan
- Mr BH Vijay Sekhar
- Mr K Sudhakar

Mine Design
- Mr C Nagaraj
- Mr Amrith T Renaldy
- Mr S Kumar Reddy
- Mr Bharath Kumar A Y

Centre for Testing Sercices
- Mr A Rajan Babu
- Dr GD Raju
- Mr S Udayakumar
- Mr M Victor
- Mr D Joseph

Engineering Geophysics
- Dr PC Jha
- Dr Sandeep Nelliat
- Mr Butchi Babu Bongu
- Mr YV Sivaram

Environmental & Exploration Geophysics
- Dr VR Balasubramaniam
- Dr Biju John
- Mrs KS Divyalakshmi
- Mr Yogendra Singh
- Mr Goverdhan Kantepudi

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
- Mrs Praveena D Jennifer
- Mr Vikalp Kumar

Project Monitoring Cell
- Dr V Venkateswarlu (additional charge)
- Mr Sultan Singh Meena
- Mr A Vijaya Kumar

Mr Sagaya Benady
Mr Royston A Victor
Mr D Prashanth Kumar
Mr Syed Asgar
Mr R Prabhu
Mr N Selvaraj

Drivers

Mr P Venkata Reddy
Mr K Manjunath

Staff Resigned during the Year

Dr Manoj Kumar
Dr RK Sinha
Mr N Maruthi P Naik

Administration

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

Staff Retired during the Year

Mr Y Ahnoch Willy

Total staff on roll : 59 *(including Director)*

Executives of the Singareni Colleries Co. Ltd. during a training course on Kinematic analysis of discontinuities Organized by NIRM at Kothagudem and Ramagundam during 10 to 12 December 2014

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.

4. Conduct training courses and workshops for professionals, and provide research facilities for higher education in the areas.

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