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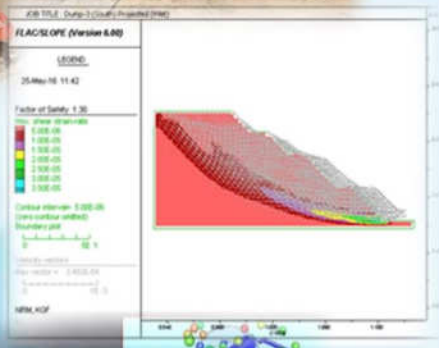
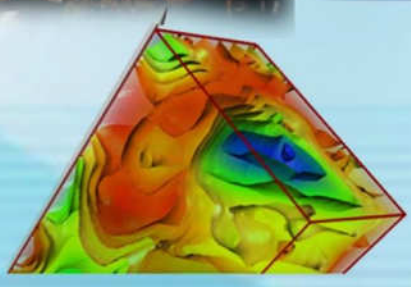
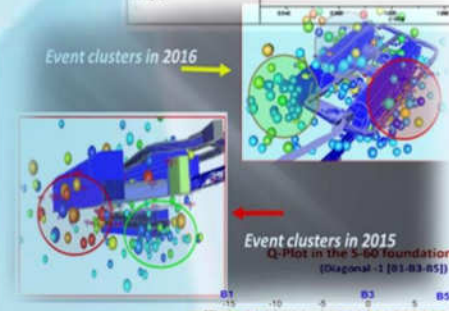
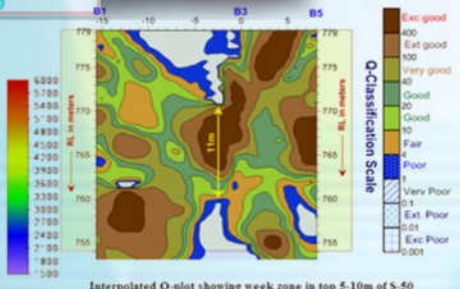
ANNUAL REPORT
2016-17









Interpolated Q-plot showing week zone in top 5-10m of S-50 platform. This might lead to uneven settlement.

राष्ट्रीय शिला यांत्रिकी संस्थान

National Institute of Rock Mechanics

(Ministry of Mines, Government of India)

Outer Ring Road, Eshwar Nagar, BSK 2nd Stage,

Bengaluru – 560 070, Karnataka, India

Border Roads Organization (BRO) Engineers during a training course on controlled blasting & excavation engineering Organized by NIRM at KGF from 25-29 July, 2016

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NATIONAL INSTITUTE OF ROCK MECHANICS

(Ministry of Mines, Government of India)

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Front Cover: Photos of project site/studies carried out by NIRM
Back Cover: RARE-2016, international conference organized by NIRM at Bengaluru

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Director's Report

I am pleased to present the Annual Report of this Institute for the year 2016-17. As you are aware, NIRM carries out applied research and provides its R&D support and expertise to the mining industry and major civil engineering projects (road / rail / hydroelectric) involving caverns and tunnels by way of executing both government and industry sponsored projects. In continuation of these activities, the Institute has executed over 50 projects during 2016-17 in the broad areas of

- Hard rock and metal mines
- Coal mines
- Hydroelectric and tunneling projects
- Infrastructure and development projects
- Testing Services

Major Achievements during 2016-17

During the year 2016-17, NIRM has completed 50 sponsored and 2 S&T projects, and work on about 50 other projects has been continuing. This year, our scientists have published 31 technical papers in international journals / national journals / conferences. NIRM received from the Ministry of Mines, Rs. 500 lacs as Non-Plan Grant-in Aid, and Rs. 235 lacs as Special Plan Grant towards equipment. The internal revenue generation from projects during this period was Rs. 450 lacs with a cash flow of around 700 lacs up by almost 10% over the previous year.

As part of information dissemination and skill development exercise, NIRM conducted three training courses during 2016-17 - one for the engineers of Border Road Organization and two for the executives of the South Eastern Coalfields Ltd. The highlights of major R&D activities during 2016-17 are given below.

Non-Coal Mines

During the year 2016-17, NIRM continued the S&T project (funded by the Ministry of Mines) on estimation of seismic hazard in and around the mined-out areas of Kolar Gold Fields. To identify potential zones of hazards due the mine induced seismicity in the area, microseismic sensor network has been commissioned.

The Institute carried out slope stability studies at the mines of Copila Gaichem Paul Iron ore mine, FOMENTO Resources, Goa, determined the in situ stress parameters at Hutti Gold mine for the design of stopes below 20th level. NIRM continued its association with the UCIL mine at Tummalapalli, and guided the mine authorities in proper method of work and support design for both footwall and hangwall lodes of the mine below 100 m depth; design of the stoping parameters for Munsar and Chikla mines of MOIL was also done.

Coal Mines

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

- Formulation of method of work and strata control investigations under difficult ground conditions like fire & high stresses
- Feasibility of extraction under surface structures, water ways and subsidence
- Mapping of old workings, and barriers around old workings from underground
- Study of cavability of roof strata and design of pillars
- Subsidence predictions and strata behaviour studies for longwall panels
- Design of methods for speedy extraction of standing pillars
- Design of support system based on RMR and in-situ stress measurements
- Study on ground vibrations, assessment and control
- Geophysical survey for mapping for hard rock patches and lignite deposits.

During the period, the Institute undertook studies mostly in the mines of SECL. The Churcha group of mines is characterized by hard and difficult-to-cave roof. NIRM designed optimal support system and continued monitoring for the strata behavior in several panels, thus contributing to safe extraction of coal in these mines.

Hydro-electric, Nuclear Power & Tunnelling Projects

NIRM has made significant contribution to the construction of almost all the hydro-electric projects in India. During the year 2016-17, investigations were carried out for the determination of in-situ stress parameters for design of underground powerhouse cavern at Vishnugad Pipalkoti Hydro-electric Project, Uttarakhand, to study the feasibility of blasting for excavation of Tail Race Tunnel under Durgapur village, in Chamoli.

Seismotectonics studies for evaluation of Light House lineament at Jaithapur Nuclear Power Plant at Ratnagiri, Maharashtra through trench studies and feasibility studies for the commissioning of the NPP at Gugulapalli, Tummalapenta, Chennyapalem & Karedu (all in AP) were carried out in detail.

NIRM has been continuing the micro-seismic monitoring of the stability of the areas in and around Tapovan-Vishnugad hydro-electric project (Uttarakhand) and the Tala hydro-electric project (Bhutan). Construction stage engineering geological mapping of foundation of dam and determining the stress regime at this place including in-situ deformation modulus of the rock mass required for construction of gravity type concrete dam were done by us.

NIRM provided technical advice on rip-rap blasting for the construction of earth cum rock filled dam at Polavaram Project (AP) and on removal of boulders and excavation of rock in the river channel of Idamalayar dam spillway for the Kerala State Electricity Board. Investigations related to ground vibration and air overpressure due to blasting at two quarries located at Beerahalli, Oblahalli and Hulavenahalli villages of Hosakote Taluk, Karnataka were carried out.

Infrastructure Projects

The Institute was involved in investing complex site investigation problems related to various infrastructure projects like larges underground storage caverns, metro rail and the railway tunnels under difficult geological conditions. During this year, NIRM continued the comprehensive investigations of major Lift Irrigation Scheme in Karimnagar District of Telangana State. In addition, the in-situ modulus of deformation of rock mass at the delivery main tunnels and surge pool of Kaleshwaram project was determined, and 3D Numerical

Modelling analyses of pump house and surge pool caverns were carried for the design of the support system for the underground surge pool and pump house.

Blast vibration study, proof checking and monitoring of blast induced vibration were carried out for the Darlipali Super Thermal Power Project (2 x 800) MW in Odisha. Monitoring of ground vibration and air overpressure for the blasts carried out at Kudankulam nuclear power plan-II in Tamil Nadu.

Geological logging of drill holes and mapping of the excavated wall faces for the DSTP project, engineering geological investigations for study the stability of the slopes around the cave area of Shri Mata Vaishno Devi Hill in J&K were done by our Scientists. Geophysical survey to ascertain the possibility of subsidence of Haldia-Barauni oil pipeline between chainage 257.700 and 258.700 km for IOCL, Kolkata, and Cross-hole Seismic Tomography Survey to study the integrity of the foundation of S60 pillar of Chenab Bridge, J&K was carried out by the Engineering Geophysics group.

Testing Services

With an accredited test laboratory, NIRM has carried out proof-load tests, destructive tests and NDT for a wide spectrum of mining and allied industries. In-situ testing of mining components in the mines of SECL, SCCL, WCL, GMDC, Hindustan Zinc Ltd., Hindustan Copper Limited, National Mineral development Corporation and NALCO. Apart from them, in-situ testing of various mining components was done for M/s China Coal, Shaft Sinkers and as well as for testing of ropeway of other service providers. Apart from them laboratory testing of ropes, material and rock samples for various physico-mechanical properties was also done.

Acknowledgement

The diverse areas of activities briefed above reflect the vision of the Institute for a quantum growth with a resolve for self-sustainability. I am indeed thankful to various sponsoring agencies and industries for reposing faith in our services through a varieties of sponsored projects and assignments.

I thank the Chairman and Members of the Governing Body and General Body of the Institute for their support and encouragement to proceed with our service motive to the industry. The generous assistance from the Ministry of Mines, Govt of India and the inspiration and guidance from the Peer Review Committee has helped us to steer the growth during this year.

I place on record the commendable work carried out by the Scientists and staff of the Institute who are at the forefront in executing the projects in time and with strict quality control. We will continue our interaction with the user industries and agencies to meet their R&D requirements so as to achieve our goal to become a global R&D entity in the field of rock engineering.

(Sivakumar Cherukuri)
Director (Additional Charge)

ENGINEERING GEOLOGY DEPARTMENT

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 data are pre-requisite for economic and safe designing of construction projects related to power sector (hydro, thermal, nuclear), communication sector (metros, rails, tunnels, roads, bridges), mining sector, crude oil storage caverns, lift irrigation sector, and also for geo-hazard assessment and mitigation.

COMPLETED PROJECTS

1. Engineering geological, geotechnical and laboratory testing for the proposed new underground surge pool and pump house of Pranahitha – Chevella Sujala Sravanthi Lift Irrigation Scheme -Package-12 in the Medak District of Telangana State (Project No.: EG-15-03): Irrigation & CAD Department of Telangana Government have taken up Pranahitha Chevella Sujala Sravanthi Lift Irrigation Scheme to Lift 160 TMC of water from Rivers Pranahitha and Godavary to Irrigate 16.40 lakh acres in backward upland drought prone areas and supply of water to drinking needs of drought prone ayacut area and twin cities of Hyderabad. The lift irrigation scheme (PCSSLIS) envisages lifting of water from the right bank of the River Pranahita, a tributary of the River Godavari at RL +152 m and delivering to Chevella reservoir at RL +635 m with multiple stage lifting and conveying through tunnels and gravity canals. The total scheme is divided into 28 packages. The Package - 12 of PCSSLI scheme comprises detailed investigations, designs and execution of lift irrigation scheme for drawl and lifting of 77.914 TMC of water from New Reservoir at Imamabad to Sri Komaravelli Mallanna Sagar by water conveyor system to irrigate an Ayacut of 1,25,000 acres. The capacity of new Sri Komaravelli Mallanna Sagar reservoir will be 50 TMC. For better rock mass classification and structural design of supporting system at new site, preconstruction stage engineering geological and geotechnical investigations were carried out for the proposed new underground pump house complex. The detailed investigation includes large scale geological mapping on 1:500 scale, logging of drill holes, in-situ stress measurements and laboratory testing on rock samples for geomechnical parameters. The basic purpose of these investigations were to identify/map different rocks and structures like joints, shear zones, faults, fracture zones etc. and to determine engineering properties of rocks and rock masses by lab testing and in-situ testing. This scheme envisages important structures such as channel, tunnel, surge pool [300 (L) x 20.60 (W) x 52.00 m (H)], draft tubes, transformer cavern [169 (L) x 15 (W) x 19.5 m (H)], pump house [190 (L) x 21 (W) x 35.18 m (H)] and main delivery tunnels. The present area falls within the geological domain of Peninsular Gneissic Complex represented by granite/gneiss (Fig. 1).

2. Engineering geological investigations of Kaleshwaram – DBRAPCSS II Lift Irrigation Scheme Package-6, Karimnagar District, T.S. (Project No.: EG-16-01 & EG-17-02): At Kaleshwaram – DBRAPCSS II lift irrigation scheme package-6, geological mapping (3-D and face mapping), rock mass assessment and support system of twin tunnels (RMT & LMT), underground pump house, transformer cavern and surge pool are being carried out by NIRM since July 2013 (Fig. 2). 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. This scheme comprises of 2.4 km long approach channel, 0.948 km gravity canal, 9.475 km long & 10 m diameter, D-shaped twin tunnels up to chainage 10.675 km and an underground pump house complex from chainage 10.675 to 10.785 km. Excavation of surge pool (25 W x 375 L x 67.8 D m), transformer cavern(16 W x 203.4 L x 27.5 D m) and pump house(25 W x 210.6 L x 49 D m) is being done from access tunnels, which are joining the caverns from left side. As per

the agreement Phase-IV (up to March 2017) is successfully completed and now project is extended upto September 2017.

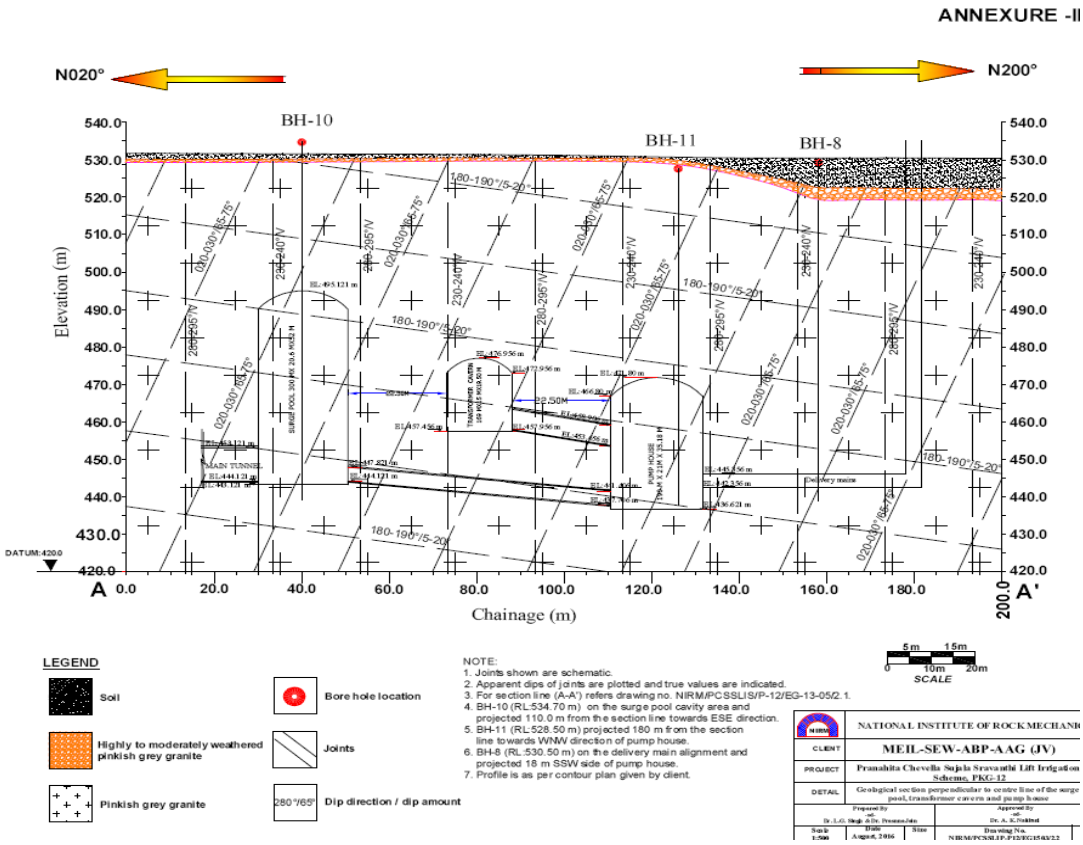

Fig. 1: Geological section perpendicular to center line of the surge pool, transformer cavern and pump house of package 12

3. Engineering geological investigations of additional surge pool of Pranahita – Chevella Sujala Sravanthi Lift Irrigation Scheme – Package 8 (PCSSLIS-P8), Karimnagar District, Telangana State (Project No.: EG-16-02): 20.20 m (w) x 58.50 m (h) x 200 m (l) additional surge was investigated during the excavation of heading portion. Rock type exposed after the heading excavation was pink granite belongs to the Peninsular Gneissic Complex of Archaean age. For structural stability of surge pool segment above concrete lined portion, rock support arrangements were recommended based on NMT (Norwegian method of Tunneling) technology and site geological condition which include steel fibre reinforced shotcrete (SFRS), rock bolt and drainage hole provisions. On the basis of geological and structural data input from the 3D engineering geological mapping of the heading portion of the additional surge pool recommendations were made for the safe construction/excavation.

4. Review of engineering geological investigations of surge shaft of Pranahita – Chevella Sujala Sravanthi Lift Irrigation Scheme – Package 10 (PCSSLIS-P10), Karimnagar District, Telangana State (Project No.: EG-16-03): The scope of the work was to review the support design based on engineering geological parameters and 'Q' system for the surge shaft. The main works under this package include: 3.40 km approach channels with a discharge capacity of 362 cumecs, 9.50 m dia 'D' shaped 7.651 km lined tunnel with a design discharge of 321 cumecs, 56 m dia and 92 m deep circular surge pool, underground pump house to enable lifting of 88.24 TMC of water in 120 days with a static head of about 94.5 m, four delivery mains of suitable diameter to carry the total discharge of 241 cumecs, delivery cistern, formation of new reservoir with capacity of about 3.500 TMC at Ananthagiri village

with associated works such as sluices, surplus weir, surplus course etc. After review and site visit changes were recommended in the support design.

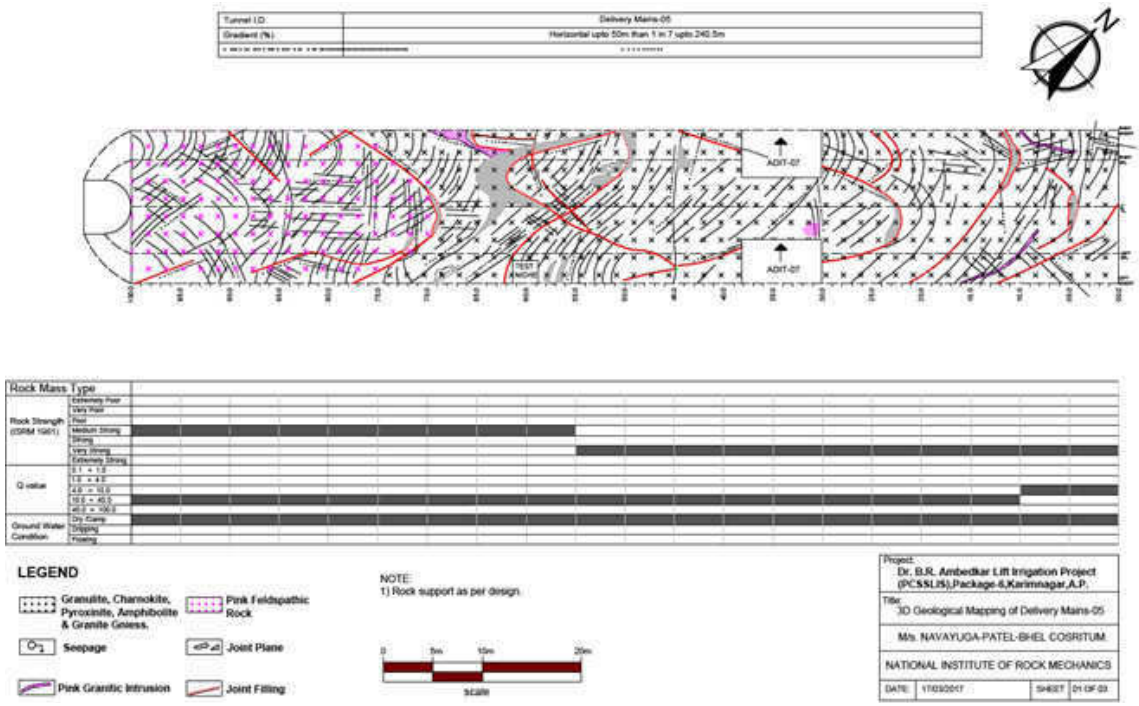

Fig. 2: 3D geological map of the delivery mains-5 of package-6

5. Geological logging of drill holes/mapping of excavated wall faces of Darlipali Super Thermal Power Project (2 x 800 MW), Odisha (Project No.: EG-16-04): Darlipali Super Thermal Power Project (2 x 800 MW) at Darlipali village in Sundargarh district of Odisha state is being constructed by NTPC Limited. Darlipali power plant is likely to be commissioned by February 2018 and the project is estimated to cost Rs 13,000 crore. Under this project the scope of work includes geological mapping of excavation wall faces at three locations of deep excavated structures, rock matrix description, rock discontinuity orientation and description, classifications of rock masses based on RMR system and review of existing bore hole logs. Total 28 bore log data sheets were reviewed. Rock Mass Rating system was used for a better assessment of rock mass quality regarding excavations purposes. Average RMR value for the foliated gneiss is 52 indicating ripping is required while for granite average value is more than 60 indicating blasting is required for excavation. Revised Exacavatability Graph model was also adopted regarding the observations with respect to excavation, indicating that excavation is possible through hard/very hard ripping machines.

6. Engineering geological investigations of the extension of surge pool and pump house caverns of Pranahita – Chevella Sujala Sravanthi Lift Irrigation Scheme – Package 8 (PCSSLIS-P8), Karimnagar District, Telangana State (Project No.: EG-16-05): Package 8 covers the area between Kakatiya canal in the NE and Mothevagu reservoir in the SE of toposheet no. 56N/2, Karimnagar District, Telangana State. The major components of the project are: 4.133 km long and 10.00 m finished diameter 'D' shaped twin tunnels, surge pool (350 m long x 20 m width x 54 m height), 58 m long five numbers of draft tube tunnels, one pump house (215 m long x 25 m width x 54 m height) and five numbers, 50 m long horizontal & 150 m vertical shaft having 5.0 m finished diameter pressure mains, 80 m long delivery cistern and 5.85 km long gravity canal from delivery cistern to join flood flow canal. Lift height is about 126 m and five numbers of pump will be installed in the pump house cavity having 130 MW capacity each. The reengineering of the project was done and because of this surge pool and pump house cavities are being extended for increased discharge from 419 to

624 cumecs. 20.20 m (w) x 69.70 m (h) x 60 m (l) extended surge pool and 25.20 m (w) x 56.95 m (h) x 104 m (l) extended pump house were investigated during the excavation of heading portions. Rock type exposed after the heading excavation is pink granite belonging to the Peninsular Gneissic Complex of Archaean age. For structural stability of surge pool and pump house segment above concrete lined portion, rock support arrangement was recommended based on NMT technology and site geological condition which include steel fibre reinforced shotcrete (SFRS), rock bolt and drainage hole provisions. On the basis of geological and structural data input from the 3D engineering geological mapping of the heading portion of the extended surge pool and pump house, recommendations were made for the safe construction/excavation.

7. Review of engineering geological investigations of pump house of Kaleshwaram Project – Package 10, Rajanna Siricilla District, Telangana State (Project No.: EG-16-06): The scope of the work was to review the support design based on engineering geological parameters and 'Q' system for the underground pump house. The rock types reported in the pump house area are pink and grey massive granite belonging to the Peninsular Gneissic Complex (PGC). For structural stability of pump house, rock support arrangement has been proposed with polypropylene fibre reinforced shotcrete, rock bolts and drainage hole provisions based on geological, wedge and 2D numerical analysis. On the basis of review of reports on engineering geological and support design and site visit, recommendations were made for the safe construction of the underground pump house cavern.

ENGINEERING GEOPHYSICS DEPARTMENT

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.

COMPLETED PROJECTS

1. Borehole GPR survey for mapping probable extensions of old working within the ore-body at 200 MRL around East-Load area of Rajpura-Dariba Mines, HZL(Project No.: GP-15-05): Rajpura Dariba Mine of Hindustan Zinc Limited (HZL) is located at the southern extremity of Rajpura Dariba Bethumni metallogenic belt in Rajsamand district of Rajasthan. At present, mining in the East load is being done below 100 mRL and the possibility of safe mining up to 200 mRL is being explored. In this process, several boreholes (inclined and horizontal) were drilled along the strike length of the ore body, crossing the ore body and into the hangwall rocks. When one such borehole was drilled inclined at $+15^0$, it punctured some water filled cavity and caused excessive water inflow into the 200 mRL drive. This borehole was later plugged and water flow was brought under control. Several older workings in the form of irregular pits, trenches and small diameter shafts were present around the area, which were not properly mapped nor was any plan map available for them.

Considering this event of major water leak, it became imperative for HZL to ascertain the presence of water logged old workings around the 200 mRL gallery. Therefore, M/S HZL sought assistance from NIRM for geophysical investigation from underground to locate the water logged old workings around the 200 mRL gallery in the East load area. Considering the site condition, it was decided to carryout crosshole GPR survey (transmission of radar waves) between horizontally drilled boreholes from the 200 mRL drive and crossing the East load. Nine horizontal boreholes (45-60 m deep) between 310N and 530N with a spacing of about 25-30 m were drilled for this purpose.

Eight sets of crosshole GPR survey was done between the adjacent pair of holes. In addition, borehole GPR profiling (reflection of radar waves) was also carried out for observing the reflection pattern around the individual boreholes.

A sample radargram for borehole GPR profiling in BH43 (56 m deep) is shown in Fig. 3. The GPR reflection in the first half of BH43 shows some near surface strong reflections as well as poor reflections from deeper levels. At about 12-22 m away from the 200 mRL gallery, there is a zone showing discontinuous reflections which might be a fault plane/ shear zone. The loss of energy may be due to mineralization or due to the conductive nature of water. However, the radargram showed a complex reflection pattern in the near surface area which might be due to mineralised pockets. No cavity type feature was mapped in the radargram.

Most of the boreholes showed complex reflections from the near field area representing shear zone or mineralized pockets. Some faults planes were also identified. At several locations reflections from circular targets were seen but most of them were falling outside the known ore body. Hence they could not be confirmed as signatures of old workings. In BH47, one target at 9 m distance from the borehole (probably from above the borehole) was marked as old working as it was located within the ore body. In some of the radargrams loss of energy was high and hence reflections from distances greater than 5-6 m were very feeble.

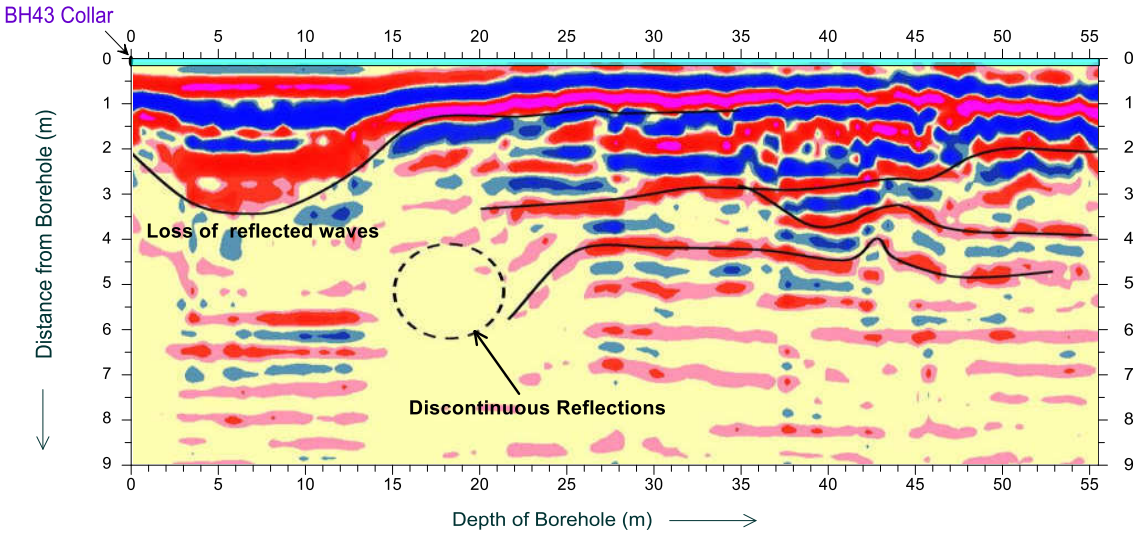

Fig.3: Radargram from GPR profiling in borehole BH43

Based on the results from the borehole GPR profiling alone, conclusive evidence of old workings around 200 mRL in the plane of survey could not be confirmed. Later cross-hole survey between two holes indicated abnormal attenuation patterns by which old workings were identified.

2. Seismic Refraction Survey at the proposed Silahalla Dam Site Kundah, Nilgiri, Tamilnadu, TANGEDCO, Chennai(Project No.: GP-16-02): Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) has proposed to construct Sillahalla dam as an 'Energy Augmentation' scheme in Nilgiris District, Tamil Nadu. Based on the recommendations from the Geological Survey of India, TANGEDCO requested for Seismic Refraction Survey to be conducted along the abutment and the proposed dam axis (as well as alternate dam axis) of the proposed Sillahalla Dam site in Nilgiris District, Tamil Nadu. The stated objectives of the survey are to map the rock level along the line of survey as well as to indicate any geological pitfalls.

Pursuant upon the receipt of the work order, a site visit was made in February 2017 to see the field condition and explain the logistics preparation required for conducting the geophysical survey. The survey lines were physically identified at site jointly by NIRM and TANGEDCO. The following BOQ was drawn during the site visit:

a. Survey along dam axis and alternate dam axis – 9 lines of 115m each
b. Survey across dam axis lines – 2 lines of 115m each (one each on either bank)

An inspection report was sent to the TANGEDCO authorities. The survey work will be taken up after site preparedness is confirmed by them (TANGEDCO).

3. Cross-hole Seismic Tomography Survey for investigation of the foundation of S60 pillar of Chenab Bridge, USBRL Project, KRCL, J & K(Project No.: GP-15-04): M/S Konkan Railway Corporation Ltd. (KRCL) is constructing a special bridge across river Chenab at village Kauri, District Reasi in the state of Jammu and Kashmir. This bridge is part of several bridges and tunnels of the Udhampur-Srinagar-Baramullaa Rail Link (USBRL) project. The proposed length of this bridge is 1315m which is covered with 18 pillars numbering from S10 to S180. The central span of steel arch covering a length of 480m is between pillar S40 and S50. This arch is designed as a two-fold ribbed arch comprising steel girders with scaffolding braces produced on the spot. In order to set up the strong foundations for the bridge, large scale rock anchoring, drilling and grouting activity has been done on both sides of the river valley.

During excavation in the foundation of S60 pillar, two sets of wide open joints apparently forming a wedge type feature were noticed. M/S KRCL officials decided to grout the visible joints and then requested to carry out tomographic investigations at the pier to know the depth and extension of left-over openings or cavities present, if any, post gouting. As suggested by NIRM, five boreholes were drilling on the foundation platform to carry out five sets of cross-hole seismic tomography up to the depth of 60m with following objectives

Five set of tomographic data acquisition was done between pairs of holes B1-B3, B2-B3, B4-B3, B5-B3 and B4-B5 using P-wave Sparker source and 12 channel hydrophone chain as receiver. The receiver spacing as well as the shot interval was chosen as 1m. Each 60m tomography data was collected as two segments with 4m overlap with the bottom segment from -19 to -60m and top segment from 0 to -23m.

After processing of the tomograms, cavities were found on the top (Fig. 4) which was not expected as the area was heavily grouted with further anchoring with staggered DYWIDAG bolts (35 ton tension) from the river end face upto a depth of 15m. Hence KRCL requested to plot the interpolated Q value against depth of the borehole. Using Barton's relation of 2002 for jointed rocks, the measured V_P values were converted into equivalent Q-values. Using the the UCS values at various intervals in post-grouting scenario as provided by the KRCL. Later, the same tomogram was plotted in terms of Q-value. Following a poor Q-value showing in foundation, the top portion was opened. The indicated portion had no trace of grout material. Thus, our contention of a weak foundation was confirmed. Further reinforcement was planned accordingly by KRCL.

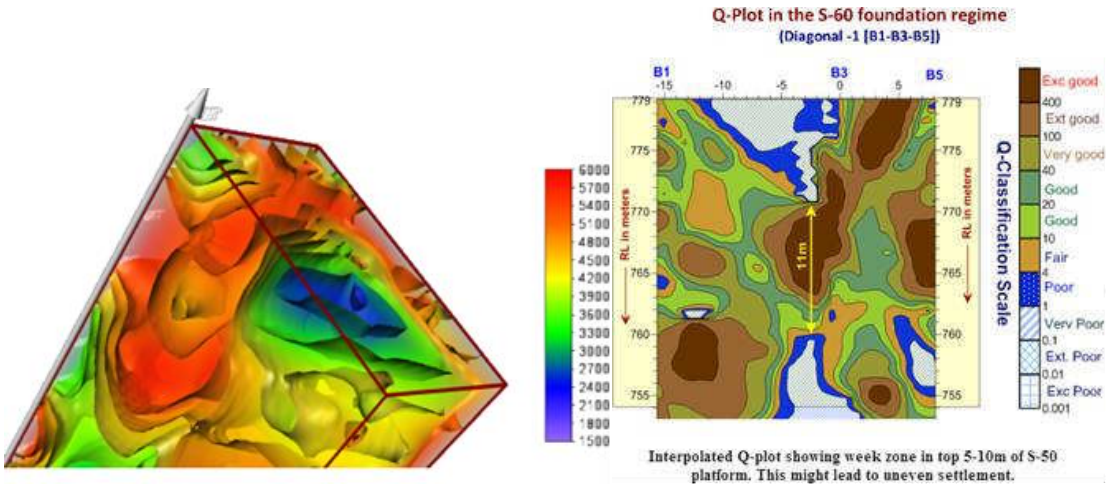

Fig. 4: P-wave tomogram indicating mapped cavity on the top of the S-50 platform

4. Geophysical Survey to ascertain possibility of subsidence of HB oil pipeline between chainage 257.700-258.700 km, IOCL, Kolkata(Project No.: GP-16-01): M/S Indian Oil Corporation Limited (IOCL) operates 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. A section of this pipeline passes through the old mining region of the Raniganj- Asansol coalfield. There had been instances of land subsidence proximate to and below the pipeline in this area. In the past, NIRM had carried out surveys in different stretches to assess the stability of the pipeline in vulnerable portions. The present geophysical survey was primarily to identify the potential subsidence zone as suggested in our earlier report. Eight sets of cross-hole survey were done along 1km of pipeline route between chainage 257.700 to 258.700km.

In addition, two sets of resistivity survey were done at distances of 10m and 20m from the pipeline alignment (on either side). The resistivity imaging exercise was planned to supplement the findings from the cross-hole survey. In order to achieve higher resolution,

depth of investigation by resistivity survey was restricted to 15m. The layout of both cross-hole and resistivity survey is shown in Fig. 5.

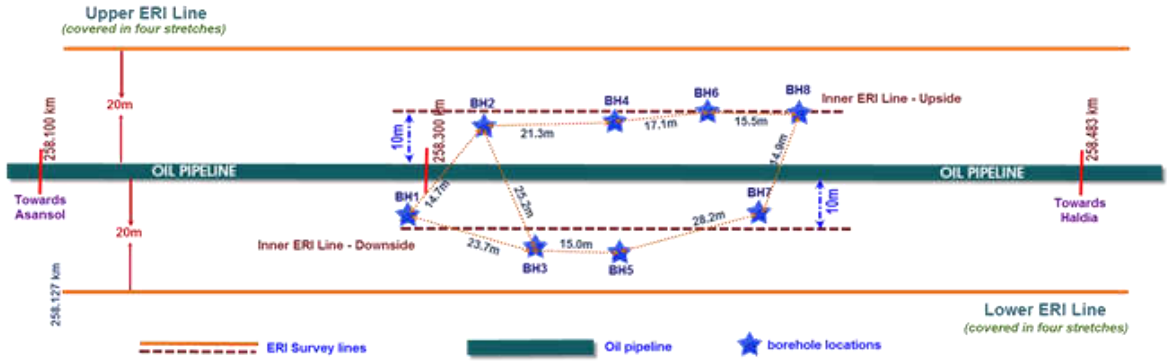

Fig. 5: Layout of cross-hole seismic and resistivity survey lines

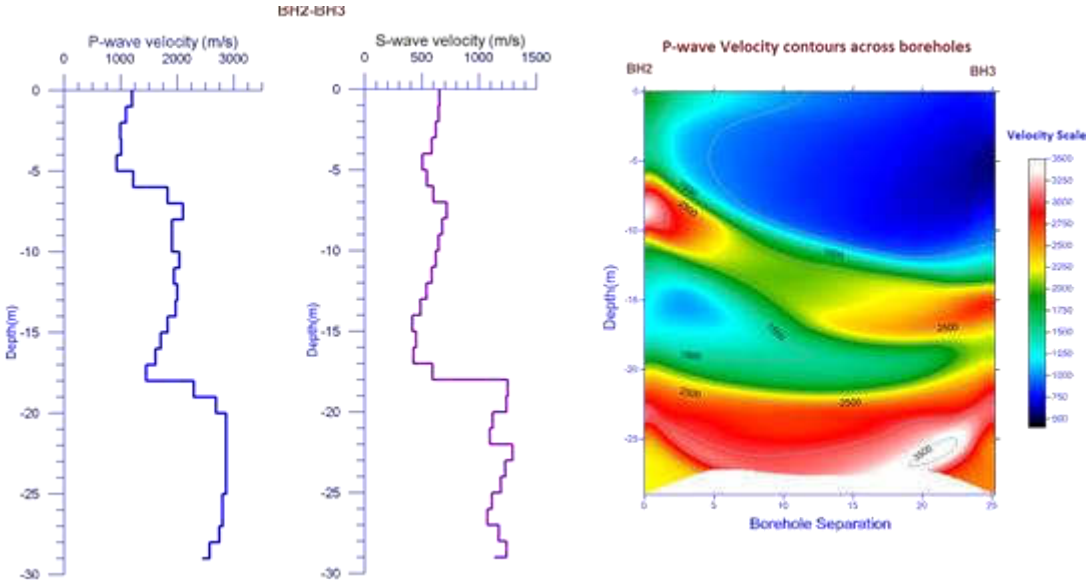

Fig. 6: Plot of cross-hole velocity section for P and S-wave at 0.5m interval between BH2-BH3 as well as P-wave contour across them

A sample velocity section between boreholes BH2 and BH3 separated by 25.2m is shown in fig.6. This section does not indicate any anomalous trend in the P and S-wave sections but the P-wave contour plot indicates a stook type feature between 7-10m depth in the BH-2 (chainage 258.315km). This layer appears going deeper towards BH-3 (Fig.6).

Combining features of three cross-hole sections - BH1-BH2; BH1-BH3 & BH2-BH3 it was found that a thin portion of hard strata was holding ground and resisting subsidence. With the anomalous trend of velocity contrast setting in between BH1-BH2, this is going to spread fast across BH2-BH3 also. Ultimately this may engulf entire portion between chainage 295.300-295.330km. The moment this 5m thick strata at 5-8m depth ruptures, entire area might witness a subsidence over a width of around 25-30m along this chainage. When this feature was confronted in the resistivity imaging sections by zooming around chainage 258.300km and 258.400km, it was found that the low resistivity zones exactly coincide with the trouble-spots identified by the cross-hole survey (Fig.7).

Therefore, it can be said that the features observed in the cross-hole sections do travel up to this distance (line of resistivity survey) on the eastern side of the pipeline. Further a low resistivity zones at these spots imply that the so called hard-rock stook identified in the cross-hole survey is a fractured and water-saturated layer which makes it's life much shorter than expected.

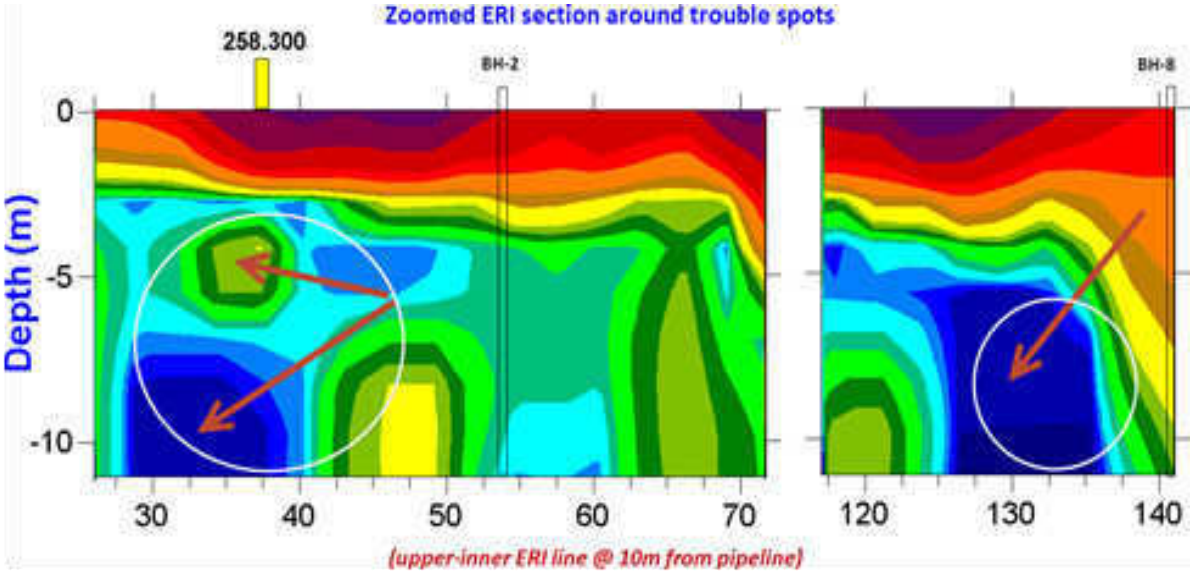

Fig. 7: Zoomed view of resistivity imaging section of upper line around problem area

Going by categorical data interpretation of cross-hole survey and resistivity imaging, it was established that there were two potential instability zones in the subsurface within the stretch of investigation carried out in this phase. In both these stretches, the zone of instability had spread upto ±10m from the pipeline as evidenced by the signature of a prominent low resistivity pocket on the inner resistivity imaging lines. With the confirmation of two potential subsidence zones within the area of investigation, IOCL escalated this matter to higher authorities for undertaking necessary corrective measures for the stability of the oil pipeline.

GEOTECHNICAL ENGINEERING DEPARTMENT

Geotechnical investigations are an essential and integral part of any civil and mining engineering projects. All the major projects where the rock excavation is involved require in-situ geotechnical investigations prior to design. In the design of underground and surface structures the decisions for geometry, shape, excavation sequence, orientation of the structure, support system, the acceptable water pressure for the conduits are dependent upon the results of different geotechnical investigations generated during the initial stage to construction stages of any project. In coal and metal mining, the mine layout, pillar design, stope design and sequence of mining are dictated by geotechnical investigation results for safe and economical extraction of the mineral. 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.

COMPLETED PROJECTS

1. **Determination of *in situ* stress tensor at underground surge pool/pump house of Pranahita Chevella Lift Irrigation Scheme (PCILS, package no 11) (Project No.: GE-16-01):** Dr. B. R. Ambedkar Pranahita Chevella Sujala Sravanthi scheme envisages diversion of 160 TMC of water from river Pranahita, a major tributary to river Godavari to irrigate an ayacut of 16,40,000 acres in Adilabad, Nizamabad, Karimnagar, Medak, Warangal, Rangareddy and Nalgonda districts of Telangana. Besides irrigation, the project also provides provisions for drinking and industrial water supply.

For the design of underground pump-house the *in-situ* stress parameters are of utmost importance because the stability of the underground cavern gets enhanced if the long axis of the cavern is oriented along or sub-parallel to that of maximum principal stress. Hence, the scope of the work was to determine the i*n situ* stress parameters at the vicinity of underground pumphouse for its best orientation.The *In-situ* stress measurements were conducted in four zones from 10 to 70 m depth of the borehole (Fig. 8). The shut-in pressure derived from the stress plot ranged between 5.1 - 8.2 MPa and the recommended orientation of the underground cavern is N110^0.

Fig. 8: Lowering of hydraulic fracture equipment at PCILS, package no 11

2. **Determination of *in situ* stress parameters at Hutti Gold mine for the design of stopes below 20th level. (Project No.: GE-15-03):**The state owned M/s Hutti Gold Mines Limited is located to the north – Western part of the Hutti – Maski belt in Raichur district of Karnataka at latitude 16^0 11’ and longitude 76^0 39’. The main auriferous zone of the Hutti gold

mines consists of nine parallel gold bearing reefs exposed on the surface. Active mining is being carried out in six lodes over a strike length of around 1.3 Km; the parallel lodes have a general strike of NNW-SSE and dips ranging from 60^0 – 70^0 due west.Hutti gold mine has completely switched over to bulk mining method of sublevel stoping with large diameter blast hole stoping. The major thrust in this mine is to establish the depth extension of the ore zones within the existing lease. For the safe extraction and designing of the stopes at the lower levels of Hutti gold mine below 20th level, evaluating the in situ stress parameters are of utmost importance. The stability of the structure gets enhanced if the long axis of the mine workings is oriented along or sub-parallel to that of maximum principal stress.

In situ stress measurements were conducted in two horizontal boreholes at 26th level at Hutti mine (Fig. 9). The results of the investigations at Borehole no – ZI-3 are σ_v = 17.585 MPa, σ_H = 24.51±1.0521 MPa, σ_h = 16.34 ± 0.7014 MPa and the recommended orientation is $N80^0$. And the results of the investigations at borehole no OR-2 are σ_v = 22.031 MPa, σ_H = 25.635±0.8593 MPa, σ_h = 17.09 ± 0.5729 MPa and the recommended orientation is $N80^0$.

Fig. 9: Execution of Hydrofracture test at Hutti Gold Mine (26^{th} level)

3. **Determination of in situ stress parameters for the design of underground powerhouse cavern at Vishnugad Pipalkoti H.E. Project, Uttarakhand (Project No.: GE-16-03):** The Vishnugad Pipalkoti Hydro Electric project (4 x 111 MW) is located on river Alakananda in the district of Chamoli about 225 km from the nearest railhead Rishikesh. The project envisages a run of river scheme with construction of a diversion dam of 65 m height and an underground powerhouse (146 m x 20.3 m x 50 m) with installed capacity of 444 MW. The catchment of river Alaknanda extends from latitude 30^0 15' 00" N to 31^0 07' 00" N and longitude 79^0 15' 00" E to 80^0 15' 00"E.For the design of the underground openings insitu stress parameters are required. Hence, the scope of the work was to determine the in situ stress parameters at the vicinity of proposed powerhouse site for its best orientation (Fig. 10). The results of the investigations at proposed powerhouse site are σ_v = 5.97 MPa, σ_H = 8.14 MPa, σ_h = 5.43 ± 0.1447 MPa and the recommended orientation of the underground powerhouse is $N130^0$. The in situ stress investigations were carried out by NIRM during 2009 at powerhouse drift at RD 504 and 509 and the orientation of maximum horizontal principal stress was found to be N 140^o. When the central gullet of the powerhouse was completed, THDC approached NIRM to carry out stress measurement at the more or less same locations to confirm the orientation of maximum compression (σ_H).The stress orientation as evaluated at RD 75 and 78 reconfirms the orientations revealed from earlier stress measurements at RD 504 and RD 509 with slight variation of 10^0 which is more or less same. Thus it was recommended to freeze the direction of desilting chamber along N 130^o.

Fig. 10: Hydraulic fracture test under progress at BH 1 Vishnugad Pipalkoti H.E. Project

4. **Determination of insitu modulus of deformation of rock mass at the delivery main tunnels of Kaleshwaram project, Dr. BR Ambedkar PCLIS-Link II (Package-6), Telangana (Project No.: GE-16-04):** The Kaleshwaram project Dr BR Ambedkar Pranahitha Chevella Lift Irrigation Scheme (PCLIS) – Link II (Package 6) is being constructed to lift 160 TMC of water from the Pranahitha River to the Chevella reservoir. Package-6 is located in Dharmarammandal of Karimnagar district, Telangana state. For the design of the steel liner of Delivery Main (DM) tunnel, the insitu deformability parameters of rock mass are essential. The modulus of deformation of rock mass is an important engineering parameter required for the stability analysis and design of rock structures.

The measured values of insitu modulus of deformation of the rock mass conducted at DM2, DM3, DM 5, DM 7 (Fig. 11) and the deformability modulus of rock mass (E_d) ranges between 26.452 to 30.157 GPa and (E_e) ranges from 30.553 to 35.293 GPa.

Fig. 11: Complete setup of plate load equipment PCLIS Package-6

GROUND CONTROL CELL

Ground control investigation and support monitoring are essential for safe design of underground mining methods and to validate the designs, it is also essential to design safe and economic slope angels in various open pit mines. This department is actively involved in rock mass characterization, support design, strata monitoring and design of safe extraction of coal and different minerals.

COMPLETED PROJECTS

1. Design of stoping parameters for Munsar mine of MOIL ltd, Nagpur (Project No.: GC-15-06): MOIL ltd (formerly Manganese ore India limited) operates 10 mines. Out of this 7 mines are underground. Munsar mine is one of the underground mines. The mining method employed here is horizontal cut &fill. MOIL Ltd initiated a project to conduct the studies to optimize the stoping parameters for better safety and productivity at Munsar mine.

The main objectives of this study includes the following

1. Determination of Geo-mechanical properties of the area
2. Rock mass classification – Q & RMR
3. 2D stress analysis of the area
4. Design of stoping parameters and optimization of barrier/crown pillars
5. Recommendation of rock mechanics instrumentation & monitoring program

Support requirements for the proposed stope block was evaluated through empirical methods and presented. It was found that the wall rocks and the ore body have distinct strength properties and the rock mass falls in to good and fair categories. Two most popular rockmass classification system used for estimating the support requirements for the proposed stope block.

Following conclusion was drawn from the study: As per the detailed empirical design, systematic support with rock bolts with 2m spacing was recommended. Performance of the rock bolts for the proposed block was studied using numerical modeling. Requirement and the stability of the crown pillar was assessed for the proposed block empirically and with numerical modeling, and found that the 5 m thick crown pillar is highly conservative estimate even with FOS of 1.5. (Fig. 12)

Fig. 12: Arrangement of Crown pillar, in the proposed stope block (not to scale)

SLOPE STABILITY CELL

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

COMPLETED PROJECTS

1. **Slope Stability Studies at Kaliapani Chromite Mine, Kaliapani, Jajpur District, Odisha, (Project No.: SS-15-01):** M/s Balasore Alloys Ltd. is operating Kaliapani chromite mine at Kaliapani, Jajpur District, Odisha. The chromite mine is excavated by mechanized opencast method with shovel-dumper combination. The mine having 19 benches with a height and width of 8 m each and the bench angle is less than 80^0 from horizontal. The mine management requested NIRM to study the stability of the pit slopes at Kaliapani mine from the present depth of 150 m to 190 m, under critical geographical conditions like, common boundary with other operating mines in east and west directions, and two active dumps in other directions. For carrying out the slope stability analysis, strength reduction technique method was used. The analysis was carried out using the software 'FLAC/SLOPE'. In this, the factor of safety of potential failure surface is computed for different sections, and the critical failure surface is identified. The analysis was carried out for the individual pit slopes to determine the optimum bench height and slope angle, and also for the overall slopes to determine the ultimate pit slope angle. A factor of safety of 1.3 was considered for the long term stability. Based on the numerical analysis, the overall slope of critical profile towards south side with a depth of 182 m with reformed dump-3 condition found to be stable with a overall angle of 26^o under fully saturated condition with a safety factor of 1.30 (Fig. 13), and 35.5^o under fully saturated with permeation grouting condition (Fig. 14) from 70 mRL to 0 mRL (70 m) depth of workings in the pit. The overall slope of critical profile towards north side with a depth of 140 m with reformed dump-2 condition was found to be stable with a overall angle of 25.5^o under fully saturated condition with a safety factor of 1.30 (Fig. 15), and 33^o under fully saturated with permeation grouting condition (Fig. 16) from 70 mRL to 0 mRL (70 m) depth of workings in the pit.

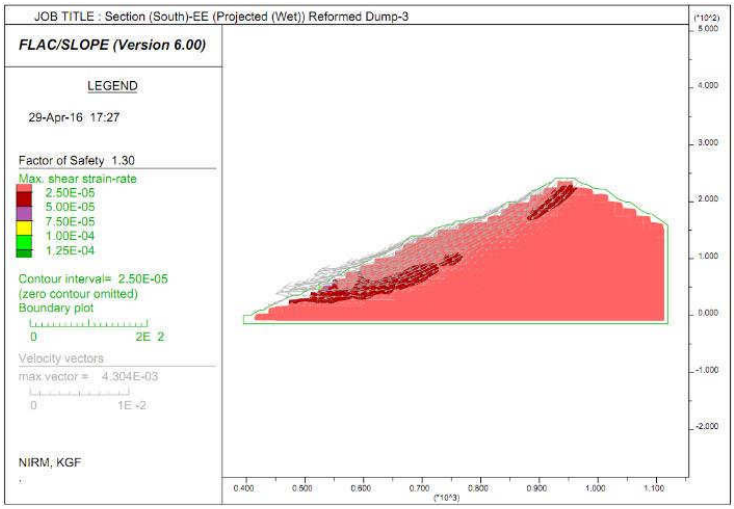

Fig. 13: Stability analysis of a critical section with reformed Dump-3 on south side

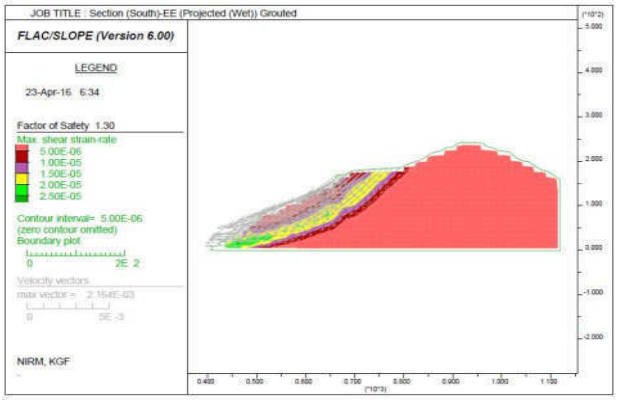

Fig. 14: Stability analysis of a critical section on south side with Permeation Grouting

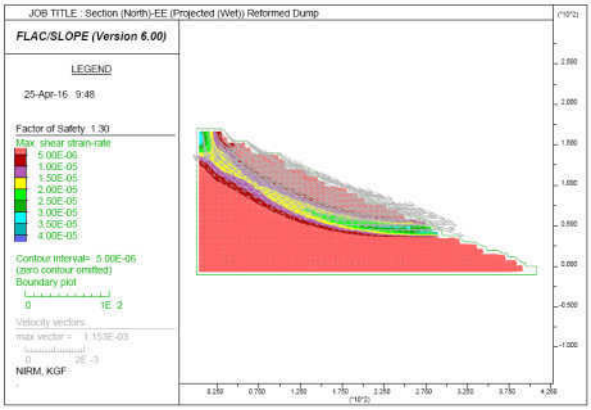

Fig. 15: Stability analysis of critical section with reformed Dump-2 on north side

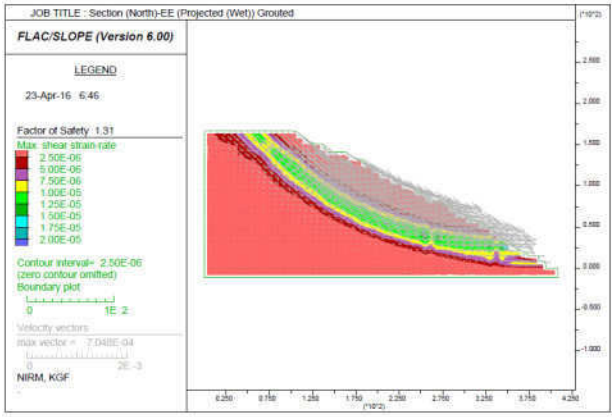

Fig. 16: Stability analysis of critical section on north side with Permeation Grouting

2. **Dump material testing and analysis of Kaliapani chromite mine at Kaliapani, Jajpur District, Odisha (Project No.: SS-15-02):** The Kaliapani Chromite Mine M/s Balasore Alloys Limited is operating the Chromite opencast mine in Sukinda valley Jajpur district, Odisha. The mine is having three dumps (Dump-1, Dump-2 and Dump-3). Dump-2 and dump-3 is located towards north and south side of the pit respectively, while dump-1 is located away from the pit and near to office. On the request of the mine management, NIRM carried out the study to determine the stability of dumps. For carrying out the slope stability analysis, large scale direct shear tests were conducted to determine the shear strength properties of dump

material and strength reduction numerical technique method was used for ascertain the stability of dump material. The analysis was carried out for individual dump slope to determine the optimum bench height and slope angle, and also for the overall slope angle. A factor of safety of 1.3 was considered for the long term stability. Based on the numerical analysis the overall safe dump slope angle for dump-1 towards north and south side under saturated condition was 35.5^0 and 36^0 respectively up to a height of 80 m (Figs. 17 & 18), and for dump-3 towards north and south side was 33^0 and 29^0 respectively up to 82 m (Figs. 19 & 20).

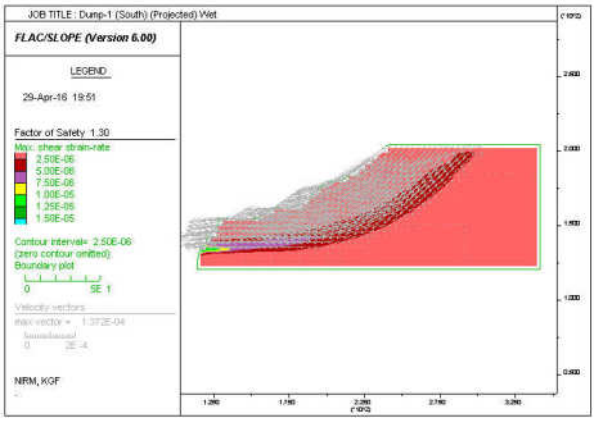

Fig. 17: Stability analysis of critical section of Dump-1 on north side

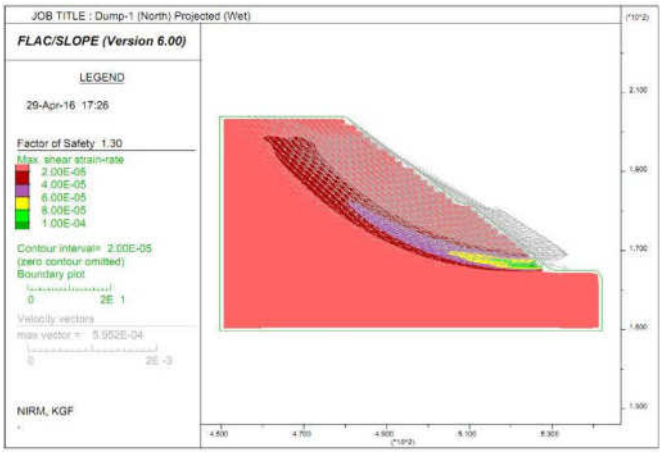

Fig. 18: Stability analysis of critical section of Dump-1 on south side

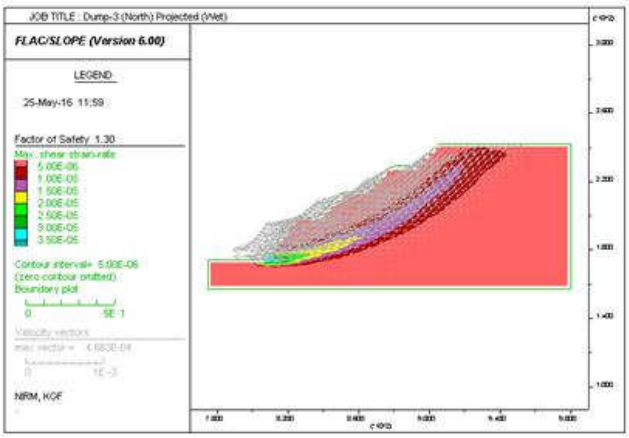

Fig. 19: Stability analysis of critical section of Dump-3 on north side

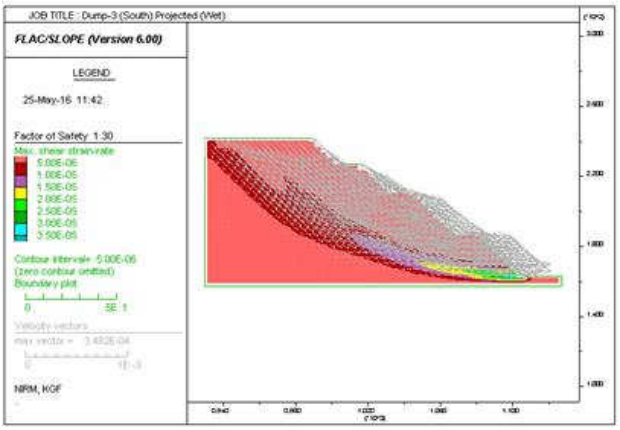

Fig. 20: Stability analysis of critical section of Dump-3 on south side

3. To review the slope stability measures at Pallava granites at Chimakurthy, Prakasam District, Andhra Pradesh of M/s Pallava Granite Industries India Pvt. Ltd (Project No.: SS-16-01): The Pallava granite industries (India) Private Limited is operating a quarry located at R. L. Puram village, Chimakurthy, Prakasam District in Andhra Pradesh. This quarry is being operated for about 20 years or so. The process of quarrying over many years has led to vertical high walls and is a cause of concern for safe working conditions. In view of this, the quarry management had earlier approached National Institute of Rock Mechanics (NIRM) in the year of 2012 for carrying out scientific studies to assess the stability of high walls at their granite quarry and to fulfill the statutory requirements related to quarrying activities with systematic and eco-friendly quarrying methods. In this regard NIRM conducted detailed field investigations in the year 2012 and submitted a report. Based on the NIRM report, the Pallava Management had taken initiatives to implement the recommendations made therein to ensure safety of the high wall for the present working depth and also efforts are underway to execute the recommendations made for mining below 60 m or so. They have also carried out significant stability measures in certain portions of the overburden by way of shotcreting etc.

Subsequently after completing some of the stabilisation measures, the mine management has requested NIRM to review the efficacy of stability measures so far carried out in the overburden portion and to suggest/recommend fresh guidelines for continuing the present production as well as the future work. A team of NIRM Scientists visited the quarry during the month of June, 2016 and reviewed the measures taken for stabilising the overburden slopes (Fig. 21).

Fig. 21: A view of overburden supported with shotcrete in Pallava granite quarry

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.

COMPLETED PROJECTS

1. Instrumentation, Monitoring and Data Analysis at Powerhouse Complex Tala Hydro Power Plant, Bhutan (Project No.: NM-15-01/NM-16-02): Tala Hydroelectric Project is a 1020 MW run of the river scheme on river Wangchu in Chukha Dzongkagh of Western Bhutan. This project work is a continuation of monitoring and analysis of the existing instruments in the Tala powerhouse complex carried out by NIRM from 2002 onwards. Currently about 150 instruments are being monitored at powerhouse complex, surge shaft and pressure shaft butterfly valve chamber. Stability of the machine hall cavern was assessed based on convergence observations of the sidewalls, load on the rock bolts and stress distribution along the length of instrumented bolts and piezometric observations in the sidewalls. Based on the analysis of the instrumentation data following observations are made

- Convergence at the machine hall cavern is continuing although at a lower rate (0.006 to 0.012 mm/day). The total convergence observed during the operational period (3816 days) varied from 23 to 44 mm.
- The caverns are undergoing time dependent deformations and stress induced deformations due to its close proximity to the Main Central Thrust.
- The failure of rock bolts is continuing as the stress redistribution is still going on in the rock mass surrounding the cavern. It may be noted that in the year 2012, there were 7 rock bolt failures in Machine Hall and 3 bolt failures in Transformer Hall Cavern, and in 2013, there were 3 rock bolts failures in Machine Hall and none in transformer hall. In 2014, 10 rock bolts have failed in Machine Hall. In 2015, 8 nos. of rock bolts failed and in 2016, 7 no in machine hall and 1 no of rock bolt in transformer hall has failed.
- Back analysis study using 3D numerical modelling conducted by NIRM indicated that more bolts are likely to fail. NIRM has installed advanced Microseismics/Nanoseismics system for monitoring the activity of the surrounding rock mass. Monitoring of the powerhouse complex and surrounding rock mass using micro-seismic monitoring will aid the assessment of the stability of the cavern in the near future.
- Minor cracks are appearing on the treated portion of earlier treated shotcrete (Between EL 515 and EL 520). DGPCL is regularly monitoring these cracks visually by using markers.

2. Analysis of Instrumentation Data of Dam, Desilting complex, Power house Complex, of NJHPS, SJVNL, Shimla (Project No.: NM-15-02/NM-16-08): 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 525m long with a cross section of 27 x 17m each separated by 46m rock pillar located at Nathpa. The instrumentation records consisted of data obtained from instruments like MPBX, piezometers, total station targets and crack meter at desilting chambers, Powerhouse complex and TRT outfall area.

The results of instrumentation data at various components is given below:

Powerhouse Cavern
The displacements at RD 160, RD 123 and RD 41 at EL 1014 on the downstream wall shows stabilizing trend currently.

- Cumulative convergence of side walls near unit 1 and unit 3 at EL 1003 was 8-9mm in 1958 days (more than 5 years).

Desilting Chambers

The piezometer at RD 150 right 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 2006. It showed pore water pressure of 2.5 to 3.0 kg/cm^2 between Jun - Sep'11. Since then it is stabilised at about 1.0 kg/cm^2 with minor fluctuations and did not show any change in pore pressure during depletion of chamber in Jul'14.

TRT Outfall

Pore water pressure measurements at seven locations indicated that pore water pressure is less than 1.0 kg/cm^2 and shows stable trend except at RD 7.5 (EL1066) and RD 25 (EL 1066), where pore water pressure was 2.57 kg/cm^2 and 1.48 kg/cm^2 respectively.

Dam

Installation of Data Acquisition System (DAS) was completed in April 2016. Data collected from SJVNL is analysed and the following observations were made:

- Analysis of the instrumentation data indicates that the values by most of the instruments are within the design limits. Although few instruments have, shown values close to or in excess of the design values, the values are not indicating any trend and are mostly random and have come back to normal values.
- Analysis of the instrumentation data have not indicated any abnormality at any of the locations represented by these instruments. This indicates normal working of the dam structure.

3. Deformation Monitoring of Underground Powerhouse Cavern of Sardar Sarovar Project, Gujarat (Project No.: NM-14-04/NM-15-05): The behaviour of underground powerhouse of Sardar Sarovar project is being monitored by NIRM since the year 2000. During construction stage, NIRM installed Magnetic Ring Multi Point Borehole Extensometers (MRMPBX), total station targets on powerhouse walls to monitor the deformations inside the cavern. During operational stage, five nos. of MRMPBX were installed from surface along centreline of the powerhouse.

The analysis of the instrumentation data for the period December 2015 to October 2016 indicated the following:

- The trend of displacement of almost all the MRMPBX's at the underground powerhouse showed stable trend.
- The displacements measured on the columns and beams were negligible and showed 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 like Ch 1516, Ch 1552 and Ch 1580 showed stable trend.

4. Support Design of Underground Surge Pool and Pump House by 3D Numerical Modelling – Pranahita Chevella Sujala Sravanthi Lift Irrigation Scheme Package-11, Telangana(Project No.: NM-16-03): M/s. Megha Engineering & Infrastructures Ltd. (MEIL), Hyderabad is constructing Surge Pool and Pump House Complex at Package-11 of the Pranahitha Chevella Sujala Sravanthi Project. NIRM designed the support for underground surge pool and pump house using empirical and 3D numerical models. 3D numerical model of Package-11 is shown in Fig. 22 & 23.

The efficacy of the proposed support system was evaluated using 3D models. Following recommendations were made to improve the stability of the caverns with permanent support system:

1. 25mm diameter, 6m long fully grouted rock bolts (Fe 500) @ 1.5m center to center staggered in the crown of surge pool and pump house along with 200mm thick SFRS or 200mm thick shotcrete with welded wire mesh.
2. 25mm diameter, 6m long fully grouted rock bolts (Fe 500) @ 2m center to center staggered in the walls of surge pool and pump house along with 100mm thick SFRS.
3. Joint surface daylighting in the walls of pump house and surge pool should be stitched with installation of rock bolts at an angle based on the site condition.
4. Controlled blasting techniques have to be adopted at site for achieving the actual profile of rock ledge. Care shall be taken such that the minimum disturbance occurs to the rock mass below the ledge.
5. Systematic instrumentation needs to be implemented and monitored during excavation to reconcile the model results.

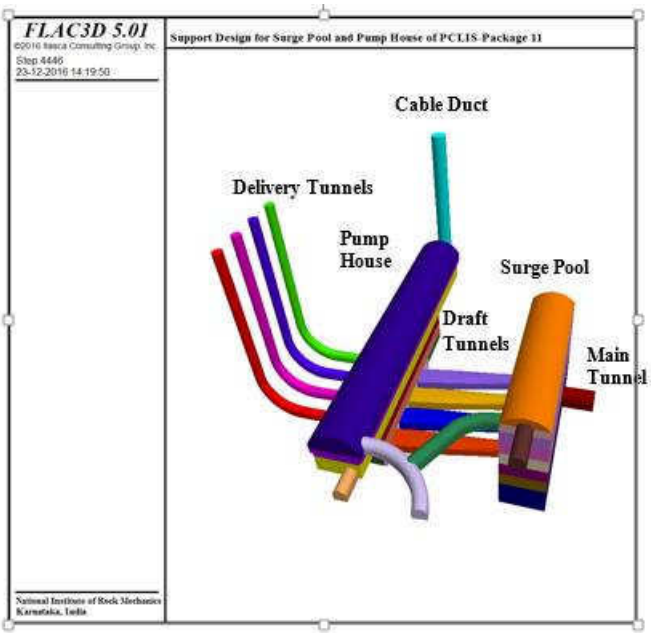

Fig. 22: 3D view of the model showing pump house, surge pool and other tunnels

Crane wheel load was applied on the concrete beam placed on the top of the rock ledge. Maximum wheel load of 72 tons (47.96 tons x 1.5 Factor of Safety = 72 tons) was applied at 8 wheel locations for a longitudinal length of 16.9m based on the wheel configuration provided by MEIL on each wall of pump house cavern to study the effect of Electrical Overhead

Travelling (EOT) crane loading on the rock ledge. It was found that the displacements were negligible after applying the crane wheel load on the rock ledge.

5. 3D Numerical modelling analysis of pump house and surge pool caverns of Pranahita – Chevella Sujala Sravanthi Lift Irrigation scheme Package-8, Telangana (Project No.: NM-16-04): M/s Megha Engineering & Infrastructures Ltd. (MEIL), Hyderabad is constructing Surge Pool and Pump House at Package-8 of the Pranahitha-Chevella Sujala Sravanthi Project. The package 8 mainly lies in granitic terrain. In this study, the behaviour of the pump house at various stages of excavation and supporting was studied using FLAC3D software. 3D continuum model was constructed with the actual geometry of the pump house, surge pool, draft tubes, cable duct, delivery tunnels and intake tunnel including the major shear zones. Fig. 24 shows view of the model showing Package-8 Complex and shear zones and Fig. 25 shows view of the shear zones showing “Slip Now” behaviour at location of the roof fall.

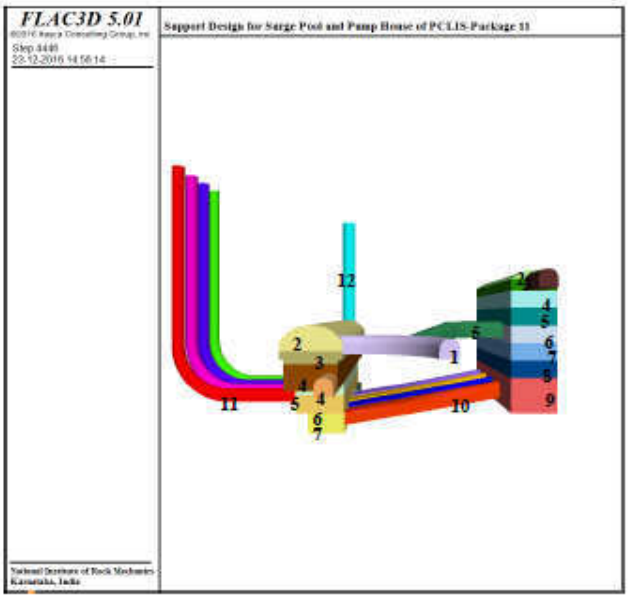

Fig. 23: Excavation sequence adopted in the model

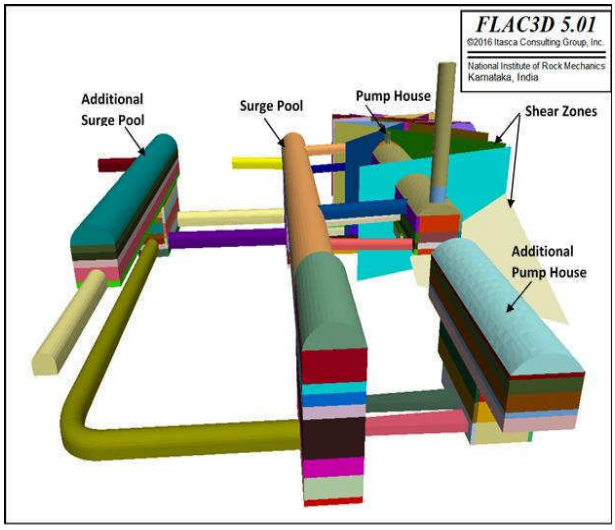

Fig. 24: 3D view of the model showing Package-8 Complex and shear zones

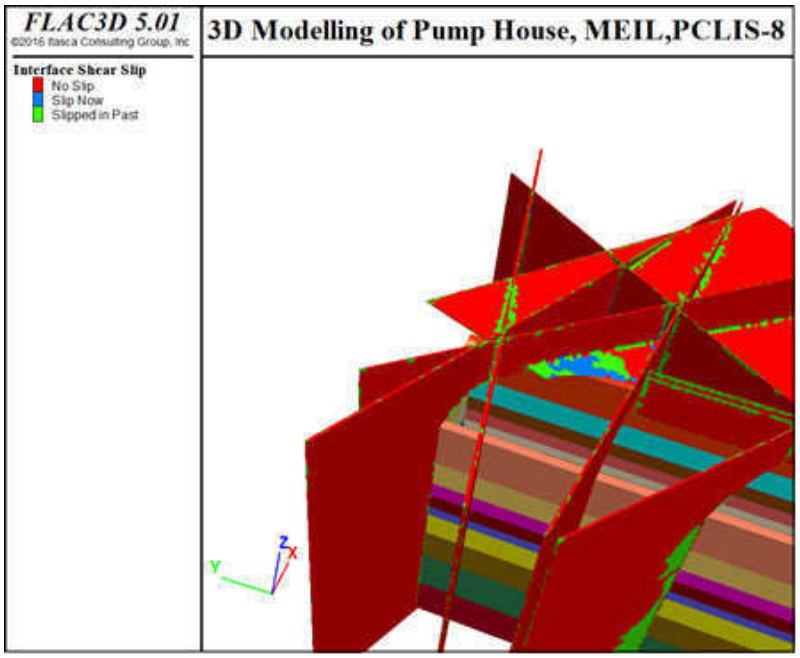

Fig. 25: 3D view of the shear zones showing “Slip Now” behaviour at location of the roof fall

Following recommendations were made to improve the stability of the caverns with permanent support system:

- Ribs, of type ISMB200, should be installed in order to provide support to concrete and to the rock in the crown. A spacing of 0.3m c/c be followed under the cavity area. The crown was found to be stable with existing rock bolts and SFRS in the numerical model in other areas of the pump house. Thus, to take care of any unexpected loose rock, ISMB200 @0.5m c/c with 1mm thick deck sheet be installed at the discretion of project authorities to ensure additional safety of men/equipment at the motor floor during course of operation. While installing ribs, contact with roof (concrete and rock, wherever applicable) be maintained throughout the length of the each rib. The cavity formed by the roof fall in the crown be filled with the concrete to form the desired shape of the crown. The voids formed after the concreting be filled with contact grouting.
- The cavity caused by the roof fall in the crown be filled by the concrete to form the desired shape of the crown. The voids formed after the concreting should be filled with contact grouting.
- Additional rock bolts of 6m length at 0.75m spacing should be installed, wherever the weaker areas are found over the rock ledge at the base of the ribs.
- Since 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.
- Model and the support system should be revised if instrumentation data differs from the model predicted results.

ROCK BLASTING & EXCAVATION ENGINEERING DEPARTMENT

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. This department 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.

COMPLETED PROJECTS

1. **Blasting guidance for removal of boulders and excavation of rock in the river channel of Idamalayar dam spillway bucket area, KSEB (Project No.: RB-15-06):** The Idamalayar dam being operated by Kerala State Electricity Board (KSEB) was constructed across the Idamalayar river. The reservoir storage is utilised for power generation and also for irrigation purpose. The spillway has been provided to pass flood discharge. Under Dam Rehabilitation & Improvement Project (DRIP), KSEB is planning to remove the boulders in the river channel beyond the spillway bucket to avoid development of non-uniform flow which may cause slippage of the river bank.

As the boulders are to be excavated close to the dam toe without causing any damage to the dam and its appurtenances, KSEB approached NIRM to conduct a scientific study and to suggest suitable blasting method. To start with, NIRM furnished a brief note incorporating the quantity of blasting materials required for conducting trial blasts. Field study was carried out during March 2016 for the removal of 100 m3 of boulders which was arranged for the trial purpose. Five rounds of boulder blasts were conducted and blast vibration were monitored by deploying four seismographs covering all the dam structures. Fig. 26 shows the blasting and monitoring of ground vibration close to dam structures. Recorded air overpressure level was within the permissible level and the ground vibration was not generated even with a minimum trigger level of 0.5 mm/s. The observed maximum flyrock distance were within 10 m.

To fragment the remaining quantity of boulders, tentative blast designs are suggested for various conditions. This report also describes the approximate quantity of explosives and detonators required for the remaining quantity of boulders.

Fig. 26: Blasting close to dam structures and monitoring of ground vibration

2. **Study on ground vibration and air overpressure due to blasting at two quarries located at Beerahalli, Oblahalli and Hulavenahalli villages (Sy. Nos. 25, 109 and 110 and QL Nos. 2554 and 2505) of Hosakote Taluk, Bangalore Rural District, Karnataka (Project No.: RB-16-01):** Scientific study on ground vibration and air overpressure was carried out in two blue metal quarries (M/s Chennakeshava Stone Crusher and M/s Mookambika Stone Crusher). Fig. 27 shows the google picture of location of quarries and surrounding villages. Twenty two blasts were monitored for ground vibration and air overpressure. Out of these twenty two blasts, twelve blasts were from M/s Chennakeshava Stone Crushers and ten were from M/s Mookambhikha Stone Crushers respectively. All the blasts monitored during the study period were safe with respect to ground vibration and air overpressure. The blast vibration data was analyzed. The suggested permissible ground vibration level is 5 mm/s for the structures located in the nearby villages of the two quarries and it was also recommended that the maximum charge per delay shall not exceed 25 kg in any of the blast.

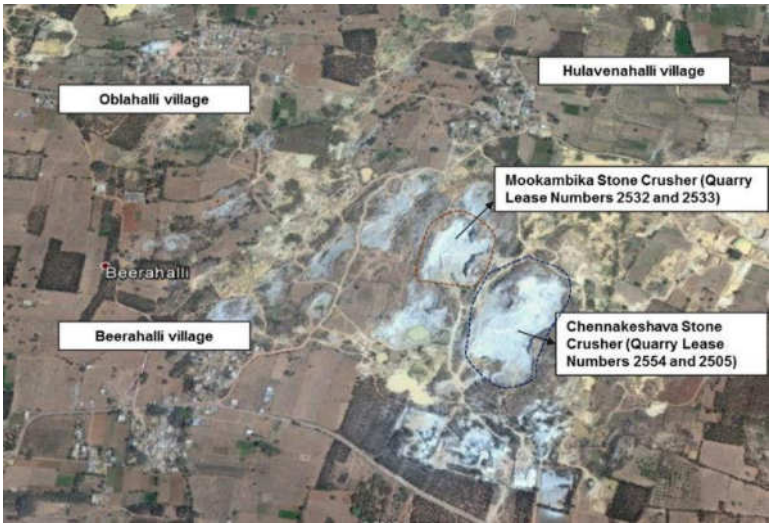

Fig. 27: Google picture showing the studied quarry and surrounding village locations

3. **Technical Advice on Rip Rap Blasting for the Construction of Earth Cum Rock Filled Dam, Indira Sagar Polavaram Project, Transstroy – JSC EC UES, Joint Venture, East Godhavari District, Hyderabad, Andhra Pradesh (Project No.: RB-13-05)**: Construction of Indira Sagar Polavaram Hydro Electric Project (960MW) is under progress in Andhra Pradesh. This project envisages construction of a 33 m high earth-cum-rock fill dam across Godavari river near Polavaram in western Godavari district to irrigate about 0.49 million hectares. 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 2454m long earth cum rock fill dam across the river, spill way with a crest level of about +25m with 48 radial gates, excavation of approach channel split channel and pilot channel to facilitate impounding of 194TMC of water and also excavation of foundation for power house, Tailrace pool and Tailrace Channel are to be constructed.

In order to maximise the output of the graded material from blasting, NIRM provided technical advice for Rip Rap blasting. Initially a method statement was submitted to Transstroy JSC EC UES Jv. NIRM assisted in establishing suitable blast designs for stable walls and sustained production with graded material. Further blast vibrations were monitored and site specific predictor equations were derived and established the permissible maximum charge per delay (Fig. 28). Safe peak particle velocities for the structures and concrete of different ages near the project site is suggested. The ground vibration attenuated below the permissible

level of vibration (10mm/s) at a distance of 450 m and fall below 1 mm/s beyond a distance of 800 m.

Assessment of fragmentation using Wip-frag was carried out for blasting at spill way area from the images taken at blast muck, at the stock yard, and random unloaded material from the dumper and overall passing percentages were arrived and presented (Fig. 29 and 30). To control the damage and to maintain the slope of the final wall rock, presplitting was carried out and the results were good.

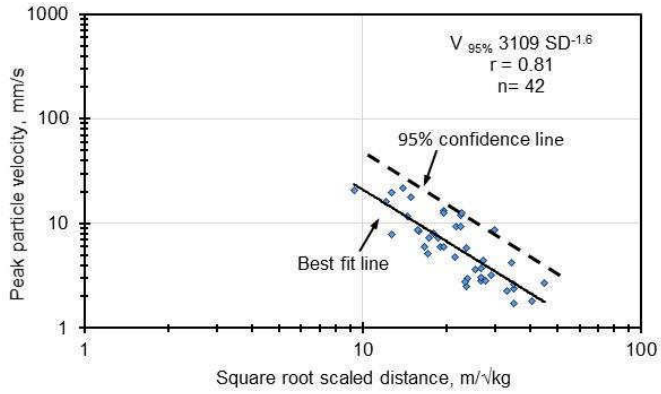

Fig. 28: Plot showing peak particle velocity versus scalded distance for Indira Sagar Polavaram project

Fig. 29: Original gray scale images for random dump

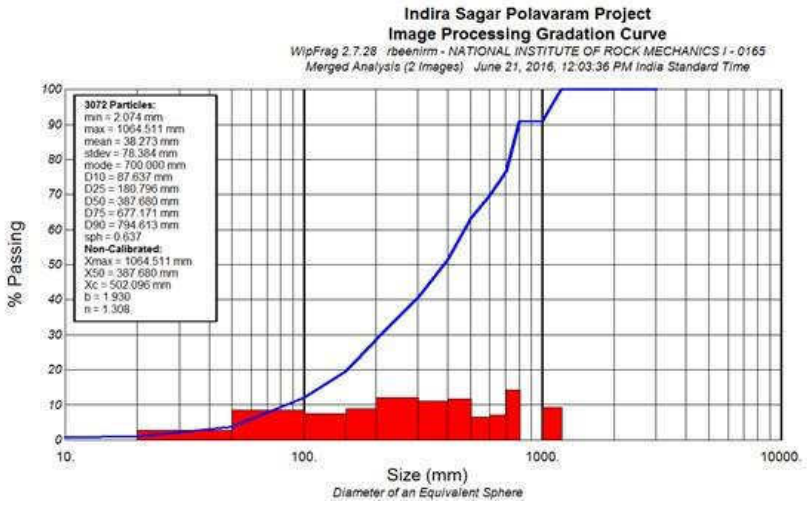

Fig. 30: Fragment size distribution (merged analysis) for random dump

4. **Study on feasibility of blasting for excavation of Tail Race Tunnel of Vishnugad Pipalkoti HEP (444MW) under Durgapur village, Chamoli, Uttrakhand, THDC India Limited (Project No.: RB-15-03):** THDC India Limited (THDCIL) is constructing a 444MW Vishnugad Pipalkoti Hydroelectric Project in Chamoli District of Uttrakhand. As part of this project, the proposed horse shoe shaped 8.8 m high tail race tunnel (TRT) had to be excavated by drilling and blasting method for a length of about 3 km. About 400 m length of proposed tail race tunnel alignment passes below a village called Durgapur with a minimum cover of about 80 m which is illustrated in Fig. 31. THDCIL had apprehensions about damages to the structures of Durgapur village due to blast vibrations from the blasts to be carried out in the portion of TRT which is located below this village. Keeping this in view, THDCIL wanted to carry out a study on feasibility of blasting for excavation of TRT and also on impact of blast vibrations on the structures located in Durgapur village.

When NIRM team reached the project site for carrying field investigation, only surface blasting for portal area was under progress. As the tunnel portion was not ready, two surface blasts were monitored to have an indication of the feasibility of blasting in the TRT and its impact on the structures of Durgapur village. Six seismographs were installed to record the ground vibration level produced from these surface blasts and the vibrations are well within the permissible limits. The safe peak particle velocity suggested for the structures of Durgapur village is 5 mm/s based on DGMS norms. The ground vibration was falling below 2mm/s beyond a distance of 80m which is same as the cover of the Durgapur village.

The recommended hole diameter is 45 mm for further excavation in surface as well as underground. The suggested maximum charge per delay is 5.5 kg. The number of holes in a blast shall not exceed 40 in any case (without vibration monitoring) as of now. Use of detonating cord and cord relays is strictly prohibited. It is opined that blast vibrations be monitored for blasts falling within 500m from any structures not belonging to the owners.

Fig. 31: Photograph showing proposed tunnel portal and Durgapur village

5. **Blast vibration study, proof checking and monitoring of blast induced vibration at nearby structures (HT line and villages), Darlipalli super thermal power project (DSTPP), Stage-I (2×800 MW), NTPC Limited, Odisha (Project No.: RB-15-05):** National Thermal Power Corporation (NTPC) is setting up 2×800 MW super thermal power project in an area of 3000 acres near Darlipalli village in Sundargarh district of Odisha State. Soil is excavated by mechanical means and the weathered and hard rock is being excavated by using high capacity rock breaker. Quantity of hard rock excavated during three months period was about 33,000 cbm only. Later, it was found that mechanical means of excavation is not feasible to remove the remaining hard rock hence drilling and blasting method was proposed

to remove the hard rock.

NIRM carried out field investigations during January 2016 (Phase-I), in which eighteen controlled blasts were designed and executed on trial basis in different DSTPP components. Ground vibration and air overpressure levels was monitored for all the blasts by deploying six seismographs. Fig. 32 depicts laying of blasting rubber mats over link mesh for restricting flyrock and the same procedure was followed for the rest of the blasts carried out near the critical structures and villages. Data was analyzed and safe permissible peak particle velocity limit of 5mm/s for surface residential structures was recommended. In Phase-II, the blast vibrations were monitored for all the ninety one blasts carried out in the site from February 2016 to September 2016 by deploying two seismograph. Blast design was reviewed whenever required. Blasts event reports of each blast was submitted to NTPC daily.

Fig. 32: Laying of blasting rubber mats over link mesh for controlled blasting

6. **Monitoring of blast induced vibration at two identified locations (Phase-III), Darilipalli Super Thermal Power Project (DSTPP), Stage-I (2×800 MW), NTPC Limited, Odisha Client: NTPC Limited, Odisha (Project No.: RB-16-04)**: NIRM had carried out phase-I field investigations and controlled blasting method of rock excavation was recommended. In Phase-II, the blast vibrations were monitored for all the ninety one blasts. Fig. 33 shows monitoring of blast vibration near switch yard area. As the blast operations continued the blast vibrations were monitored as Phase-III studies for another four months period (September, 2016 to January, 2017). During this study period, 383 blasts were monitored and the blast event reports were submitted periodically to NTPC. All the monitored blasts were safe with respect to blast vibrations and flyrock.

7. **Phase II (extension 2-4) To monitor ground vibration and air overpressure for the blast conducted to construct unit 3 & 4 of Kudankulam nuclear power plant, Kudankulam, Tamil Nadu (Project No.: RB-16-02, RB-16-03, RB-16-05 and RB-16-06):** Nuclear Power Corporation of India Limited have taken up the construction of 6 x 1000 Mwe Nuclear power project at Kudankulam and units 1 & 2 (2 x 1000 Mwe) are commissioned. The proposed units 3 & 4 (2 x 1000 Mwe) are being constructed near the existing units 1 & 2. As part of this work, about 7 lakh cubic meter of hard rock had to be excavated by drilling and blasting methods for site grading and foundation excavations so as to facilitate the construction of various civil structures. As the blasting operations need to be carried out in the vicinity of a commissioned Nuclear power plant, NIRM suggested a method statement for excavation by blasting. In order to establish the safe charge per delay for complying with the approved vibration limits, blast vibrations were monitored and the site specific predictor

equation was arrived at phase 1 study. During this period, in addition to ground vibration monitoring, all the blast designs were vetted through NIRM, which helped in ensuring the ground vibration levels were within stipulated limits. Fig. 34 illustrate blast monitoring carried out adjacent to reactor building 2. Blasts were also designed to suite the site specific conditions for special excavation like wells and pre-split blasts were demonstrated and proved for attaining stable slopes at locations suggested by the contractor.

Fig. 33: Monitoring of blast vibration near switch yard area

8. **Monitoring of machine vibration at Kadubesanahalli project, Kalyani Developers, Bangalore Client: Kalyani Developers, Bangalore (Project No.: RB-16-08**): Kalyani Developers is constructing high rise commercial buildings at Kadubesanahalli, Bangalore. The foundation excavation for some parts of the buildings were competed and construction of buildings at these locations were under progress. At some locations the foundation excavation is still under progress. While excavating these foundations, hard rock was encountered at some locations and it was planned to excavate these hard rock by deploying diamond wire saw cutting, chemical expansion compound, hydraulic splitters and rock breakers. As some private high rise buildings were located near to this hard rock, Kalyani Builders wanted to conduct a study on effect of machine vibrations on these nearby structures.

Fig. 34: Blast monitoring adjacent to reactor building 2 (Geophone buried and mike on the stand)

Vibration due to machine activities at this location was monitored. It was found that vibration due to drilling of holes and wire saw cutting are negligible even at close monitoring of 1m to 5m and vibration due to rock breaker too is well within the limits (5.81mm/s) at close distance of 8.7m and 3.67mm/s at 13m. Fig. 35 shows vibration monitoring due to jackhammer drilling and rock breaker operation. The literature review suggests that impulsive blast vibrations generated due to blasting are higher than the construction activities and the restrictions suggested for blast vibrations shall be conservative and practicable in all cases. Based on DGMS standards, a conservative permissible level of 10mm/s is suggested safe for the residential structures adjacent to Kalyani Developers.

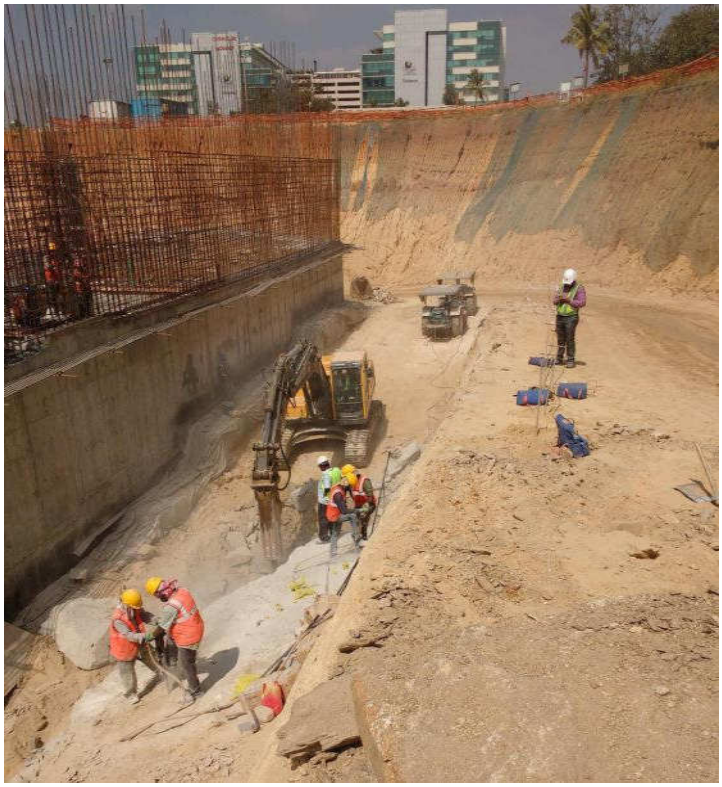

Fig. 35: Vibration monitoring due to jackhammer drilling and rock breaker operation

SEISMOTECTONIC CELL

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

ONGOING PROJECTS

1. **Evaluation of Light House Lineament related with Jaithapur Nuclear Power Plant, through trench studies, Ratnagiri, Maharashtra. (Project No.: EE-14-02):** Confirmation of the existence of the Light House lineament, which is originally identified by GSI, is being carried out by NIRM through evaluation of a 100 m long and 26 m deep trench across the suspected feature. The two sets of fractures mapped at the surface shows an acute angle between them and are traced up to 7-8 m depth. There are three types of fractures continuing in laterite. Vertical fractures are mostly in sealed condition with iron precipitate. The gentle south dipping fractures are mostly filled with clay (Fig. 36). The continuity of fractures below laterite is found as limonitic veins. The trench exposed 7-8 m thick laterite cap covering the laminated clay which is overlying the altered basalt. The contact between basalt and clay is gentle in the northern side of the trench and is gentle to steep in the central to southern side of the trench.

Deformation zones with compressive structural elements observed both in laminated clay (Fig. 37A) and laterite (Fig. 37B). The small scale movement is noticed where ever it cut across markers (Fig. 38 A&B). In the northern side of the trench a number of shear indicators are observed (Fig. 39 A&B). The preliminary observations show that the south dipping structural features indicating a near N-S strike (Fig. 40). The compilation of the further information gathered from the trench is under progress.

Fig. 36: Gentle south dipping fracture filled with clay observed in the Eastern wall of eastern trench

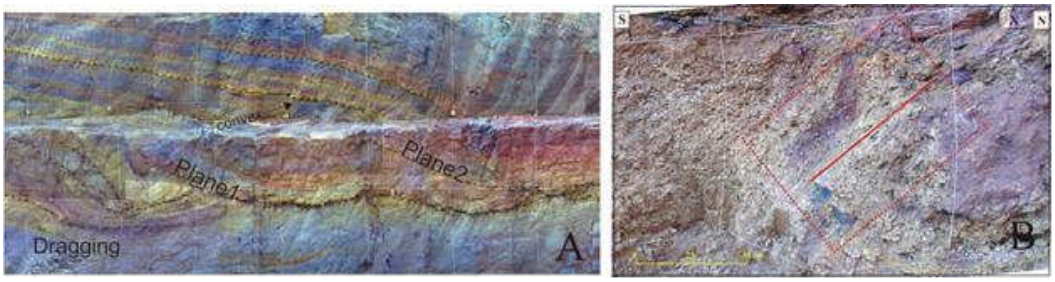

Fig. 37: Different kind of deformational observed in the western face; A bedding plane dragging and normal drag in local reverse movement within laminated clay B. Offset observed in the limonitic layer

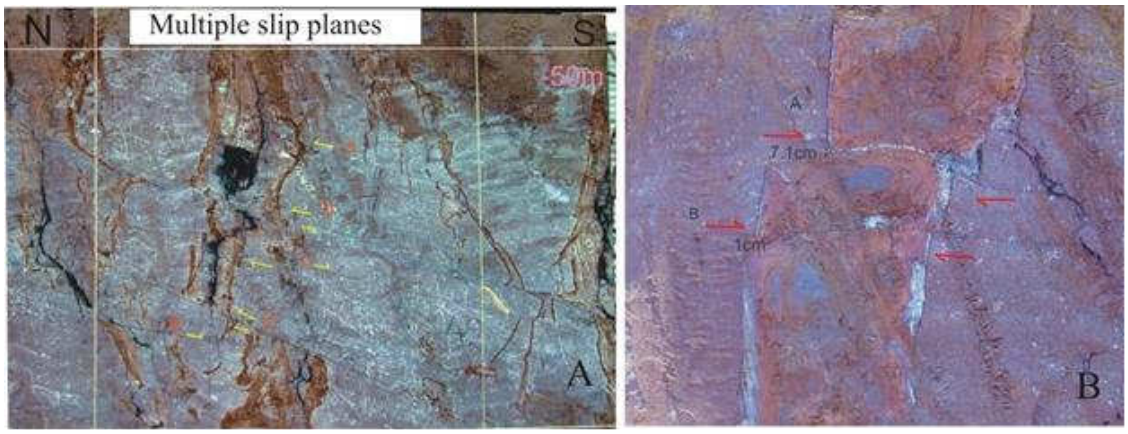

Fig. 38: Photographs showing multiple slip planes observed in the eastern wall of central trench. A) Within clay at 49 m chainage; B) observed across dyke at 55m chainage

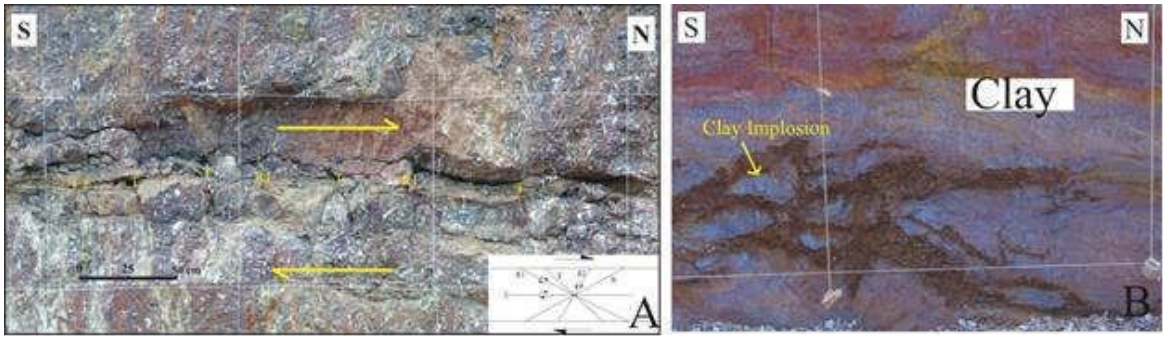

Fig. 39: Tensional structures observed in the trench A. Tensional fractures observed in the laterite; B. Angular fragment of clay observed witin the fracture zone.

Fig. 40: The red dotted line shows the general strike of the south dipping structures observed in the trench

2. **Seismotectonic Evaluation (Feasibility) of the Proposed Nuclear Power Project Site at Gugulapalli, Nellore District, Anhdra Pradesh (Project No.: ST-16-01):** The proposed Nuclear Power Project around Gogulapalli is located in the North east of Gogulapalli village near the east coast, Alluru Mandal, Sri Potti Sriramulu Nellore District. The study area falls in the seismic zone III. The rivers /nalas draining the area are Pennar river, Paideru Nala and Upputeru River. The remote sensing studies used various satellite images (LISS IV,

Cartosat, Landsat) to delineate the linear structures in the study area. The study identified 7 new lineaments, viz., N1, N2, N3, N4, N5, N6, N7 trending in different directions. In addition to these, eight more lineaments/ faults (L43, L33, L38, L39, F11, F12, F13, F14), whose existence discussed in the literature are also taken into consideration for evaluation of the area (Fig 41A). The site is located on mud flats, which is converted into salt pans and aquaculture ponds. There is indentation of sea water during high tides towards site. An emergent sand bar is seen along the open coast.

During the preliminary field investigations, it is observed that half of the study area is covered with alluvium. In the western side of the study area, the hard rock with a capping of laterite is exposed. The NE-SW trending N2 as well as F11 is identified as contact between the alluvium and laterite at the northern boundary of Pennar delta (Fig 41B). Signature of faulting is observed on northern and southern end of the lineament L43 which is described as fault in SEISAT. The F13 and F12 are identified as the faults in the geomorphic expressions (Fig 41C). Though F12 is identified as a fold in remote sensing studies, field investigation identified signature of slip along this lineament. N2 is identified as a prominent lineament on the basis of linear drainages and elongated outcrops in the field. N7 is a prominent lineament connecting geomorphic anomalies and paleochannels. The lineament N1, N4, N5, N6 does not show the clear surface indications during the preliminary field investigation. A preliminary report was submitted to NPCIL regarding these observations. Further detailed investigation for the lineaments are in progress.

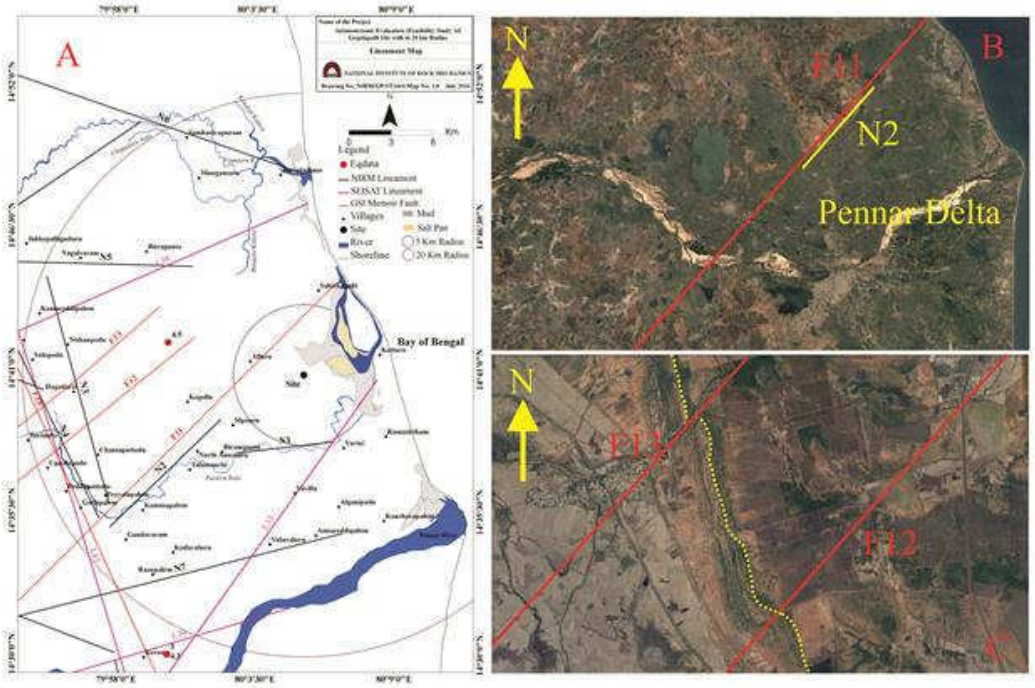

Fig. 41: A) Lineament map of the 20 km radius of the Nellore project. B) Dislocation of ridges identified in the remote sensing data along F13. C) Textural contrast observed (F11 and N2) along the northern boundary of Pennar river delta.

3. **Seismotectonic Evaluation (feasibility Study) for the Proposed Nuclear Power Project Site at Tummalapenta, Chennyapalem & Karedu, in Andhra Pradesh (Project No.: ST-16-02):** During the site selection process for NPP site in the state of Andhra Pradesh, the site selection committee has suggested three additional sites for evaluation. The proposed sites are Karedu,(located in Olavapadu Mandal, Prakasam district), Chennayapalem (located in Kavali mandal, Nellore district) and Tummalapenta (located in Kavali mandal, Nellore

district) (Fig. 42). NIRM team was involved in locating these sites along with the site selection committee. The project started only in the month of March 2017.

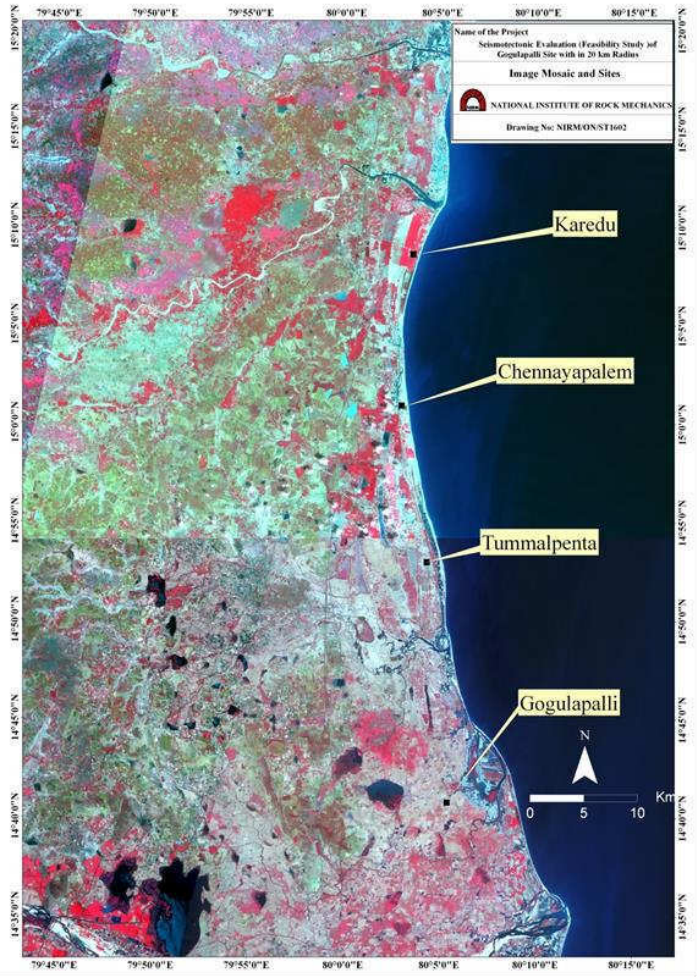

Fig. 42: Study locations in Andhra coast.

4. **Geological and geomorphic characterization of the frontal thrust fault at central and northeast Himalaya (collaborative project with JNCASR and IISc) (Project No.: EE-15-01)**: The potential threat of great earthquakes from the Himalayan sources is a major scientific and societal concern. The ongoing paleoseismological studies in the selected locations within the central seismic gap and Bhutan frontal thrusts (Fig. 43) are aimed at determining ages, sizes and the extent of the earthquake ruptures.

During this period, a trench was excavated across a south-facing scarp at Padampur, near Dholia Village, the part of southernmost fringe of the Himalaya where the foothills are in contact with the plains. As is the case with the Himalayan foothills, the sedimentary formations are made up of Upper to Middle Siwalik succession made of fluvial sediments. The trench site is located on the southern end of a ~16-km wide alluvial fan deposit which has suggested to have been faulted on the southern and northern sides. The stratigraphy exposed on the western wall of 30-m-long and 3-4-m-deep trench R1displays seven sedimentary units (Fig. 44). The bottom-most unit is an alluvial fan gravel sequence (unit 1; 2-2.5 m) composed mainly of sub-rounded to rounded cobbles and boulders (Fig. 9a). Unit 2 (0.5-0.75 m) represents thin sandy stringers with well-aligned pebbles, within unit 1.Unit 3 comprises~2-m thick massive yellowish brown fine sand with some thin linear bands of grayish sand with scattered pebbles (unit 4).Texturally, unit 5 is similar to the underlying unit 3 except that it contains scattered

pebbles and is therefore demarcated as an independent unit. Blackish silty-sand (unit 6; thickness: 0.2-0.5 m) developed at the top level on the middle part of the section partly overlies unit 3(Fig. 9b) and a thin layer of black sandy soil (unit 7) constitutes the top soil unit, present at the northern and southern parts of the section. The over thrusting of boulder bed is observed in the northern half of the trench and colluvium in the southern half of the trench. Further studies are going on.

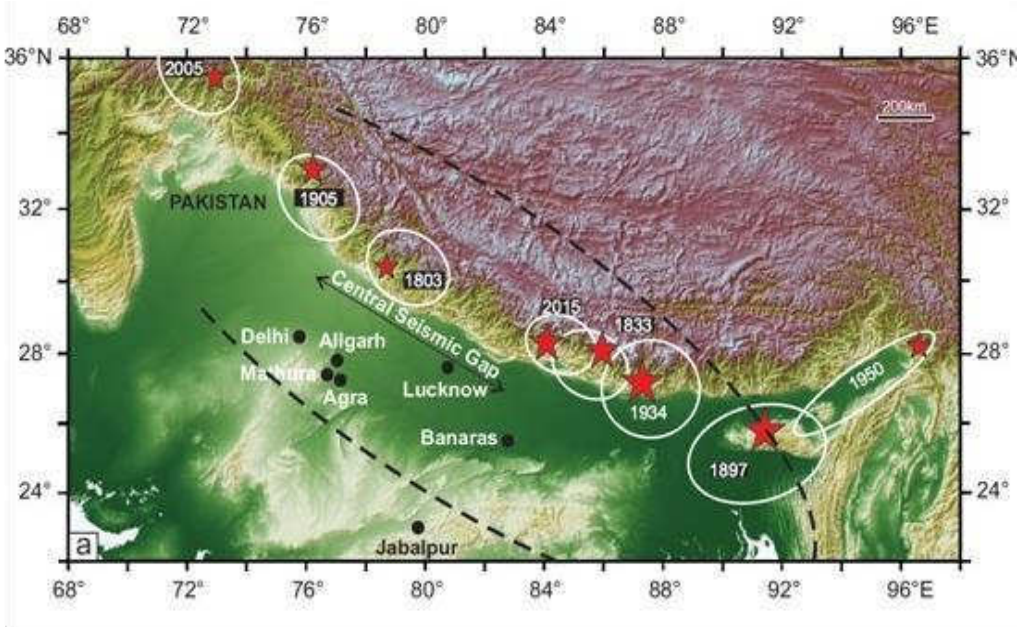

Fig. 43: Map showing locations of Himalayan earthquakes and central seismic gap

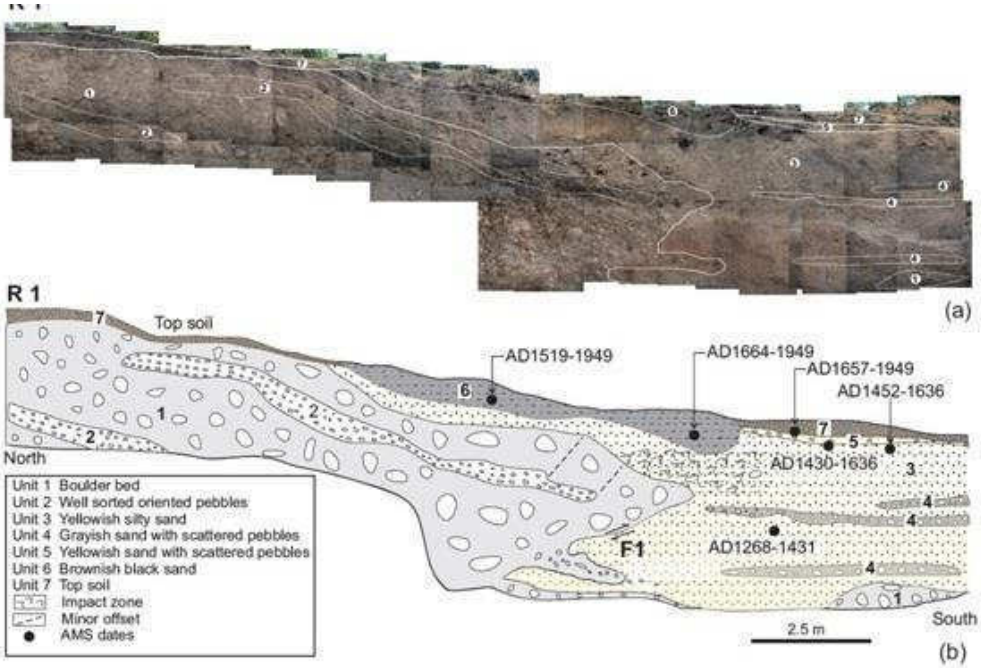

Fig. 44: Trench at Padampur a) photo mosaic of western wall; b) corresponding log deciphering different sedimentary units.

MICROSEISMICS AND ENGINEERING SEISMOLOGY DEPARTMENT

Microseismics and engineering seismology department is engaged in real time strata monitoring of the underground excavations that include hydroelectric projects, powerhouse caverns, oil storage caverns, transportation tunnels, mining tunnels, etc., using real time microseismics and online automation instrumentation systems for long-term stability assessment.

ONGOING PROJECTS

1. **Microseismic monitoring of Powerhouse cavern of THPP, DGPC (Bhutan) (Project No.: MS-16-01):** Microseismic monitoring system which was installed with sixty channels during SEP 2013 is functioning well and generating noise free high quality data. Data acquisition is round the clock and there is no interruption. The acquired data is processed, analyzed and interpreted for the strata condition of the caverns and correlated with the rockbolt failures. Conclusion made with the results indicate that the caverns strata condition is stable and that there are no noticeable stress changes. The failure of bolts could be due to their material properties and grouting method. Because bolts failures are not found related to ground movements or stress changes. The results are presented to the management are illustrated in Fig. 45 to 49.

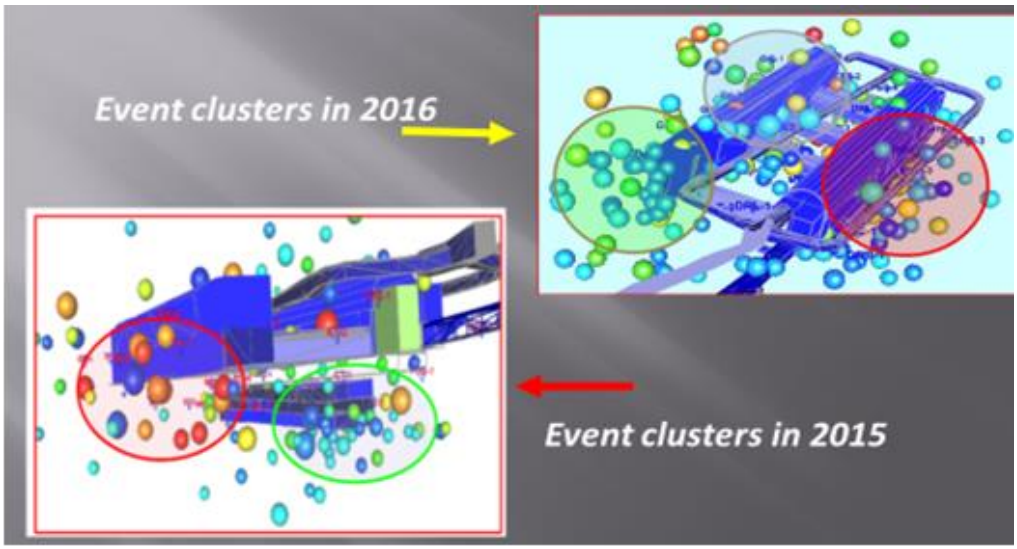

Fig. 45: Mapped microseismic events and their clusters in a course of time

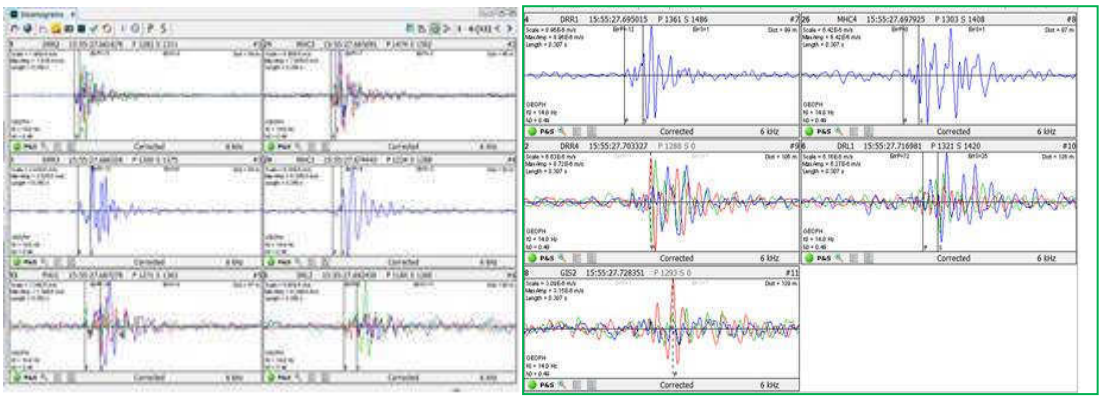

Fig. 46: Seismic signatures of the rock bolt failure and shoot out from rock

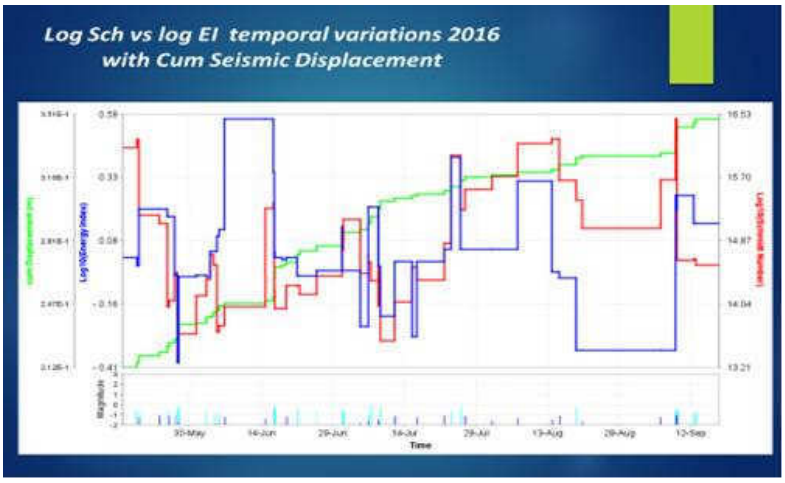

Fig. 47: Time history graph of log (Sh) vs log for March-SEP 2016 data, at THPP, Bhutan

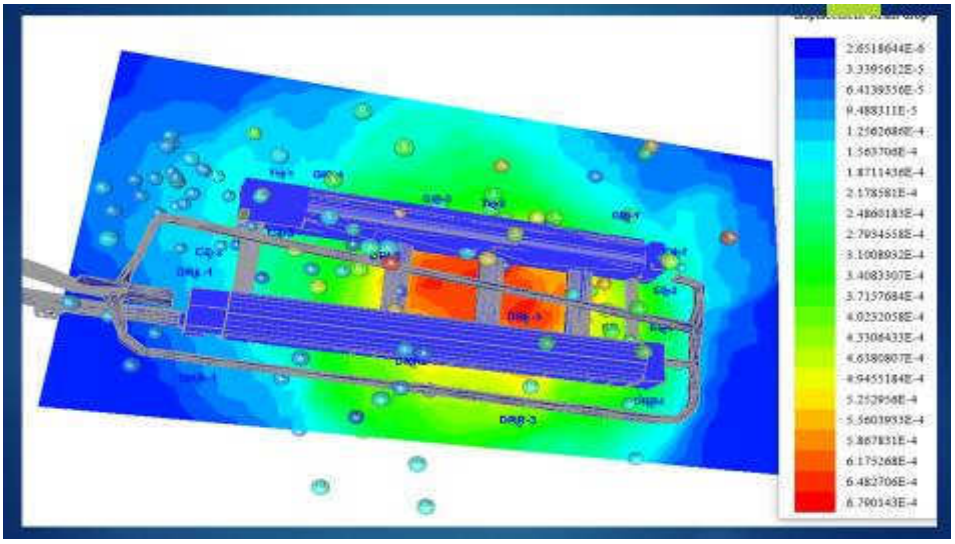

Fig. 48: Displacement counters for data from Jan- Nov 2016 of strata seismic response

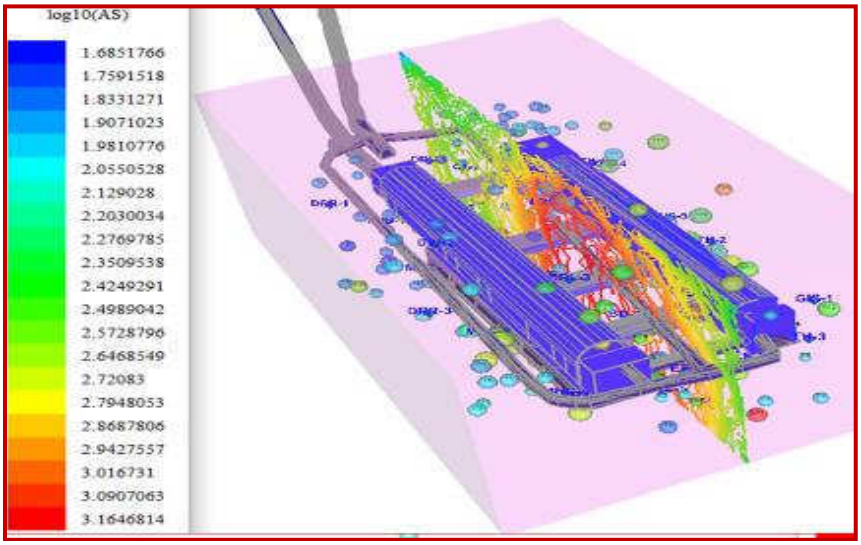

Fig. 49: Contours of Apparent stress for data from Jan-Nov 2016 of strata seismic response

Observations and conclusions:

Cavern stability:

1. The system is providing information of changes in Stresses at a micro level. It is observed that there is no noticeable stress changes and building up of new stress regions.
2. The displacement of the cavern strata (Jan-Sept 2016) shows very low value i.e. about 6.96E-4 m (6.96X10-4).
3. Minor fracture activity is observed from the inner layers of the cable tunnel and at the Junction of the bus duct 2-3. No other block movement signals were observed, this indicates the stability of the cavern.
4. Rock bolt failures examined in depth and correlated with microseismic activity to obtain precursory information.
5. All the rock bolt failures manually detected/ recorded by working staff gave the clear precursory microseismic signatures which were processed and computed. The seismic parameters indicates their magnitudes at about -1.0.
6. As per our observation the rock bolt failure can be attributed to a. Breakage of the bolt partially (May be left out portion) b. Forcible ejection of the bolt from Rock strata (time variant process).
7. Metal breakage signals are observed in about 50% of failures, precursory indications are still under observation to get the estimated time of it's failure/ ejection.
8. Some precursory signals not resulted in failures within the estimated time and some seismic failure signals recorded did not get confirmation from field staff.

2. Powerhouse caverns monitoring at Taphovan Vishnugargh Hydropower Project, NTPC limited, Utharakhand using Nanoseismics (Project No.: MS-11-01-B): Nanoseismic monitoring network designed and installed with thirty stations. The Data acquired from FEB 2016 to OCT 2017 was analysed offline only, as the data communication part was unable to obtain the dedicated link. Data acquired for the part of two-year contract was completed and the necessary reports submitted. Still the construction work at the caverns is in progress and hence a permanent room is required for installation of the system, even permanent cabling is pending. The two year contract of monitoring was completed and M/s NTPC is requested to extend the same for further period (Fig. 50 to 52).

Fig. 50: Installed Nanoseismic Instrumentation at TVHPP, NTPC

3. Monitoring Indian Shield Seismicity with 10 BBS to understand Seismotectonics of the region using V-SAT connectivity (Project No.: ES-15-01-R): DST approved is project to continue the broadband station operation from Dec 2014 for three years of duration. The Broadband station is working well and generating continuous data without any interruption. The data is transmitted to the IMD, Delhi and to NGRI through dedicated VSAT link. Data is also archived continuously and database is being prepared, stored in optical media and sent to IMD. The data is also scanned for seismic events along with mine induced rock bursts.

Strong motion accelerograph installed along with BB station is being used for recording and to study the seismicity trend and local earthquake activity for the preliminary seismic risk assessment in the BGML region. Power spectral density of Strong motion data is being analysed for obtaining response spectra of individual event for the stability/risk assessment of structures in the mining area

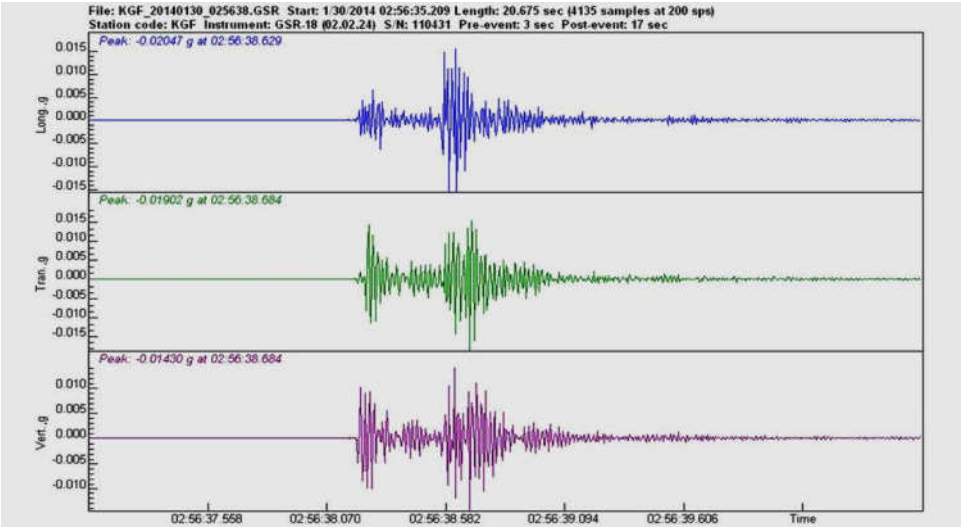

Fig. 51: Rockburst Signals recorded by SMA Unit at KGF Broad band Observatory

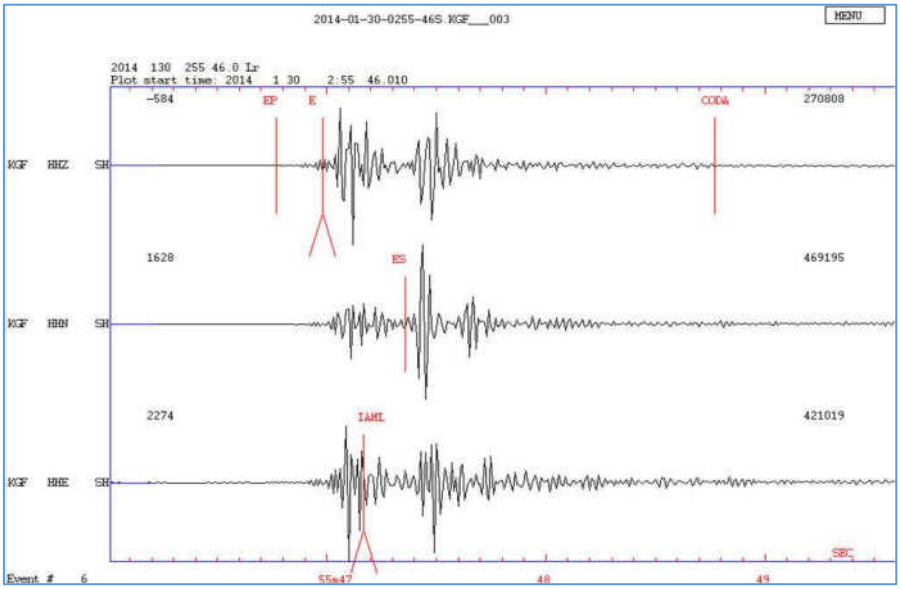

Fig. 52: Rock burst signals Recorded by Broad band Sensor at KGF Observatory

ENVIRONMENTAL AND EXPLORATION GEOPHYSICS DEPARTMENT

Environmental and Exploration Geophysics department (EEGD) works with an objective of research and application of near surface geophysical imaging and monitoring techniques to address various geo-environmental and engineering problems in our surrounding environment that is witnessing rapid development. Typical problems are like evaluation of urban planning and construction, subsurface utilities imaging, structural monitoring, and investigation for vulnerability to natural and artificial hazards like earthquake, landslide, structural degradation and subsidence. Thus, as part of the efforts to aid safety of important structures like nuclear power stations, hydroelectric projects and strategic underground structures, this department works to provide solutions related to safety and stability issues by geophysical investigations.

Estimation of seismic hazard in and around the mined-out areas of Kolar Gold Fields: (Project No.: ES-12-02) A science and technology project for estimation of seismic hazard to monitor seismic activities in and around the mined-out areas of Kolar Gold Fields to identify potential zones of hazards due the mine induced seismicity is in progress. After arrival of equipment, necessary verification, testing has been completed and subsequently work on configuration of sensors and network communications has been done (Figure 53).

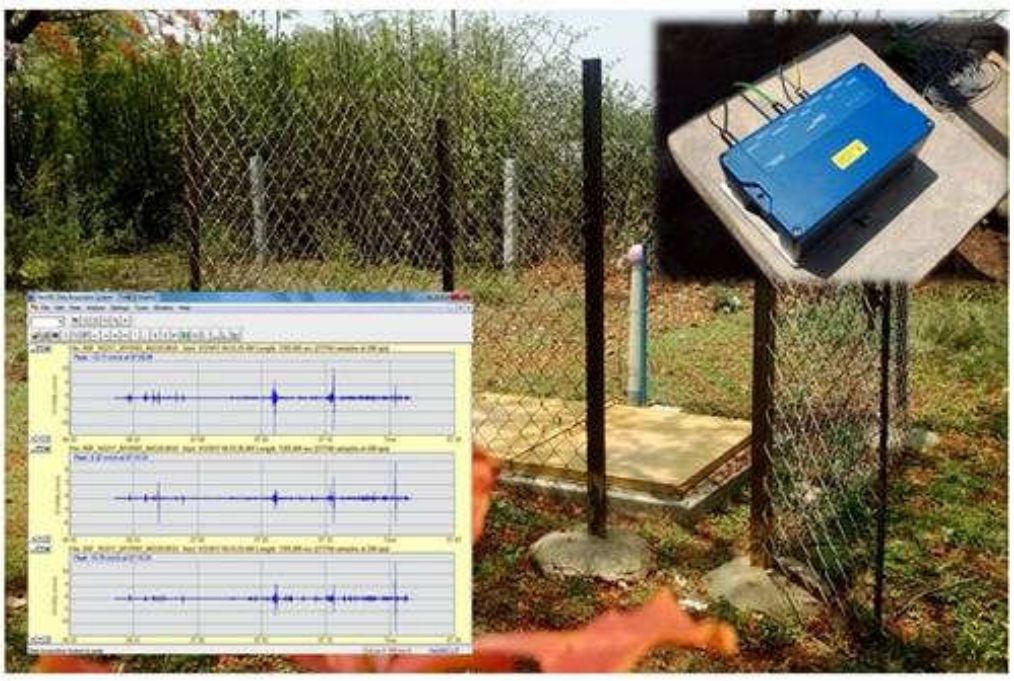

Fig. 53: Seismic station with the recording of signals as part of the seismic monitoring network

Trial monitoring including noise monitoring survey has been completed at all the sites and basic data analysis has been done. Constructions of seismic stations are in progress for housing the data acquisition modules. The sensors will be installed shortly in the identified locations for a continuous monitoring.

CENTRE FOR TESTING SERVICES - MATERIAL TESTING LABORATORY

Material Testing Laboratory (MTL) of Centre for Testing Services (CTS) is one of the most technically advanced engineering laboratories in India. It has been performing proof load tests, destructive tests and non-destructive tests for the entire spectrum of mining and allied industries throughout the country. The tests are conducted both at the project site and as well as in the laboratory. The tests conform to various ASTM and Indian standards. Based on the reports/certification, the industries get approval to use the mine machineries and extension for winding ropes to be put to continuous use for the next six months or one year. Destructive tests on steel wire ropes are carried out to determine their residual life. The fiscal year 2016-17 has witnessed the testing of 122 steel wire ropes with diameters ranging 8 mm to 51 mm.

No. of destructive tests conducted on wire ropes during 2016-17

Total no of ropes = 122												
No. of clients/companies = 16												
Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
13	07	09	05	19	15	12	14	13	07	04	04	

Apart from destructive tests, Material Testing Laboratory is also providing services in the field of non-destructive tests. During the financial year 2016-17, twelve NDT projects were taken up.

1. Non-destructive tests for M/s Arulmigu Dhandayuthapani Swamy Thirukkoil, Palani, Tamil Nadu (Project No.: ND-16-10-C): M/s Arulmigu Dhandayuthapani Swamy Thirukkoil (ADST) is located in the town of Palani in Dindigul district, Tamil Nadu. The temple is at a distance of 290m from the base station. It is operating three man riding haulage winches through which the devotees travel from the base station to the hill temple. As a statutory requirement the winches and all their associated vital components should be periodically evaluated for their fitness. As NIRM has the capability and expertise to carry out the Non-destructive evaluation of winches, M/s ADST requested Non-destructive testing of winches and associated components.

During May 2016, non-destructive tests such as magnetic particle test and ultrasonic tests were conducted on rope socket, socket pin (bolt & nut) and link set bolt at NIRM lab (Fig. 54).

Fig. 54: NDT on rope socket, socket pin & link set at NIRM lab, M/s ADST.

The test results indicated that the tested components were free from surface, sub-surface and internal flaws.

During March 2017, NIRM team visited the project site to conduct NDT (Fig. 55) on:

- 80HP winch vital components, bogie attachments and wire rope.
- 60HP winch vital components, bogie attachments and wire rope.
- 110HP winch vital components, bogie attachments and wire rope.
- Material trolley attachments.
- Spare rope socket, socket pin (bolt & nut) and link set bolt.

Fig. 55: NDT on winch vital parts, bogie attachments & wire ropes, M/s ADST.

2. In-situ non-destructive tests for M/s Hindustan Zinc Limited – Rajpura Dariba Mines and Zawar group of mines, Rajasthan (Project No.: ND-16-1A-C): M/s Hindustan Zinc Limited (HZL) is the second largest zinc producer in the world. It operates different mines; which include Rajpura Dariba mine situated at Dariba and Zawar group of mines located in Udaipur district, Rajasthan. The safety of operations is of prime importance and the Director General of Mines Safety (DGMS) has set out guidelines for testing the winders and its associated components. As NIRM has the proficiency to carry out the Non-Destructive Tests (NDT) of mine machineries, M/s HZL requested Non-Destructive Testing (NDT) to be conducted on winders and associated components for a period of two years.

a) Rajpura Dariba Mines: It is an underground mine with two vertical access shafts (Main shaft and Auxiliary shaft). NDT was carried out using MPT and UT on winder vital components and suspension gear parts (Fig. 56) of the following winders:

- 236kW cage winder at Main shaft
- 740kW skip winder at Main shaft
- 225kW cage winder at Auxiliary shaft

Fig. 56: NDT on winder vital components & suspension gear parts, Rajpura Dariba Mines, M/s HZL.

The NDT results on winder vital components and suspension gear parts indicated that they were free from surface, sub-surface and internal flaws.

The wire ropes in operation were also subjected to NDT using wire rope defectograph (Fig. 57). The inspected wire ropes include:

- Ø32mm FLC cage ropes – 2 Nos. at Auxiliary shaft.
- Ø18mm FLC cage ropes – 5Nos. at Main shaft.
- Ø24mm FLC skip ropes – 4Nos. at Main shaft.

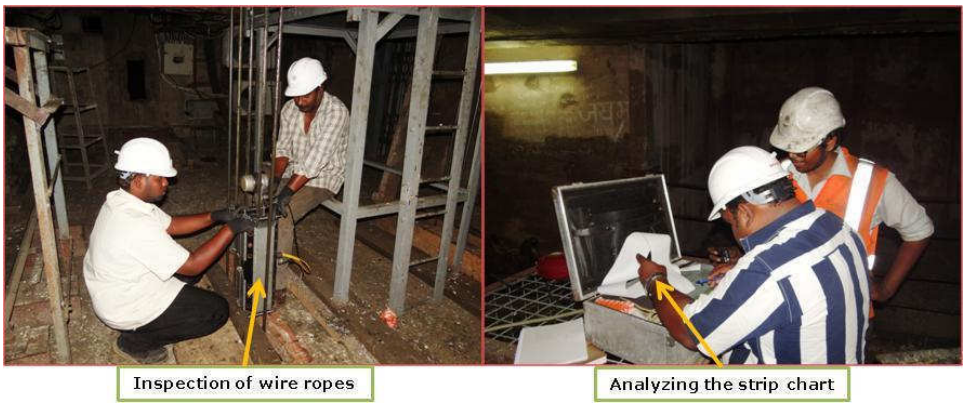

Fig. 57: Inspection of wire ropes, Rajpura Dariba mines, M/s HZL.

The observations that were made during tests on the wire ropes were;

- The cage rope at Auxiliary shaft indicated wear throughout its length.
- The N1 skip rope at Main shaft indicated an isolated fatigue crack at a distance of 310m to 360m from the cappel end.

The scanned length of other ropes: counter weight side rope at Auxiliary shaft, cage ropes (E1, E2, E3, E4 & E5) and skip ropes (N2, N3 and N4) at Main shaft revealed that there were no anomaly and they were also free from local faults (LF) such as pitting, corrosion and broken wires and there was no loss of metallic cross-sectional area (LMA).

b) Zawar Group of Mines (Project No.: ND-16-1B-C): Zawar Group of Mines comprises of four mines namely Balaria mine, Zawar Mala mine, Central Mochia mine and West Mochia mine. NDT was conducted on vital components of the winders and suspension gear parts (Fig. 58) of the winders:

- 383HP cage winder at Balaria mine.
- 560HP skip winder and 70HP cage winder at Zawar Mala mine.
- 236HP cage winder at West Mochia mine.
- 400HP skip winder and 200HP cage winder at Central Mochia mine.

Fig. 58: NDT on winder vital components & suspension gear parts, Zawar Group of Mines, M/s HZL.

The test results indicated seven surface cracks on the chain links of skip-B suspension gear assembly at Zawar Mala Mine during April 2016 visit. The defective chain links were:

- 3rd, 13th and 35th link on North-West side chain.
- 17th, 18th and 23rd link on North-East side chain.
- 16th link on South-West side chain.

It was recommended to replace the chain links. The test results of other components indicated that they were free from surface, sub-surface and internal flaws.

There are 17Nos. of wire ropes at Zawar Group of Mines used for men and material hoisting. The wire ropes were subjected to defectograph tests (Fig. 59). The details of the tested wire ropes are as follows:

- Ø32mm FLC cage ropes – 2Nos. at Balaria mine.
- Ø16mm FLC cage ropes – 2Nos. at Zawar Mala mine.
- Ø30mm FLC skip ropes – 2Nos. at Zawar Mala mine.
- Ø20mm FLC cage ropes – 3Nos. at West Mochia mine.
- Ø24mm FLC skip ropes – 4Nos. at Central Mochia mine.
- Ø16mm FLC cage ropes – 4Nos. at Central Mochia mine.

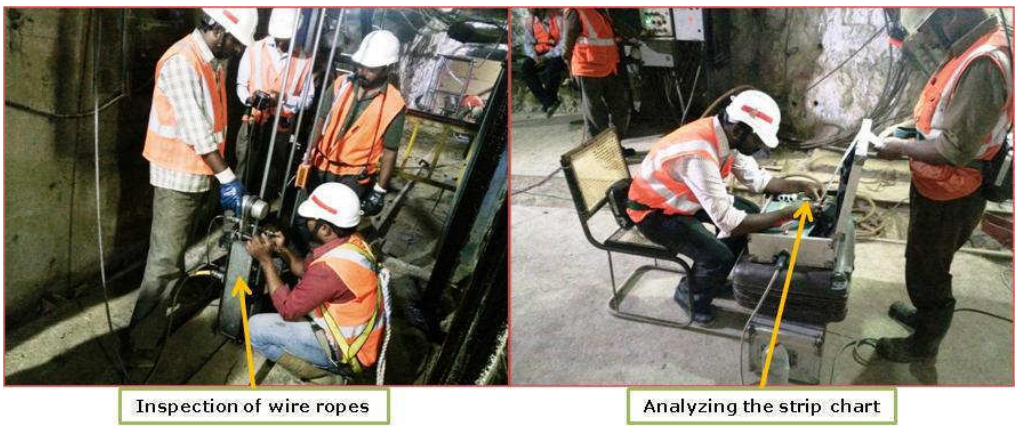

Fig. 59: Inspection of wire ropes, Zawar group of mines, M/s HZL.

The test results revealed an isolated fatigue crack on N1 rope at West Mochia Mine which lies between 148m to 192m from the cappel end. The scanned length of other ropes indicated that there were no anomaly and they were also free from local faults (LF) such as pitting, corrosion and broken wires and there was no loss of metallic cross-sectional area (LMA).

3. In-situ non-destructive tests for M/s Shaft Sinkers Mauritius – Rampura Agucha Mines, Rajasthan (Project No.: ND-16-03-C): M/s Shaft Sinkers Mauritius (SSM) has undertaken shaft sinking operations at Rampura Agucha Mines of M/s Hindustan Zinc Limited. As a statutory requirement the equipment/components/ropes used for sinking operations has to be periodically evaluated for their fitness. As NIRM has the expertise and capability, a MoU for a period of three was signed between M/s SSM and NIRM for providing test services.

NDT such as magnetic particle tests and ultrasonic tests were conducted (Fig. 60) to determine surface, sub-surface and internal flaws on:

- Dymot winch vital parts (9Nos.) at South Ventilation Shaft.
- Stage attachments at South Ventilation Shaft.
- 5200HP kibble winder vital components and kibble attachments at Main Shaft.
- 190kW stage winder vital parts at Main Shaft.

Fig. 60: NDT on winder/winch vital components & kibble attachments, M/s SSM.

The NDT results on winder/winch vital components, stage attachments and kibble attachments signified that they were free from surface, sub-surface and internal flaws.

Wire rope defectograph studies was carried out to determine the local Faults (LF) such as pitting, corrosion, broken wires and Loss of metallic cross-sectional area (LMA) on:-

- Ø24mm RHL winch ropes – 6Nos. at South Ventilation Shaft.
- Ø48mm multi-strand kibble ropes – 2Nos. (Underlay & Overlay) at Main Shaft.
- Ø44mm multi-strand stage winder ropes – 5Nos. at Main Shaft.

The winch ropes and kibble ropes were made to run through the magnetic head of the wire rope defectograph that is placed in a stationary position. The rope is passed through the magnetic head at a constant speed while the actual condition of the rope gets coded on the strip chart recorder (Fig. 61).

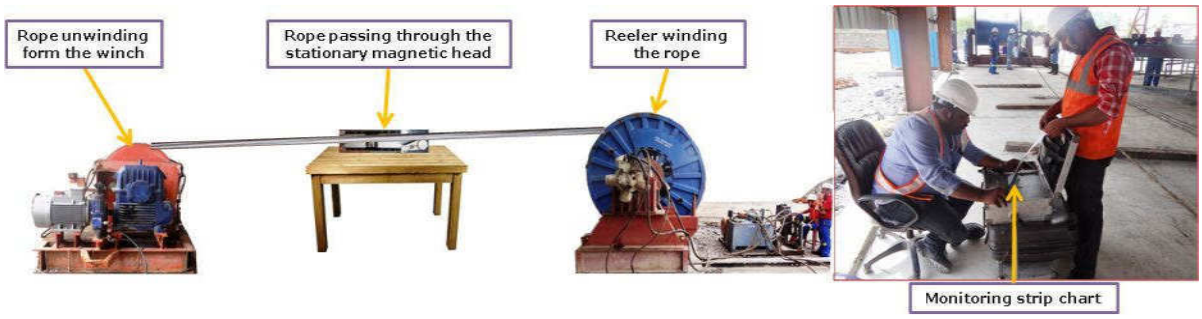

Fig. 61: Testing of winch ropes & kibble ropes, M/s SSM.

For testing the stage ropes, special steel frames were fabricated at site to carry out defectograph studies. The arrangement facilitated the movement of magnetic head throughout the length of stage rope which was stationary (Fig. 62).

All the tests were completed successfully and the results have been evaluated. Based on results obtained on winder/winch vital components and kibble attachments, it was concluded that they were free from surface, sub-surface and internal flaws. The scanned length of all the dymot winch ropes (6Nos.) revealed that they were free from local faults (LF) such as pitting, corrosion and broken wires and also there was no loss of metallic cross-sectional area (LMA). Analysis of the tests conducted on wire ropes of stage winder rope (ϕ44mm) at Main Shaft, indicated few isolated fatigue cracks and also wear were noticed at the regular intervals of the ropes.

Fig. 62: Testing of stage winder ropes, M/s SSM.

4. In-situ non-destructive tests, proof load tests and wire rope defectograph studies on EOT cranes, monorail hoists, chain blocks, electric winch & hydraulic jacks for M/s National Mineral Development Corporation Limited (OCSL Plant), Chhattisgarh (Project No.: ND-16-02-C): M/s National Mineral Development Corporation (NMDC) Limited is owned by the Government of India and is under administrative control of Ministry of Steel. It is involved in the exploration of iron ore at Bailadila Iron Ore Mine (BIOM), Bacheli complex, Chhattisgarh. The mined out ore is transported through conveyor belt system to Ore, Crushing, Screening& Loading (OCSL) plant at various locations. As per the DGMS guidelines, non-destructive test, proof load test & wire rope inspection has to be carried out periodically on mine equipment to ensure fitness and safe operations. In view of this M/s NMDC Limited requested M/s NIRM to conduct the required tests on the equipment operating in its OCSL

plant at Bacheli complex. Accordingly NIRM team visited the project site to take up the NDT works.

Non-destructive tests such as visual inspection, magnetic particle test and ultrasonic tests were conducted on EOT cranes, monorail hoists, chain blocks and electric winch. Proof load test was conducted on EOT cranes and hydraulic jacks. Wire rope inspection was carried out on the hoist ropes using wire rope defectograph (Fig. 63).

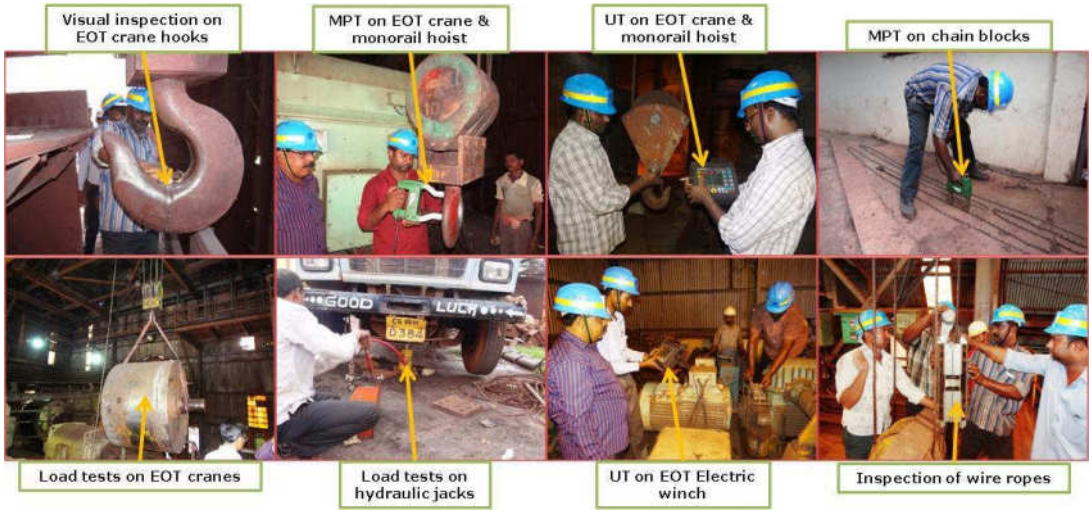

Fig. 63: NDT, proof load tests and wire rope defectograph studies on EOT cranes, monorail hoists, chain blocks, electric winch & hydraulic jacks, M/s NMDC, OCSL Plant.

The results and observations made after the field investigations of the plant equipment are detailed below:

a) Visual inspection: Inspection of the 15nos 30t EOT operational cranes revealed that 3 of the crane hooks at the following locations had deep wear:

- Primary crusher plant, Auxiliary hoist, (CP-1).
- Secondary crusher plant, Main hoist, (CP-1).
- Tertiary crushing plant, Main hoist, (SP-1).

b) Magnetic particle test: Following were the defects noticed during the magnetic particle inspection on chain pulley blocks:

- . Two chain links of 1t capacity chain pulley blocks at CP-1.
- One Fatigue crack on 1t capacity chain pulley blocks at SP-1.
- One chain link of 3t capacity chain pulley block was found to be welded

The test results on other EOT cranes, monorail hoists, chain pulley blocks and electric winches indicated that they were free from surface and sub-surface flaws.

c) Ultrasonic test: From the scanned test results, it was observed that all the tested components of EOT cranes, mono rail hoists, electric winches and hydraulic jacks were free from internal flaws.

d) Wire rope defectograph studies: The test results of wire rope inspection indicated 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).

e) Load test: The load test results on EOT cranes and hydraulic jacks revealed that they did not undergo any deformation and also the components sustained the proof load.

5. In-situ non-destructive tests for M/s Hindustan Copper Limited, Rajasthan (Project No.: ND-16-04-C): M/s Hindustan Copper Limited (HCL) is a public sector under the administrative control of the Ministry of Mines. It has the distinction of being the nation's only vertically integrated copper producing company as it manufactures copper right from the stage of mining to beneficiation, smelting, refining and casting of refined copper metal into downstream saleable products. The ore is extracted at different prominent belts which include Khetri and Kolihan mines. The operations at these mines are carried out through shafts run by winders. As a statutory requirement, the winders and all their associated vital components should be periodically evaluated for their fitness. As NIRM has the capability and expertise to carry out the Non-destructive evaluation of winders, M/s HCL requested non-destructive testing of winders and associated components at Khetri and Kolihan Mines.

Ultrasonic tests on the winder vital components and suspension gear parts and wire rope defectograph studies were carried out (Fig. 64) of the following winders.

- 1600kW cage winder vital parts, suspension gear parts and Ø51mm langslay cage ropes (2Nos.) at service shaft of Khetri Mine.
- 2870kW koepe skip winder vital parts, suspension gear parts and Ø25mm FLC skip rope (1No.) at production shaft of Khetri Mine.
- 400kW cage winder vital parts, suspension gear parts and Ø32mm cage rope (1No.) at Kolihan Mine.
- 800HP koepe skip winder vital parts, suspension gear parts and Ø24mm FLC E2 skip rope (01No.) at Kolihan Mine.
- Ø16mm FLC rope at '0' MRL (01No.) at Kolihan Mine.
- Ø19mm FLC rope at 184MRL (01No.) at Kolihan Mine.

Fig. 64: NDT on winder vital components, suspension gear parts and wire ropes, M/s HCL.

Based on the tests conducted on winder vital components and suspension gear parts, it was concluded that all the tested components were free from internal flaws. Non-destructive tests conducted on the wire ropes of West side cage rope at service shaft of Khetri Mine indicated an isolated fatigue crack at a distance of 145m to 170m from the cappel end. The test results of other wire ropes revealed that there were no anomaly and they were also free from local faults (LF) such as pitting, corrosion and broken wires and there was no loss of metallic cross-sectional area (LMA).

6. In-situ non-destructive evaluation on cable belt drive ropes for M/s National Aluminium Company Limited, Damanjodi, Odisha (Project No.: ND-16-06-C): M/s National Aluminium Company Limited (NALCO) a public sector enterprise under the Ministry

of Mines produces Aluminium. NALCO's bauxite mine located at Panchpatmali hills in Koraput District of Odisha State. Alumina refinery plant of the company is situated at Damanjodi which is 15km from the Panchpatmali bauxite mines. The mined bauxite is transported to refinery plant by a 14.66km long single flight multi-curve 1,800 tonnes per hour (TPH) capacity cable belt conveyor. The contour path of the belt conveyor is directed by metallic deflection pulleys through two wire ropes (Left hand side and Right hand side). These ropes have to be periodically checked for their fitness. Considering NIRM's capability and expertise to carry out the non-destructive evaluation, M/s NALCO requested NIRM to evaluate the operational cable belt drive ropes.

The length of each rope (left side and right side) is 30km, which is made up of five ropes measuring 6km each and joined (spliced). Wire rope defectograph studies were carried out on the cable belt drive ropes and the scanned strip charts were analyzed (Fig. 65).

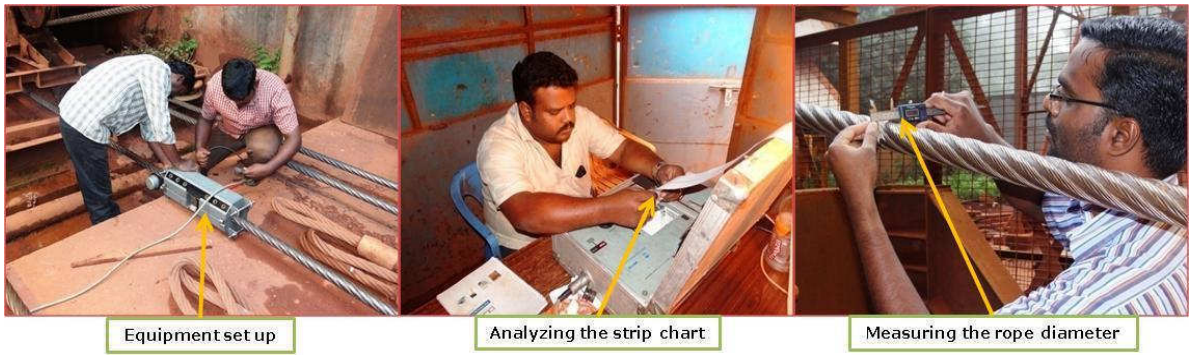

Fig. 65: Inspection of cable belt drive ropes, M/s NALCO.

Based on the tests carried out on the cable belt drive ropes (Left and Right sides), it was concluded that:

- Fatigue cracks have developed on the Left side rope that was replaced during April 2015. Few broken wires were also noticed.
- The left side rope was found to have uniform wear throughout the length of rope.
- On the right side rope, one new splice (Orange splice) was identified between Green and Yellow splice which lies at a distance of 526m from the Green splice.
- The right side rope was found to be deteriorated and characterized with excessive wear. A large number of isolated fatigue cracks and few broken wires were noticed.
- The percentage reduction in diameter of left side rope is 5.45% and that of right side rope is 6.98%. As the reduction in diameter of both the ropes is well below 10%, the ropes can be continued to be put to use as per discard criteria.
- In general, the right side rope has undergone excessive wear clubbed with isolated fatigue cracks and few broken wires throughout its length.
- It was recommended to subject the ropes to periodic tensile tests to know the minimum breaking force. Therefore it was recommended to subject specimen samples of the rope from every spliced region of left and right side to tensile test at NIRM.
- It was recommended to introduce non-metallic liners on the deflection pulley grooves to reduce excessive wear.

7. In-situ non-destructive tests of Aerial ropeway and drive system at Jakhu ropeway, M/s Jagson International Limited, Shimla, Himachal Pradesh (Project No.: ND-16-07-C): Jakhu ropeway is an integral part of M/s Jagson International Limited (JIL). Jakhu cable ropeway was proposed to join Jakhu temple with the downtown covering nearly 400m at Shimla city, Himachal Pradesh. Before opening the ropeway system to the general public, M/s JIL wanted the aerial ropeway system to be subjected to Non-destructive Tests (NDT). As

NIRM has the capability and expertise to carry out the Non-destructive evaluation on aerial ropes and the drive systems, M/s JIL requested NIRM to take up NDT on aerial ropeway system. Accordingly, NIRM team visited the project site and conducted the required tests.

Various NDT techniques were applied to study the integrity of the ropeway system. Initially Visual inspection of wire rope was carried out to determine the Loss of metallic cross-sectional area. It was followed by load test on the cabins, for which the cabins were loaded with a known weight of 0.495t (Maximum allowable load), and a trial run was taken. During this process, the system was stopped at a fussy point where the cabins meet at the midway. In load condition the whole system was dwelled for a particular period of time and the critical components of the system were scanned using thermal imaging camera to locate the stress raised zones. Simultaneously the vital components of the drive and driven system were subjected to ultrasonic tests to determine the internal flaws. Finally the wire rope was tested using wire rope defectograph (Fig. 66).

Fig. 66: NDT on aerial ropeway system, M/s JIL.

The test results and conclusions drawn are specifically to determine the condition of the wire rope and vital components of the drive system. Based on the tests conducted, the following were inferred.

- **Visual inspection:** Based on the diameter measured at various points on the wire rope, it was found that the reduction in diameter was about 0.3%. Since the reduction in diameter is well below 10%, the rope can be put in to use.
- **Load test:** The scanned images using thermal imaging camera on loaded condition of the system indicated that have no thermal anomaly.
- **Ultrasonic tests:** The tested vital components were found to be free from internal flaws.
- **Wire rope defectography:** During non-destructive tests conducted on aerial wire rope, two broken wires and six fatigue cracks were noticed. The defects were addressed to the concerned engineers at the site and the same was rectified by their experts.
- It was recommended that the wire rope has to be maintained in accordance with the rope way standards.

ROCK FRACTURE MECHANICS

1. **Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of location-II, Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu. (Project No.: RF-16-01):** SECON Private Limited (SECON), Bangalore requested NIRM to carry out laboratory geotechnical investigations on core samples from Location-II of Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam, Tamil Nadu.The scope of work includes determination of the mechanical properties of the rock such as Uniaxial compressive strength (UCS) on dry samples (Fig. 67); Young's modulus and Poisson's ratio on dry samples; Cohesion and Friction angle from triaxial compression test (Multiple failure method) on both dry and saturated samples (Fig. 68).

Fig. 67: Uniaxial Compression test for strength and elastic constants

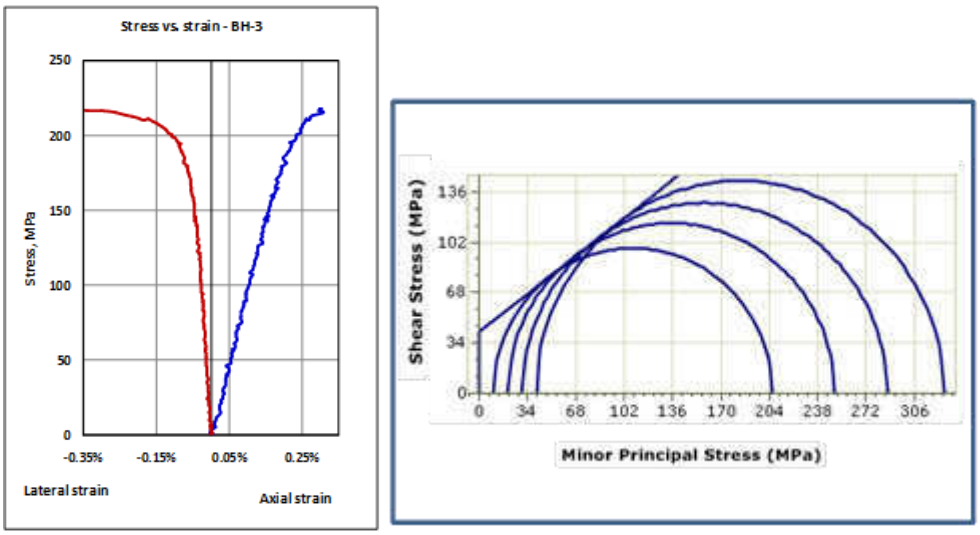

Fig. 68: Triaxial Compression test for Shear strength and Angle of friction

Laboratory testing for various mechanical properties were conducted as per ISRM standard. The final report was submitted to the client. The summary of the average values of test results is given in Table below:

Summary of the average values of test results:

Property	**Dry**	**Saturated**
Compressive Strength (MPa)	221	-
Young's Modulus (GPa)	87.74	-
Poisson's ratio	0.25	-
Cohesion (MPa)	53.01	41.70
Friction Angle (degree)	46.79	45.26

2. **Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of Dr. B.R.A. Pranahitha Chevella Lift Irrigation Scheme, Package-12-Mega Engineering and Infrastructure Limited. (Project No.: RF-15-03):** Laboratory geotechnical investigations were carried out by National Institute of rock Mechanics (NIRM) on the rock core samples belonging to Mega Engineering and Infrastructure Limited (MEIL), for the purpose of support Design for the Underground Surge Pool and Pump House, Dr. B.R.A. Pranahitha Chevella Lift Irrigation Scheme, Package-12. The core samples were received from 4 Boreholes of Pump house and Surge poolfor determining physico mechanical properties. Accordingly the laboratory tests were conducted to determine various physico mechanical properties.

The scope of work includes determination of Bulk Density; Uniaxial compressive strength, Young's modulus and Poisson's Ratio; Cohesion and Friction angle from triaxial compression test (Multiple failure method)

The average values determined are as follows:

Property	**Power House**	**Surge Pool**
Density kg/m3	2639	2637
Uniaxial Compressive Strength (MPa)	266	273
Young's Modulus (GPa)	72	70
Poisson's ratio	0.24	0.25

Cohesion (MPa) Dry Condition	51	52
Friction Angle (Degrees) Dry condition	56	53
Cohesion (MPa) Saturated condition	46	54
Friction Angle (Degrees) Saturated Condition	57	52

INTER-DISCIPLINARY WORK/OTHER TESTING ACTIVITIES

3. Determination of Physico mechanical properties for design of stoping parameters for Mansar mine, MOIL ltd. (Project No.: GC-15-06): MOIL ltd (formerly Manganese ore India limited) operates 10 mines. Out of this 7 mines are underground. Munsar mine is one of the underground mines. As part of the design of stoping parameters for Mansar mine, rock properties were determined for various rock types collected from the mine and the results will be utilized in the modelling and empirical designs for the project.

TRAINING PROGRAMMES CONDUCTED

1. Training was conducted on controlled blasting & excavation engineering for the Engineers of Border Roads Organization (BRO), Govt. of India, for one week at NIRM Registered Office, KGF from 25-29 July 2016.

2. One-week training programme was conducted on “Strata Control-Instrumentation & Monitoring” for four the Executives of South Eastern Coalfields Ltd. [Batch-I] at NIRM, Bengaluru HO from 30th January -29 February, 2016.

3. One-week training programme was conducted on “Strata Control-Instrumentation & Monitoring” for four the Executives of South Eastern Coalfields Ltd. [Batch-II] at NIRM, Bengaluru HO from 13th – 17th February, 2016.

TRAINING PROGRAMMES ATTENDED

1. Dr. LG Singh and Prasnna Jain, EGD attended National Training Programme on “Control measures for landslides” organized by National Institute of Disaster management, New Delhi and CSIR-CBRI, Roorkee between 18th and 22nd July 2016 at CBRI Roorkee

2. Dr. DS Rawat, EGD attended Department of Science and Technology, Govt. of India sponsored programme on “Communication and Presentation Skills” at Institute of Management Training & Research (IMTR) Goa during 29th August to 2nd September 2016.

3. Mrs. Praveena Das Jennifer, EEGD attended training on “Geotechnical aspects of earthquake engineering” at Indian Institute of Information Technology (IIIT) in Hyderabad.

4. Dr. V R Balasubramaniam, Mrs. Praveen Das Jennifer and Goverdhan Kantepudi, EEGD participated in week long training programme at NGRI, Hyderabad on seismic data processing.

5. Mr. AmrithRenaldy, EEGD organised and conducted a training programme for 38 officials of M/s South Eastern Coalfields Limited (SECL) on *Strata Control and instrumentation for underground coal mines, in January and February of 2017*.

6. Dr. V R Balasubramaniam, EEGD conducted a training session on “microseismic monitoring” as part of the training programme on *Strata Control and instrumentation for underground coal mines, in January and February of 2017* in Bengaluru.

7. Mr. K Vamshidhar, GED attended training programme on "Managerial Effectiveness Enhancement Programme" by Institute of Management Training & Research (IMTR), Goa, from 28th November to 2nd December 2016

8. Mr. Sripad R Naik, NMD delivered lectures on “Introduction to Numerical Modelling and Applications in Mines” and “Purpose of Strata Control in Coal Mines” at Training programme conducted for SECL Executives. (30th Jan to 3rd Feb and 13th-17th Feb, 2017)
9. Mr. Aditya Mishra, NMD attended Workshop on “Successful Introduction of High Capacity Long Wall at Adriyala”, 14th Apr 2016, Hyderabad.

10. Mr. B N V Siva Prasad, NMD has attended "International Symposium on New Equipment, New Technology, Management & Safety in Mining & Mineral Based Industries”, Geo Mine Tech,11-12 May 2016, Bhubaneshwar.

11. Mr. Aditya Mishra, Mr. K Sudhakar & Mr. B H Vijay Sekar, NMD attended Technical Workshop on “Latest Trends in Strata Control in Longwall Mining with Special Reference to Strata Monitoring Techniques”, 20th Jan 2017, Dhanbad.

12. Mr. B H Vijay Sekar & Mr. B N V Siva Prasad, NMD delivered a lecture on Geotechnical Instrumentation in Underground Coal Mines for SECL Executives on 16th Feb 2017, Bengaluru.

13. Dr. Divyalakshmi K. S. and Mr. Yogendra Singh, Seismotectonic Cell attended training on Microwave Remote Sensing from 10 – 04 -2016 to 22 -04 -2016 at National Institute of Rock Mechanics.

14. Yogendra Singh presented an invited lecture in the national seminar on the current trends in earth system sciences held at Trivandrum, Kerala during 22-23, March 2017.

INTERNATIONAL CONFERENCE ON RECENT ADVANCES IN ROK ENGINEERING (RARE-2016) - an ISRM SPECIALIZED CONFERENCE (16-18 NOVEMBER, 2016, BENGALURU, INDIA)

The National Institute of Rock Mechanics (NIRM), Bengaluru, has successfully conducted the Conference RARE-2016, as scheduled on 16th to 18th November, 2016 at Movenpick Hotel & Spa, Bengaluru. The Conference was organized under the aegis of the International Society for Rock Mechanics as a Specialized Conference of ISRM, supported by the Indian National Group of ISRM, and patronized by the Ministry of Mines, Govt of India, along with the Ministry of Coal and the Department of Science and Technology.

In the Inaugural Session on 16th Nov, 2016, at the outset, the good-will message of DrSeokwon Jeon (ISRM Vice President for Asia) was read out by the Chairman, Organizing Committee of RARE-2016.

"On behalf of the International Society for Rock Mechanics Shri Seokwon Jeon ISRM Vice-President for Asia congratulated the National Institute of Rock Mechanics for hosting this Conference in Bengaluru. He also highlighted that lots of mining and civil activities are on-going or expected and the conference has addressed the problems, challenges and solutions for rock mechanics and engineering. He also emphasized that Asian rock mechanics community has grown up owing to the fast development in Asia with lots of rock engineering projects and this is also reflected by the number of membership in ISRM. He also advised scientists and engineers get actively involved in education, research, and engineering practices with the National Groups. He acknowledged the kind support from MrBalvinder Kumar, Mr Anil Swarup, Prof Ashutosh Sharma, Secretaries to the Govt of India, in patronizing the Conference and he highly appreciate the efforts of Chairman Dr V Venkateswarlu and Organizing Secretary Dr HS Venkatesh, and all the Advisory and Organizing Committee members in making this Conference successful. He extended the thanks to National Institute of Rock Mechanics and the Indian National Group of ISRM and to the sponsors, student and staff members".

The Conference was formally inaugurated by Shri R Sridharan, Special Secretary, Ministry of Mines, Govt of India. He emphasized the importance that the Govt. is giving to the science of rock mechanics, and advised for institutional cooperation among the research and academic institutes on one hand and with the user industries on the other, at both national and international levels.

The Inaugural Session was presided over by Prof. BB Dhar (former Director, Central Mining Research Institute, now CIMFR), Shri M Raju (Director General, Geological Survey of India), Shri DorjiPhuntshok, (Joint Managing Director, PHPA 1&2, Bhutan) and Dr. PK Singh (Director, Central Institute of Mining & Fuel Research).

The Conference was attended by 285 participants including over 150 registered delegates, from India, Bhutan, China, Ireland, Lebanon, Malaysia, Qatar, South Africa and USA. The delegates represented nearly 70 organizations from India and abroad. The Conference was sponsored by 25 organizations.

A 620-page print volume of the Conference (+ CD) was brought out ahead of the event; it contained the full texts of the accepted papers as well as the Keynote Papers. The papers were also published on-line by Atlantis Press (http://www.atlantis-press.com/php/pub.php?publication=rare-16). In addition, Abstracts of the papers and full text of the Keynote Papers were printed as a Souvenir volume.

Fig. 69: Inaugural function

All the authors of the accepted papers were given an opportunity to make oral presentations. Spread over 17 Technical Sessions, 10 Keynote Papers and 83 papers were presented during the 3-day event. Two sessions were allocated exclusively for presentations by young geoscientists and engineers. The presentations were followed by lively discussions. The Chairmen and Co-Chairmen conducted the Sessions strictly as per schedule.

Fig. 70: Key note speech by Prof. B B Dhar

Fig. 71: Dr. H S Venkatesh, Organizing Secretary, RARE-2016 presenting a lecture

The two evenings of the Conference were made colourful, with a stick & string-. manipulated Puppet Show (on the story of "Ashtavakra" by Dhaatu group, Bengaluru) on 16th Nov, 2016 evening, and with a Contemporary Dance programme (by Rhythmotion group, Bengaluru) on 17th Nov, 2016 evening.

A Recommendations Committee was formed out of the eminent personalities among the participants in the Conference, with Mr Dorji Phuntshok as its Chairman. Based on the papers presented and the discussions held during the 3day Conference, a set of recommendations were drafted. The Valedictory Session was held on 18th Nov, 2016 evening. Prof. B B Dhar presided over the Session, in which the draft recommendations were presented by the Chairman of the Committee. The participants deliberated on the points, and the recommendations were finalized.

Recommendations:

1. ***The research organisations, academia and user industry should create and maintain a database of rock mechanics case studies and research and experiences, and make it available to various user industries.***
2. ***There should be better partnership and integration of research and education in real world design and construction.***
3. ***Co-ordinated efforts among geotechnical community to impart training to fresh engineers and refresher training to operational engineers as per the need of mining/civil and hydroelectric power sectors, which may include interaction with international experts.***
4. ***Constructive independent peer review may be integrated into the project construction and management plan.***
5. ***Co-ordinated effort is required between researchers and industries to implement recent developments in rock mechanics with more efforts on digitisation and implementation of best rock mechanics practices.***
6. ***Emphasis on DPR and pre-construction stage investigations with appropriate percent of project cost is required.***

7. ***Quality control should remain with the owners rather than with contractors with more emphasis on reliability instead of factor of safety and there is a strong need to modify and implement tender documents to ensure quality, safety and reliability.***
8. ***Design of support system during tunnel construction should invariably account for blast induced damage.***
9. ***Planning, design, implementation and analysis of instrumented data in a timely manner should be with the owner and be continuously monitored by experts. More emphasis should be on adoption of instruments with new technology with highest quality and reliability.***
10. ***Modern and more effective technologies should be implemented for protection of slopes, particularly soil slopes, which has a cascading effect on the project life cycle.***
11. ***Research efforts are needed to develop more effective reinforcement systems like nano technology, using carbon-nano composites in steel, and nano silicates in place of resin, keeping in mind the safety and health of workers and obvious benefits of nano materials.***
12. ***IS codes on shotcreting needs updation as deliberated in the Conference.***
13. ***There was an agreement amongst the delegates that best practices available worldwide should be used in Tunnelling. Accelerated rates of tunnelling with reliable rock supports are necessary for all types of projects. Over reliance on the steel ribs supports is to be discouraged.***
14. ***Construction and infra projects should be monitored for blasting quality control ensuring safety and productivity.***
15. ***There is a need to develop centers of excellence in various fields of geotechnical engineering with emphasis on inter-disciplinary inputs.***

Conference was formally closed after presentation of Vote of Thanks by Dr. H S Venkatesh, Organizing Secretary.

ANNUAL ACCOUNTS

INDEPENDENT AUDITOR'S REPORT

To

The Board of Directors of
NATIONAL INSITITUTE OF ROCK MECHANICS
Bangalore

Report on the Financial Statements

We have audited the accompanying financial statements of **NATIONAL INSITITUTE OF ROCK MECHANICS, Bangalore** ("the Institute") which comprise the Balance Sheet as at 31st March 2017, the Income and Expenditure Account and the Receipts and Payments Account for the year then ended, and a summary of the 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 and financial performance of the Institute in accordance with applicable accounting standards. This responsibility includes design, implementation and maintenance of internal controls relevant to the preparation of the financial statements that 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 judgement, including the assessment of the risks of material misstatement of the financial statement, 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 the 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.

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

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Basis for qualified opinion

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

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

iii. ***Non-reconciliation of Income tax - TDS receivable as described in Note No. 6 of the Notes on Accounts to the financial statements, 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 matters described in the Basis for Qualified Opinion paragraph, the aforesaid financial statements give a true and fair view:

a. In the case of the Balance Sheet, of the State of Affairs of the Institute as at 31st March 2017;
b. In the case of the Income and Expenditure Account, of the excess of Income over Expenditure for the year ended on that date; and
c. In the case of the Receipts and Payments Account, of the Receipts and Payments for the year ended on that date.

Place of Signature: Bengaluru

Date : September 18, 2017

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

for **G. MANJUNATH & Co.**
Chartered Accountants
Firm Regn. No. 001995S

CA G. MANJUNATH
Proprietor
M.R.N.: 027968

NATIONAL INSTITUTE OF ROCK MECHANICS
BANGALORE.

SCHEDULE-29

ACCOUNTING POLICIES AND NOTES ON ACCOUNT FORMING PART OF BALANCE SHEET AND INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDING 31ST MARCH 2017.

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.

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

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

F. Retirement / Long Term Employee Benefits:

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

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

G. Depreciation:

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

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

2. NOTES ON ACCOUNTS: -

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

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

3. Accounting for expenses and liability towards group leave encashment and group gratuity is based on contributions sought by LIC of India, with whom the Institute has entered into an arrangement for payment of gratuity and leave encashment.

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

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

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

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

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

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

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

18/9/17

(Ravi S)
Finance & Accounts Officer (Ag)
& Secretary, NIRM

18/9/17

(Sivakumar Cherukuri)
Director (Additional Charge)

Member
Governing Body

Refer our report of even date
For **G. MANJUNATH & CO.**
Chartered Accountants
(FRN : 001995S)

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

CA. G. MANJUNATH
Proprietor
(MRN : 027968)

Place: Bangalore
Date: 18th September 2017

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

CONSOLIDATED BALANCE SHEET AS AT 31ST MARCH 2017

(Amount in Rs)

Sl. No.	Liabilities	Sch No.	Balance as on 31-03-2017	Balance as on 31-03-2016	Sl. No.	Assets	Sch No	Balance as on 31-03-2017	Balance as on 31-03-2016
1	2	3	4	5	6	7	8	9	10
1	**CAPITAL FUND**	1							
	a) Capital Reserve		32,44,334	32,44,334	1	**CURRENT ASSETS**	7		
	b) Internal Capital Reserve		2,50,42,413	2,50,42,413		a) Cash in Hand		36,859	1,72,411
						b) Cash at Bank		1,15,06,716	22,57,311
2	**OTHER CAPITAL FUNDS**	2				c) Stock - Stationery Items		-	1,43,080
	a) Deferred Government Grant		8,26,27,845	7,31,52,489	2	**INVESTMENTS**	8		
	b) Institute's Development Fund		4,60,00,000	4,60,00,000		a) Fixed Deposits - Institute Development Fund		4,60,00,000	4,60,00,000
						b) Short term deposits against project advances received from clients		12,54,80,053	13,52,36,052
3	**CURRENT LIABILITIES**				3	**Deposits**	9	6,35,628	5,46,628
	a) Sundry Creditors - Staff	3	22,07,821	14,09,807	4	**LOANS AND ADVANCES**			
	b) Sundry Creditors - Others	4	1,21,62,277	83,58,692		a) Advances - Staff	10	9,58,092	5,97,783
	c) Project Advaces Received	5	18,40,99,555	17,52,68,397		b) Advances - Suppliers	11	4,22,06,272	1,15,77,729
	d) Provisions	6	1,67,19,049	1,78,28,292					
					5	Other Current Assets	12	3,42,25,321	3,86,25,281
					6	Expenses on Ongoing Projects	13	5,08,05,690	5,19,24,598
						SUNDRY DEBTORS	14	1,87,09,167	1,87,82,688
					8	**FIXED ASSETS**	15	2,86,48,945	2,37,30,567
	Significant Accounting Policies &	29							
	Notes on Accounts					**Income & Expenditure A/c. (Dr)**	16	1,28,90,551	2,07,10,296
	TOTAL		**37,21,03,294**	**35,03,04,424**		**TOTAL**		**37,21,03,294**	**35,03,04,424**

The Schedules referred to above form an integral part of the Balance Sheet

For National Institute of Rock Mechanics

18/9/17

(Ravi S)
Finance & Accounts Officer (Ag)
& Secretary, NIRM

18/9/17

(Sivakumar Cherukuri)
Director (Additional Charge)

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

Member
Governing Body

As per our Report of even date
For G Manjunath & Co
Chartered Accountants
(FRN : 001995S)

(CA G.Manjunath)
Proprietor
(MRN: 027968)

Place : Bangalore
Date : 18th September 2017

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

CONSOLIDATED INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2017

(Amount in Rs)

Sl. No.	Expenditure	Sch No	2016-17	2015-16	Sl. No.	Income	Sch No	2016-17	2015-16
1	2	3	4	5	6	7	8	9	10
1	Administrative Expenses	17	71,69,577	95,86,072	1	Grant-in-Aid received from Ministry of Mines	24	5,94,00,000	5,00,00,000
2	Pay & Allowances	18	8,74,11,896	7,12,56,121	2	Amount Received Against Completed Projects	25	7,05,63,734	8,77,86,746
3	Travelling Expenditure	19	6,18,019	8,42,727	3	Interest Received	26	1,44,12,440	1,42,74,223
4	Upkeep of Assets	20	9,82,321	10,30,529	4	Miscellaneous Income	27	3,56,904	2,59,660
5	Expenditure on Completed Projects	21	2,78,97,222	4,58,40,253	5	Withdrawal of Depreciation	28	5,24,644	7,95,757
5	Depreciation on Fixed Assets	15	80,26,547	56,49,940					
6	Prior Period Expenses	22	66,916	5,18,369					
7	Tax Expenses	23	52,65,479	95,03,523					
8	Excess of Income over Expenditure		78,19,745	88,88,852					
	Total:-		**14,52,57,722**	**15,31,16,386**		**Total:-**		**14,52,57,722**	**15,31,16,386**

The Schedules referred to above form an integral part of the Balance Sheet

Notes forming part of the accounts -refer schedule 29

For National Institute of Rock Mechanics

18/9/17

(Ravi S)
Finance & Accounts Officer (Ag)
& Secretary, NIRM

18/9/17

(Sivakumar Cherukuri)
Director (Additional Charge)

Member
Governing Body

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

As per our Report of even date
For G Manjunath & Co
Chartered Accountants
(FRN : 001995S)

(CA G.Manjunath)
Proprietor
(MRN: 027968)

Place : Bangalore

Date : 18th September 2017

NATIONAL INSTITUTE OF ROCK MECHANICS
BANGALORE

Consolidated Receipts and Payments Account for the year ending on 31st March 2017

(Amount in Rs)

	Receipts	Amount	Amount		Payments	Amount	Amount
1	2	3	4	5	6	7	8
To	Opening Balance			By	Staff Welfare (Fund)		1,42,035
	Cash	1,72,411		"	TDS Remittances - Contractors Payment		8,543
	Bank	22,57,311	24,29,722	"	TDS on Fixed Deposits		10,82,642
"	Capital Grant Received		1,00,00,000	"	TDS receivable on Project Receipts		77,52,073
"	Grant in Aid (Non Plan) Received		5,94,00,000	"	Remittances of Payroll Deductions		2,13,40,539
"	Licence Fee Received		28,638	"	Release of Retention Money (net)		2,00,000
"	Other Income Received		3,11,475	"	Payment of Retirement Benefits (net)		11,42,402
"	Security Deposits Recovered		3,89,043	"	Purchase of Computer Software		15,29,535
"	Penalty recovered		600	"	Purchase of Lab Equipment		3,20,600
"	Interest Received on Savings Bank Deposits		5,16,209	"	Transfer to Fixed Deposits		21,57,70,071
"	Interest Received on Term Deposits		1,19,58,871	"	Prepaid Expenses - AMC & Insurance		16,537
"	Interest on Staff advance		31,113	"	Deposit with BESCOM - Bangalore		1,00,000
"	Recovery of Defect Liability (net)		1,53,000	"	Deposit for Telex & Telephone		500
"	Earnest Money & Sec. Deposit received (net)		86,500	"	CenVAT Credit on Expenses		2,61,447
"	Undisbursed Payment to Employees (Net)		2,45,86,291	"	Advances to Others		2,95,97,794
"	Staff Advance Recovered		14,41,083	"	Project Institute Adjustment Account		2,33,887
"	Fixed Deposits Matured		22,55,26,070	"	Prior period Expenses		1,300
"	Advance Received - R&D Projects		1,08,410	"	Administrative Expenses		79,41,483
"	Advance Received - Sponsored Projects		1,80,617	"	Salaries & Wages		8,44,97,456
"	Advance Received - Centre for Testing service		32,000	"	Travel Advance (net)		2,67,006
"	Realisation of Sundry Debtors-Project		8,81,91,914	"	Travelling Expenses		5,09,012
"	Realisation of Sundry Debtors-C T S		36,15,600	"	Up Keep of Assets		36,43,908
"	Other Advances Recovered		48,46,105	"	Imprest		15,000
	Unencashed cheques		24,800		Project Contingency (B)		5,54,519
"	Income tax refund received with Interest		71,62,760	"	Honorarium/ Incentive (Projects / MTL)		2,70,597
"				"	Payment to Sundry Creditors		2,59,806

18/9/17

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

Consolidated Receipts and Payments Account for the year ending on 31st March 2017

(Amount in Rs)

	Receipts	Amount	Amount		Payments	Amount	Amount
1	2	3	4	5	6	7	8
"				"	Advance to Staff		14,33,215
"				"	Institute-Project Adjustment Account		1,47,55,226
"				"	Advances - Capital Material (net)		1,40,82,466
"				"	Advances marterial Purchases (net)		3,01,472
				"	Expenditure on R&D Running Projects		2,77,812
				"	Expenditure on Completed Sponsored Projects		1,07,75,983
				"	Contigency - Centre for Testing Servcies		1,43,594
				"	Payment of Service tax and Cess		96,69,791
				"	Expenditure on Completed Sponsored Projects		5,78,995
				"	**Closing Balance**		
				"	Cash	36,859	
				"	Bank	1,15,06,716	1,15,43,575
	Total:-		44,10,20,821		Total:-		44,10,20,821

For National Institute of Rock Mechanics

18/9/17

(Ravi S)

Finance & Accounts Officer (Ag)
& Secretary, NIRM

18/9/17

(Sivakumar Cherukuri)

Director (Additional Charge)

Member

Governing Body

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

As per our Report of even date

For G. MANJUNATH & CO.

Chartered Accountants

(FRN : 001995S)

(CA G.Manjunath)

Proprietor

(MRN: 027968)

Place : Bangalore

Date : 18th September 2017

NATIONAL INSTITUTE OF ROCK MECHANICS

Bangalore

Schedule - 15

DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2017

(Amount in Rs)

		Gross Block						Depreciation				Net Block	
Name of the Assets	Rate of Depreciation %	Balance as on 01-04-2016	Assets Written off/Trans-ferred	Purcchases up to 30.09.2016	Purchases between 1.10.2016 to 31.12.2016	Purchases After 01.01.2017	Total as on 31.03.2017 (Total of Col 3 to Col 7)	Balance as on 01-04-2016	Depreciation written off	Depreciation for the year	Total Depreciation as on 31-03-2017 (Total of Col 9 to Col 11)	As on 31-3-2017 (Col 8 - Col 12)	As on 31-3-2016
1	2	3	4	5	6	7	8	9	10	11	12	13	13
Buildings	5	91,08,642	-	86,11,720	18,75,060	21,37,545	2,17,32,967	90,90,397	-	5,22,327	96,12,724	1,21,20,243	18,245
Plant & Machinery	7.5	3,29,20,234	-	3,20,600	-	-	3,32,40,834	3,19,22,368	-	10,21,811	3,29,44,179	2,96,655	9,97,866
Water Supply	5	3,28,926	-	-	-	-	3,28,926	3,21,573	-	7,253	3,28,826	100	7,353
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	27,33,769	-	2,28,313	29,62,082	16,04,174	18,32,487
Office Equipment	5	27,60,664	-	-	-	-	27,60,664	16,91,361	-	1,38,033	18,29,394	9,31,270	10,69,303
Vehicle	7.5	7,83,835	-	-	-	-	7,83,835	7,83,735	-	-	7,83,735	100	100
Laboratory Equipment	7.5	3,31,31,820	-	-	-	-	3,31,31,820	2,25,02,309	-	24,84,887	2,49,87,196	81,44,624	1,06,29,511
Technical Books	5	46,93,917	-	-	-	-	46,93,917	32,94,507	-	2,34,696	35,29,203	11,64,714	13,99,410
Computer Software	15	1,83,58,034	-	-	-	-	1,83,58,034	1,33,08,521	-	27,53,705	1,60,62,226	22,95,808	50,49,513
Computer Hardware	20	1,46,33,368	-	-	-	-	1,46,33,368	1,43,93,872	-	2,39,396	1,46,33,268	100	2,39,496
Conversion of Power line	5	17,99,459	-	-	-	-	17,99,459	13,34,411	-	89,973	14,24,384	3,75,075	4,65,048
Env Geo Tech Lab	7.5	21,13,409	-	-	-	-	21,13,409	16,03,156	-	1,58,506	17,61,662	3,51,747	5,10,253
PROJECT:													
Vehicle	7.5	19,68,620	-	-	-	-	19,68,620	4,56,738	-	1,47,647	6,04,385	13,64,235	15,11,882
Total:-		**12,76,70,618**	**-**	**89,32,320**	**18,75,060**	**21,37,545**	**14,06,15,543**	**10,39,40,051**	**-**	**80,26,547**	**11,19,66,598**	**2,86,48,945**	**2,37,30,567**
Advance for capital material purchase		-	-	-	-	-	-	-	-	-	-	-	-
(Previous year figures)		***11,93,12,502***	-	**17,77,491**	**9,75,850**	**56,04,775**	**12,76,70,618**	**9,82,90,111**	**-**	**56,49,940**	**10,39,40,051**	**2,37,30,567**	**2,10,22,391**

Note: 1. Items not put into use : NIL

2. Depreciation has been charged on Straight Line Method.

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

Institute A/c

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

BALANCE SHEET AS AT 31ST MARCH 2017

(Amount in Rs.)

Sl No.	Liabilities	Sch No.	Balance as on 31-03-2017	Balance as on 31-03-2016	Sl No.	Assets	Sch No	Balance as on 31-03-2017	Balance as on 31-03-2016
1	2	3	4	5	6	7	8	9	10
1	**CAPITAL FUNDS**	1			1	**CURRENT ASSETS**	7		
	a) Capital Reserve		32,44,334	32,44,334		a) Cash in Hand		33,450	12,970
	b) Internal Capital Reserve		2,50,42,413	2,50,42,413		b) Cash at Bank		1,15,06,714	22,57,311
2	**OTHER CAPITAL FUNDS**	2			2	**INVESTMENTS**	8		
	a) Deferred Government Grant		8,26,27,845	7,31,52,489		a) Fixed Deposit (IDF)		4,60,00,000	4,60,00,000
	b) Institute's Development Fund		4,60,00,000	4,60,00,000		b) Fixed Deposits - Short Term		8,89,08,242	13,03,56,854
					3	**DEPOSITS**	9	6,35,628	5,46,628
3	**CURRENT LIABILITIES**								
					4	**LOANS AND ADVANCES**			
						a) Advances - Staff	10	1,37,700	2,50,085
	a) Sundry Creditors - Staff	3	22,07,200	14,08,592		b) Advances - Others	11	2,82,09,014	1,15,47,329
	b) Sundry Creditors - Others	4	1,01,02,679	69,20,982					
	c) Provisions	5	1,67,19,049	1,78,28,292	5	Other Current Assets	12	96,82,445	79,90,657
	d) Project Account	6	33,48,20,787	32,04,83,035					
					6	**FIXED ASSETS**	13	2,72,84,711	2,22,18,685
					7	**Income & Expenditure Account (Dr)**	14	30,83,66,403	27,28,99,618
	TOTAL		**52,07,64,307**	**49,40,80,137**		**TOTAL**		**52,07,64,307**	**49,40,80,137**

The Schedules referred to above form an integral part of the Balance Sheet

For National Institute of Rock Mechanics

18/9/17

(Ravi S)
Finance & Accounts Officer (Ag)
& Secretary, NIRM

18/9/17

(Sivakumar Cherukuri)
Director (Additional Charge)

Member
Governing Body

As per our Report of even date
For G Manjunath & Co
Chartered Accountants
(FRN : 001995S)

(CA Manjunath G)
Proprietor
(MRN : 027968)

G. MANJUNATH & CO. ★ FRN 001995S ★ Chartered Accountants

Place : Bangalore

Date : 18th September 2017.

Institute A/c

NATIONAL INSTITUTE OF ROCK MECHANICS
BANGALORE

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2017

(Amount in Rs.)

EXPENDITURE					INCOME				
Sl No.	Head of Account	Sch No	2016-17	2015-16	Sl No.	Head of Account	Sch No	2016-17	2015-16
1	2	3	4	5	6	7	8	9	10
1	Administrative Expenses	15	71,69,577	95,86,072	1	Grant-in-Aid received from Ministry of Mines	21	5,94,00,000	5,00,00,000
2	Pay & Allowances	16	8,74,11,896	7,12,56,121	2	Miscellaneous Income	22	3,16,943	1,29,630
3	Travel Expenditure	17	6,18,019	8,42,727	3	Interest Received	23	1,36,19,118	1,24,51,974
4	Up Keep of Assets	18	9,82,321	10,30,529	4	Withdrawal of Depreciation	24	5,24,644	7,95,757
5	Prior Period Expenses	19	1,300	5,18,369	5	Excess of Expenditure over Income		3,54,66,786	3,22,53,870
6	Depreciation on Fixed Assets	13	78,78,899	55,67,641					
7	Tax Expenses	20	52,65,479	68,29,772					
	Total:-		**10,93,27,491**	**9,56,31,231**		**Total:-**		**10,93,27,491**	**9,56,31,231**

The Schedules referred to above form an integral part of the Balance Sheet

For National Institute of Rock Mechanics

18/9/17

(Ravi S)
Finance & Accounts Officer (Ag)
& Secretary, NIRM

18/9/17

(Sivakumar Cherukuri)
Director (Additional Charge)

Member
Governing Body

As per our Report of even date
For G Manjunath & Co
Chartered Accountants
(FRN : 001995S)

(CA Manjunath G)
Proprietor
(MRN : 027968)

G. MANJUNATH & CO. ★ Chartered Accountants ★ FRN 001995S

Place : Bangalore

Date : 18th September 2017

Institute A/c

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

Schedule - 13

(Amount in Rs)

DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2017

		Gross Block						Depreciation			Net Block	
Name of the Assets	Rate of Depreciation %	Balance as on 01-04-2016	Assets Written off/Trans-ferred	Purcchases up to 30.09.2016	Purchases between 1.10.2016 to 31.12.2016	Purchases After 01.01.2017	Total as on 31.03.2017 (Total of Col 3 to Col 7)	Balance as on 01-04-2016	Depreciation for the year	Total Depreciation as on 31-03-2017 (Total of Col 9 to Col 11)	As on 31-03-2017 (Col 8 - Col 12)	As on 31-03-2016
1	2	3	4	5	6	7	8	9	11	12	13	13
Buildings	5	91,08,642	-	86,11,720	18,75,060	21,37,545	2,17,32,967	90,90,397	5,22,327	96,12,724	1,21,20,243	18,245
Plant and Machinary	7.5	3,29,20,234	-	3,20,600	-	-	3,32,40,834	3,19,22,368	10,21,811	3,29,44,179	2,96,655	9,97,866
Water Supply	5	3,28,926	-	-	-	-	3,28,926	3,21,573	7,253	3,28,826	100	7,353
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	27,33,769	2,28,313	29,62,082	16,04,174	18,32,487
Office Equipment	5	27,60,664	-	-	-	-	27,60,664	16,91,361	1,38,033	18,29,394	9,31,270	10,69,303
Vehicle	7.5	7,83,835	-	-	-	-	7,83,835	7,83,735	-	7,83,735	100	100
Laboratory Equipment	7.5	3,31,31,820	-	-	-	-	3,31,31,820	2,25,02,309	24,84,887	2,49,87,196	81,44,625	1,06,29,511
Technical Books	5	46,93,917	-	-	-	-	46,93,917	32,94,507	2,34,696	35,29,203	11,64,714	13,99,410
Computer Software	15	1,83,58,034	-	-	-	-	1,83,58,034	1,33,08,521	27,53,705	1,60,62,226	22,95,808	50,49,513
Computer Hardware	20	1,46,33,368	-	-	-	-	1,46,33,368	1,43,93,872	2,39,396	1,46,33,268	100	2,39,496
Conversion of Power line	5	17,99,459	-	-	-	-	17,99,459	13,34,411	89,973	14,24,384	3,75,075	4,65,048
Env Geo Tech Lab	7.5	21,13,409	-	-	-	-	21,13,409	16,03,156	1,58,506	17,61,662	3,51,747	5,10,253
Total:-		**12,57,01,998**	**-**	**89,32,320**	**18,75,060**	**21,37,545**	**13,86,46,923**	**10,34,83,313**	**78,78,899**	**11,13,62,212**	**2,72,84,711**	**2,22,18,685**
(Previous Years Figures)		***11,85,05,613***	***-***	***17,77,491***	***9,75,850***	***44,43,044***	***12,57,01,998***	***9,79,15,672***	***55,67,641***	***10,34,83,313***	***2,22,18,685***	***2,05,89,941***

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

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

Project A/c

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

BALANCE SHEET AS AT 31ST March 2017

(Amount in Rs)

Sl No.	Liabilities	Sch No.	Balance as on 31-03-2017	Balance as on 31-03-2016	Sl No.	Assets	Sch No	Balance as on 31-03-2017	Balance as on 31-03-2016
1	2	3	4	5	6	7	8	9	10
1	**OTHER CAPITAL FUNDS**				1	**CURRENT ASSETS**			
	Income & Expenditure Account	1	29,54,75,852	25,21,89,322		a) Cash in Hand	5	3,409	1,59,441
						b) Institute Account	6	33,48,20,787	32,04,83,035
2	**CURRENT LIABILITIES**					c) Stock - Stationery Items	7	-	1,43,080
	a) Project Advances Received	2	18,40,99,555	17,52,68,397					
	b) Sundry Creditors - Others	3	20,39,648	14,37,710	2	**INVESTMENTS**			
	c) Sundry Creditors - Suppliers & Employees	4	20,571	1,215		a) Short Term Deposits against Project Advances received from clients	8	3,65,71,811	48,79,198
					3	**LOANS AND ADVANCES**			
						a) Advances - Staff	9	8,20,392	3,47,698
						b) Advances - Suppliers	10	1,39,97,258	30,400
					4	**Other Current Assets**	11	2,45,42,876	3,06,34,624
					5	**Expenses on Ongoing Projects**	12	5,08,05,690	5,19,24,598
					6	**Sundry Debtors**	13	1,87,09,167	1,87,82,688
					7	**Fixed Assets**	14	13,64,236	15,11,882
	TOTAL		**48,16,35,626**	**42,88,96,644**		**TOTAL**		**48,16,35,626**	**42,88,96,644**

The Schedules referred to above form an integral part of the Balance Sheet

For National Institute of Rock Mechanics

18/9/17

(Ravi S)
Finance & Accounts Officer (Ag)
& Secretary, NIRM

Place : Bangalore

Date : 18th September 2017

18/9/17

(Sivakumar Cherukuri)
Director (Additional Charge)

Member
Governing Body

As per our Report of even date
For G Manjunath & Co
Chartered Accountants
(FRN: 001995S)

(CA Manjunath G)
Proprietor
(MRN : 027968)

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

Project A/c

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31ST MARCH 2017

(Amount in Rs)

Sl No.	Expenditure	Sch No	2016-2017	2015-2016	Sl No.	Income	Sch No	2016-2017	2015-2016
1	2	3	4	5	6	7	8	9	10
1	Expenditure on Completed Projects	15	27897222	4,58,40,253	1	Amount Received Against Completed Projects	16	70563734	8,77,86,747
2	Depreciation on Fixed Assets - Vehicle	14	147647	82,299	2	Interest Received	17	402220	18,22,249
3	Tax Expenses		0	26,73,751	3	Other Income	18	431060	1,30,029
4	Prior Period Expenditure	15A	65616	-					
5	Excess of Income over Expenditure		43286529	4,11,42,722					
	Total:-		**71397014**	**8,97,39,025**		**Total:-**		**71397014**	**8,97,39,025**

The Schedules referred to above form an integral part of the Balance Sheet

For National Institute of Rock Mechanics

18/9/17

(Ravi S)
Finance & Accounts Officer (Ag)
& Secretary, NIRM

18/9/17

(Sivakumar Cherukuri)
Director (Additional Charge)

Member
Governing Body

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

As per our Report of even date
For G Manjunath & Co
Chartered Accountants
(FRN : 001995S)

(CA Manjunath G)
Proprietor
(MRN: 027968)

Place : Bangalore

Date : 18th September 2017

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2017

Schedule - 14

(Amount in Rs)

		Gross Block						Depreciation				Net Block	
Name of the Assets	Rate of Depreciation %	Balance as on 01-04-16	Assets Written off/Transferred	Purcchases up to 30.09.16	Purchases between 1.10.16 to 31.12.16	Purchases After 01.01.17	Total as on 31.03.17	Balance as on 01-04-16	Depreciation written off	Depreciation for the year	Total Depreciation as on 31-03-17	As on 31-3-17	As on 31-03-16
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Vehicle	7.5	19,68,620	-	-	-	-	19,68,620	4,56,738	-	1,47,647	**6,04,385**	13,64,236	15,11,882
Total:-		**19,68,620**	**-**	**-**	**-**	**-**	**19,68,620**	**4,56,738**	**-**	**1,47,647**	**6,04,385**	**13,64,236**	**15,11,882**
(Previous year figures)		***8,06,889***	**-**	**-**	**-**	***11,61,731***	***19,68,620***	***3,74,439***	**-**	***82,299***	***4,56,738***	***15,11,882***	***4,32,450***

Note: 1. Items not put into use : NIL

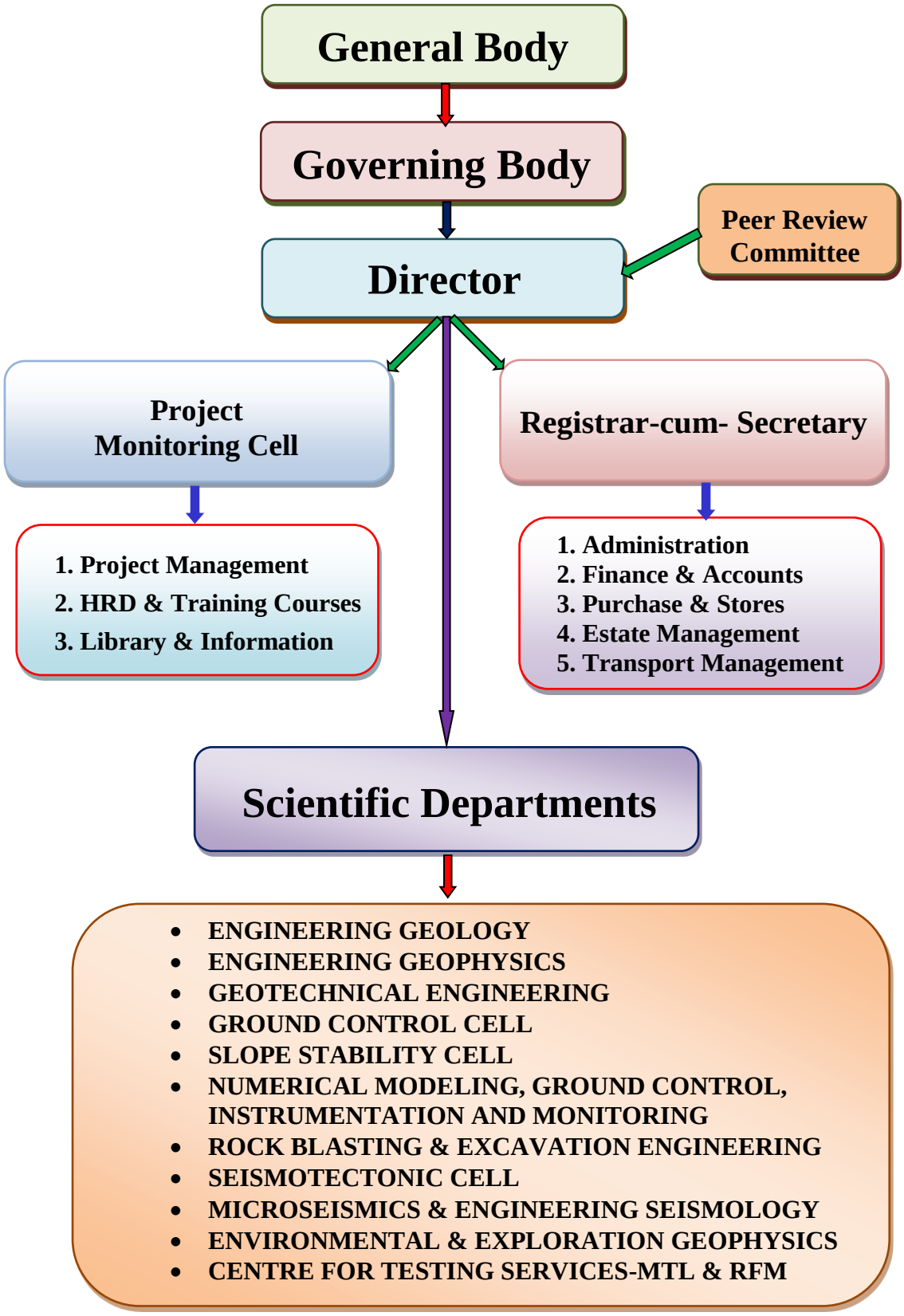
2. Depreciation has been charged on Straight Line Method.

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

Annexure

Annexure - 1

NIRM ORGANISATION CHART



Annexure – 2a

MEMBERS OF THE GENERAL BODY **(1st January 2014-31st December 2016)**		
Chairman		
Shri Balvinder Kumar, IAS Secretary to Govt. of India Ministry of Mines		
Members		
Additional Secretary ,Ministry of Mines, Govt. of India		Prof D C Panigrahi Director Indian School of Mines, Dhanbad
Joint Secretary & Financial Advisor Ministry of Mines, Govt. of India		Shri B Ramesh Kumar Director (Operations) Singareni Collieries Company Limited, Kothagudem
Economic Advisor Ministry of Mines, Govt. of India		Excutive Director(Geology),NHPC Ltd.
Dy Secretary (Technical) Ministry of Mines, Govt. of India		Prof B B Dhar, Ex-Dir, CIMFER Director (Research), AIU; Director (R&IC), Amity Univ.; Advisor, HESRT&SD, New Delhi
Shri M Raju Director General Geological Survey of India Kolkata.		Shri AK Rudra Retd. Director General (DGMS) Kolkata
Shri Prashanta K Sarkar Director General Directorate General of Mines Safety, Dhandad.		Shri A Sundaramoorthy Retd. Director General (GSI) Chennai
Dr. Pradeep K Singh Director, CSIR Central Institute of Mining & Fuel Research, Dhanbad.		Director National Institute of Rock Mechanics, Bengaluru.
Secretary (Non-member)		
Shri A N Nagarajan Registrar-cum-Secretary National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru.		

Annexure – 2b

MEMBERS OF THE GENERAL BODY **(1st January 2017-31st December 2019)**		
Chairman		
Shri Arun kumar, IAS Secretary to Govt. of India Ministry of Mines		
Members		
Additional Secretary to Govt. of India Ministry of Mines, Govt. of India		Shri B Ramesh Kumar Director (Operations) Singareni Collieries Company Limited, Kothagudem
Joint Secretary & Financial Advisor Ministry of Mines, Govt. of India		Prof VR Sastry Mining Engineering Department National Institute of Technology, Surathkal
Economic Advisor Ministry of Mines, Govt. of India		Prof BB Dhar, Ex-Dir, CIMFER Director (Research), AIU; Director (R&IC), Amity Univ.; Advisor, HESRT&SD, New Delhi
Dy Secretary (Technical) Ministry of Mines, Govt. of India		Shri AK Rudra Retd. Director General (DGMS) Kolkata
Shri M Raju Director General Geological Survey of India Kolkata.		Shri A Sundaramoorthy Retd. Director General (GSI) Chennai
Shri Prashanta K Sarkar Director General Directorate General of Mines Safety, Dhandad.		The Controller General Indian Bureau of Mines NAGPUR
Dr. Pradeep K Singh Director, CSIR Central Institute of Mining & Fuel Research, Dhanbad.		Director National Institute of Rock Mechanics, Bengaluru.
Prof DC Panigrahi Director, Indian School of Mines, Dhanbad		
Secretary (Non-member) Shri AN Nagarajan Registrar-cum-Secretary National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru-560 070 (Superannuated on 30.04.2017)		**Secretary (Non-member)** Shri S Ravi PSO/FAO (Ag)-cum-Secretary National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru-560 070 (From: 01.05.2017)

Annexure – 3a

MEMBERS OF THE GOVERNING BODY **(1st January 2014-31st December 2016)**		
Chairman		
Shri Balvinder Kumar, IAS Secretary to the Government of India Ministry of Mines		
Members		
Addl. Secretary to the Govt. of India Ministry of Mines, R.No. 308-A III Floor, A Wing, Shastri Bhawan New Delhi – 110 115		Shri Rahul Guha Director General Directorate General of Mines Safety Dhanbad – 826 001 Jharkhand
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
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
Dy Secretary (Technical) Ministry of Mines, R.No. 306 III Floor, D Wing, Shastri Bhawan New Delhi – 110 115		Shri AS Walvekar Executive Director (Geology / R&D Div.) National Hydro-Power Corporation Ltd NHPC Office Complex, Sector-33 Faridabad – 121 003, Haryana
Shri Harbans Singh Director General Geological Survey of India (GSI) Kolkata - 700 016		Shri 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		Shri AK Rudra Retd. Director General of Mines Safety Kolkata – 700 002
Alternate members		
The Advisor (Projects) Ministry of Coal 3rd floor, A Wing, Shastri Bhawan New Delhi – 110 001		Shri A Sundaramoorthy Director General (Retd.), GSI Chennai – 600 099

Prof B B 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)		
Shri A N Nagarajan Registrar-cum-Secretary National Institute of Rock Mechanics Champion Reefs Kolar Gold Fields - 563 117		

Annexure – 3b

MEMBERS OF THE GOVERNING BODY **(1st January 2017-31st December 2019)**		
Chairman		
Shri Arun kumar, IAS Secretary to Govt. of India Ministry of Mines		
Members		
Additional Secretary to Govt. of India Ministry of Mines, Govt. of India		Prof DC Panigrahi Director Indian School of Mines, Dhanbad
Joint Secretary & Financial Advisor Ministry of Mines, Govt. of India		Shri B Ramesh Kumar Director(Operations) Singareni Collieries Company Limited Kothagudem Collieries
Economic Advisor Ministry of Mines, Govt. of India		Member (D&R) Central Water Commission New Delhi
Dy Secretary (Technical) Ministry of Mines, Govt. of India		Shri YK Handa CE (Designs (NW&S) New Delhi
Shri M Raju Director General Geological Survey of India Kolkata.		The Advisor (Projects) Ministry of Coal Govt. of India, New Delhi
Shri Prashanta K Sarkar Director General Directorate General of Mines Safety, Dhandad.		Prof BB Dhar, Ex-Dir, CIMFER Director (Research), AIU; Director (R&IC), Amity Univ.; Advisor, HESRT&SD, New Delhi
Dr.Pradeep K Singh Director, CSIR Central Institute of Mining & Fuel Research, Dhanbad.		The Controller General Indian Burea of Mines IndraBhavan Nagapur
Prof VR Sastry Mining Engineering Department National Institute of Technology, Surathkal		Shri A Sundaramoorthy Retd. Director General (GSI) Chennai
		Director National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru-560 070

Secretary (Non-member) Shri AN Nagarajan Registrar-cum-Secretary National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru-560 070 (Superannuated on 30.04.2017)		**Secretary (Non-member)** Shri S Ravi PSO/FAO (Ag)-cum-Secretary National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru-560 070 (From: 01.05.2017)

Annexure – 4a

MEMBERS OF THE PEER REVIEW COMMITTEE **(1st January 2014 - 31st December 2016)**		
Chairman		
Shri A K Rudra Director General of Mines Safety (Retd.) Kolkata – 700 002		
Alternate Chairman		
Shri A Sundaramoorthy Director General (Retd.) Geological Survey of India, Chennai – 600 099		
Members		
Prof VR Sastry Mining Engineering Department National Institute of Technology Mangalore – 575 025		Shri M Koshy John The Director, C-TEMPO Ministry of Mines, Govt. of India New Delhi – 110 003
Shri Achyuta Krishna Ghosh Chief Scientist, CSIR-CIMFR Professor, AcSIR-CIMFR Central Institute of Mining & Fuel Research, Dhanbad – 826 015		The General Manager /HOD (Geophysics) Exploration Dept Central Mine Planning & Design Instt HQ Ranchi – 834 008
Shri SVSS Ramalingeswarudu General Manager (R&D) The Singareni Collieries Company Limited ,Kothagudem Colleries – 507101		Dr. V. Venkateswarlu Director National Institute of Rock Mechanics Champion Reefs Kolar Gold Fields - 563 117
Dr Asim Kumar Sinha Director (S&T) Directorate General of Mines Safety DHANBAD – 826 001		
Secretary (Non-member) Shri A N Nagarajan Registrar-cum-Secretary National Institute of Rock Mechanics Champion Reefs Kolar Gold Fields - 563 117		

Annexure – 4b

MEMBERS OF THE PEER REVIEW COMMITTEE (1st January 2017 - 31st December 2019)		
Chairman		
Prof.B B Dhar Formerly: Director, CIMFR; Director (Research), AIU Director(R&IC),Amity Univ. Adviser, HESRT&SD NEW DELHI – 110 048		
Alternate Chairman		
Prof V R Sastry Mining Engineering Department National Institute of Technology, Surathkal Srinaivasa nagar – 575 025		
Members		
Shri A Sundaramoorthy, (retd. Director General , GSI), Chennai-600 099		Prof. VMSR Murthy, Professor and Associate Dean (International Relations and alumni Affaris), Department of Mining, ISM, Dhanbad-826 004
Shri AK Meghraj, Dy.Director General Directorate General of Mines Safety, South Zone, Koramangala, Bengaluru-560 034		Shri T K Sivarajan, CE (Designs (N&W)), Centeral water commission, SevaBhavan, New Delhi-110 066
Shri Syed Abdul Fateh Khalid, Executive Director, (Mines), Neyveli Lignite Corporation Ltd., Mine I & IA Administrative Officer, Neyveli-607 803		Prof. T G Sitharam, Department of Civil Engineering, IISc, Bengaluru-560 001
Officer nominated by SCCL		Director National Institute of Rock Mechanics, Banashakari 2nd Stage, Bengaluru-560 070
Secretary (Non-member) Shri AN Nagarajan Registrar-cum-Secretary National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru-560 070 (Superannuated on 30.04.2017)		**Secretary (Non-member)** Shri S Ravi PSO/FAO (Ag)-cum-Secretary National Institute of Rock Mechanics Banashakari 2nd Stage, Bengaluru-560 070 (From: 01.05.2017)

Annexure - 5

SUPPORTING ORGANISATIONS & MAJOR CLIENTELE

Central Government Ministries & Departments

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

State Government

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

Public Sector Organisations

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

Central Government Ministries & Departments

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

State Government

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

Public Sector Organisations

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

Private Companies

Balsore Alloys Limited Ltd
China Coal No.5 Constructions Pvt Ltd.
Ferro-Alloys Corporation Limited (FACOR)
Technology House (India) Pvt. Ltd.
Chennakeshava stone crusher.
RS DCI Pvt. Ltd
Secon Pvt.ltd
MSRDC, Mumbai
Prathima Infr.Ltd.
Kalyani developers, Bangalore
SDFI Pvt. Ltd
Gammon India Ltd.
HES Infra Private Ltd
Hindustan Construction Company Limited (HCC)
India Resources Limited.
IOT Infrastructure & Energy Services Ltd
Jindal Power Limited
Kare Power Resources Private Limited (KPRPL)
Larsen & Toubro (L&T) Construction
Megha Engineering & Infrastructures Ltd

Navayuga Engineering Company Limited
Navyuga Kommu Venkateshwara Metal Miners
Patel Engineering Ltd.
Prathima Infrastructures Ltd.
Ramco cements Ltd.
Sesa Mining Corporation Ltd.
Shaft Sinkers Mauritius Ltd.
Shriram EPC Limited
SNC-Lavalin Infrastructure Private Ltd.
Soham Renewable Energy Private Limited (SREPL)
The India Cements Limited (ICL)
Transstroy-AFCONS JV, Chennai
Transstroy-JSC-EC-UES, AP
Waddera Sangam
Zeenath Transport Company (ZTC)
Zuari Cement Limited
RIL,Yargol
TANGEDCO Ltd.

International Organisations

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

Annexure-6

LIST OF COMPLETED AND ONGOING PROJECTS

ENGINEERING GEOLOGY				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
1	EG-15-03	Engineering geological, geotechnical and laboratory testing for the proposed new underground surge pool and pump house of Pranahitha - ChevellaSujalaSravanthi Lift Irrigation Scheme -Package-12 in the Medak District of Telangana State	AK Naithani, LG Singh and Prasnna Jain	Completed
2	EG-16-01	Engineering geological investigations of Kaleshwaram – DBRAPCSS II Lift Irrigation Scheme Package-6, Karimnagar District, T.S.	AK Naithani and Rajesh Patel	Completed
3	EG-16-02	Engineering geological investigations of additional surge pool of Pranahita - ChevellaSujalaSravanthi Lift Irrigation Scheme – Package 8 (PCSSLIS-P8), Karimnagar District, Telangana State	AK Naithani, L G Singh, Prasnna Jain and DS Rawat	Completed
4	EG-16-03	Review of engineering geological investigations of surge shaft of Pranahita - ChevellaSujalaSravanthi Lift Irrigation Scheme – Package 10 (PCSSLIS-P10), Karimnagar District, Telangana State	AK Naithani	Completed
5	EG-16-04	Geological logging of drill holes/mapping of excavated wall faces of Darlipali Super Thermal Power Project (2 x 800 MW), Odisha	AK Naithani, DS Rawat, LG Singh and Prasnna Jain	Completed
6	EG-16-05	Engineering geological investigations of the extension of surge pool and pump house caverns of Pranahita - ChevellaSujalaSravanthi Lift Irrigation Scheme – Package 8 (PCSSLIS-P8), Karimnagar District, Telangana State	A K Naithani, D S Rawat, Prasnna Jain and LG Singh	Completed
7	EG-16-06	Review of engineering geological investigations of pump house of Kaleshwaram Project – Package 10, RajannaSiricilla District, Telangana State	AK Naithani	Completed
8	EG-15-02	Construction stage engineering geological mapping of pond floors and pump houses of Natural Draft Cooling Towers (NDCT) of Rajasthan Atomic Power Project (RAPP) Units 7&8, Rawatbhata, Rajasthan.	AK Naithani, LG Singh and Prasnna Jain	On-going
9	EG-15-04	Engineering geological investigations of the cave area of Shri Mata VaisnoDeviji, Reasi District of Jammu and Kashmir State	AK Naithani	On-going
10	EG-17-01	Construction stage engineering geological foundation mapping of Yargol Gravity type concrete dam in BangarpetTaluk of Karnataka State	AK Naithani, LG Singh, Prasnna Jain and D S Rawat	On-going
11	EG-17-02	Engineering geological investigations of Kaleshwaram – DBRAPCSS II Lift Irrigation Scheme Package-6, Karimnagar District, T.S.	AK Naithani and Rajesh Patel	On-going

ENGINEERING GEOPHYSICS				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
12	GP-12-02	Development of a viable technique for assessment of safety of structures under settling environment.	P C Jha, N Sandeep , Butchi Babu and Y V Sivram	On-going
13	GP-15-05	Cross-hole GPR survey for mapping probable extensions of old working at 200mRL of RD Mines, Dariba.	P C Jha, N Sandeep , Butchi Babu, Y V Sivram and Shashinath Verma	On-going
14	GP-16-02	Seismic Refraction Survey at the proposed Silahalla Dam Site Kundah, Nilgiri, TN.	P C Jha, N Sandeep , Butchi Babu, Y V Sivram and Shashinath Verma	On-going
15	GP-15-04	Cross-hole Seismic Tomography Survey for investigationof the foundation of S60 pillar of ChenabBridge, USBRL Project, J & K.	P C Jha, N Sandeep , Butchi Babu, Y V Sivram and Shashinath Verma	On-going
16	GP-16-01	Geophysical Survey to ascertain possibility of subsidence of HB oil pipeline between chainage 257.700-258.700 km.	P C Jha, N Sandeep , Butchi Babu, Y V Sivram and Shashinath Verma	On-going
GEOTECHNICAL ENGINEERING				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
17	GE-16-01	Determination of in situ stress tensor at underground surge pool/pump house of PranahitaChevella Lift Irrigation Scheme (PCILS, package no 11)	D S Subrahmanyam, G Shyam, K Vamshidhar, S Vikram and K N Shashidhara	Completed
18	GE-15-03	Determination of in situ stress parameters at Hutti Gold mine for the design of stopes below 20th level.	D S Subrahmanyam, G Shyam, K Vamshidhar, S Vikram and K N Shashidhara	Completed
19	GE-16-03	Determination of in-situ stress parameters for the design of underground powerhouse cavern at VishnugadPipalkotiH.E. Project, Uttarakhand.	D S Subrahmanyam, G Shyam, K Vamshidhar, S Vikram and K N Shashidhara	Completed
20	GE-16-04	Determination of in-situ modulus of deformation of rock mass at the delivery main tunnels of Kaleshwaram project, Dr. BR Ambedkar PCLIS-Link II (Package-6), Telangana.	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram, R Vinay Reddi and K N Shashidhara	Completed
21	GE-16-05	Determinations of in-situ shear parameters at the proposed dam across Markendayya River at Yargol near Kolar for the design of dam.	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram, R Vinay Reddi and KN Shashidhara	On-going
22	GE S&T-15-01	Assessment of horizontal stress field in deeper horizons and development of	DS Subrahmanyam, G Shyam,	On-going

		roof hazard maps of coal resources in SCCL command area – (Ministry of Coal)	K Vamshidhar, S Vikram, K N Shashidhara and R Vinay Reddi	
GROUND CONTROL CELL				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
23	GC-15-06	Design of stoping parameters for Munsar mine of MOIL ltd, Nagpur	G D Raju, Prasnna Jain, V Venkateswarlu and A Rajan Babu	Completed
24	GC-15-05	MoU with UCIL- Various titles during MoU period up to April -2017 (4 projects)	G D Raju, L G Singh, V Venkateswarlu and A Y Bharath Kumar	On-going
SLOPE STABILITY				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
25	SS-15-01	Slope Stability Studies at Kaliapani Chromite Mine, Kaliapani, Jajpur District, Odisha	S K Reddy and A Rajan Babu	Completed
26	SS-15-02	Dump material testing and analysis of Kaliapani chromite mine at Kaliapani, Jajpur District, Odisha	S K Reddy and A Rajan Babu	Completed
27	SS-16-01	Review the slope stability measures at Pallava granites at Chimakurthy, Prakasam District, Andhra Pradesh of M/s Pallava Granite Industries India Pvt. Ltd	A Rajan Babu, S K Reddy, G D Raju, S Udayakumar and AY Bharath Kumar	Completed
28	SS-16-02	Slope stability studies of CopilaGaichem Paul Iron ore mine, Sigao and Collem village, Dharbandorataluka, South Goa	G D Raju, S K Reddy A Rajan Babu and AY Bharathkumar	On-going
NUMERICAL MODELING, GROUND CONTROL, INSTRUMENTATION AND MONITORING				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
29	NM-12-01	Geodetic monitoring of SardarSarovar Dam, SSNNL, Kevedia, Gujarat	Sripad R Naik, K Sudhakar, Rabi Bhusan and B H Vijay Sekar	On-going
30	NM-13-03	3D analysis of underground powerhouse complex of Mangdechhu Hydroelectric Project, Bhutan	Sripad R Naik, B H Vijay Sekar, Rabi Bhusan and K Sudhakar	On-going
31	NM-13-07	Slope stability analysis of abutment cut slopes for concrete gravity dam at Mangdechhu Hydroelectric Project, Bhutan	Sripad R Naik, B H Vijay Sekar, Rabi Bhusan and K Sudhakar	On-going
32	NM-14-03	Stability analysis of rock slopes for pothead yard location at Mangdechhu Hydroelectric Project, Bhutan	Sripad R Naik, B H Vijay Sekar, Rabi Bhusan and K Sudhakar	On-going
33	NM-14-04/15-05	Deformation monitoring of underground powerhouse cavern of SardarSarovar Project, Gujarat	Sripad R Naik, K Sudhakar, Rabi Bhusan and B H Vijay Sekar	Completed and On-going

34	NM-15-01/16-02	Instrumentation, monitoring and data analysis at powerhouse complex Tala Hydropower Plant, Bhutan	Sripad R Naik, K Sudhakar, Rabi Bhusan, Aditya Mishra and B H Vijay Sekar	Completed and On-going
35	NM-15-02/16-08	Analysis of instrumentation data of dam, desilting complex, powerhouse complex of NJHPS, SJVNL, Shimla	Sripad R Naik, K Sudhakar, Rabi Bhusan and B H Vijay Sekar	Completed and On-going
36	NM-15-03	Temporary and permanent support design of underground surge pool and pump house draft tube and delivery main tunnel using 3D numerical modeling at PCSSLIS- Package 12, Telangana	Sripad R Naik, Rabi Bhusan, B H Vijay Sekar and K Sudhakar	On-going
37	NM-15-04	Pit slope stability analysis of North East benches of A Narrain Mines, Chitradurga, Karnataka	Sripad R Naik, Rabi Bhusan, B H Vijay Sekar and K Sudhakar	On-going
38	NM-16-01	Analysis of data obtained from normal compression test and direct shear tests : Specimens collected over Indian sub-continent region	Sripad R Naik, RajanBabu, Aditya Mishra, Udaya Kumar, B H Vijay Sekar, BNV Siva Prasad, Rabi Bhusan and K Sudhakar	On-going
39	NM-16-03	Support design of underground surge pool and pump house by 3D Numerical Modelling of Pranahita-ChevellaSujalaSravanthi Lift Irrigation Scheme (PCSSLIS) Package-11, Telangana	Sripad R Naik, Rabi Bhusan, B H Vijay Sekar, Aditya Mishra, BNV Siva Prasad and K Sudhakar	Completed
40	NM-16-04	3D numerical modelling analysis for pump house and surge pool caverns of Pranahita-ChevellaSujalaSravanthi Lift Irrigation Scheme Package-8, Telangana	Sripad R Naik, Rabi Bhusan, B H Vijay Sekar, Aditya Mishra and BNV Siva Prasad	Completed
41	NM-16-05	Geotechnical instrumentation installation and monitoring at Kaleswaram Project-Package-11, Telangana	Sripad R Naik, K Sudhakar, B H Vijay Sekar, Aditya Mishra, BNV Siva Prasad and Rabi Bhusan	On-going
42	NM-16-06	Scientific study to assess the stress and displacement limits at Zawar Mines, HZL	Sripad R Naik, Aditya Mishra, B H Vijay Sekar, BNV Siva Prasad, Rabi Bhusan and K Sudhakar	On-going
43	NM-16-07	Assessment of stability of the mine pertaining to extraction of an Ore block at Baroi Mine, HZL	Sripad R Naik, Aditya Mishra, B H Vijay Sekar, BNV Siva Prasad, Rabi Bhusan and K Sudhakar	Completed

44	NM-16-09	Establishing the dimensions of cap rock and estimating the stoping parameters for K Series and Northern series of lenses at North Baroi Mine, HZL	Sripad R Naik, Aditya Mishra, B H Vijay Sekar, BNV Siva Prasad, Rabi Bhusan and K Sudhakar	On-going
45	GC-15-03	To carryout rock mechanics investigations, evaluation of the stability of excavations & optimization of stoping parameters, design of support system etc. below 20th level in all the reefs of Hutti Gold Mines, Karnataka	Sripad R Naik, Rabi Bhusan, B H Vijay Sekar, Aditya Mishra, BNV Siva Prasad, AmrithRenaldy and K Sudhakar	On-going
46	GC-15-04	To carryout rock mechanics investigations, evaluation of the stability of excavations & optimization of stoping parameters, design of support system at Uti and Hirabuddini mines of the Hutti Gold Mines Company Limited, Karnataka	Sripad R Naik, Rabi Bhusan, B H Vijay Sekar, Aditya Mishra, BNV Siva Prasad, Amrith Renaldy and K Sudhakar	On-going
ROCK BLASTING AND EXCAVATION ENGINEERING				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
47	RB-15-06	Blasting guidance for removal of boulders and excavation of rock in the river channel of Idamalayar dam spillway bucket area, KSEB	A I Theresraj, R Balachander, G Gopinath, G C Naveen and H S Venkatesh	Completed
48	RB-16-01	Study on ground vibration and air overpressure due to blasting at two quarries located at Beerahalli, Oblahalli and Huluvanahalli villages (Sy. Nos. 25, 109 and 110 and QL Nos. 2505R1, 2554R3, 2533R2 and 2532R2) of Hoskote Taluk, Bengaluru Rural District, Karnataka	RBalachander, G C Naveen, A ITheresraj, G.Gopinath and H S Venkatesh	Completed
49	RB-13-05	Technical Advice on Rip Rap Blasting for the Construction of Earth Cum Rock Filled Dam, Indira SagarPolavaram Project, East Godhavari District, Andhra Pradesh	G Gopinath, R Balachander, A I Theresraj, G C Naveen and H. S. Venkatesh	Completed
50	RB-15-03	Study on feasibility of blasting for excavation of Tail Race Tunnel of VishnugadPipalkoti HEP (444MW) under Durgapur village, Chamoli, Uttrakhand, THDC India Limited	R Balachander, A I Theresraj, G C Naveen, G Gopinath and H S Venkatesh	Completed
51	RB-15-05	Blast vibration study, proof checking and monitoring of blast induced vibration at nearby structures, Darlipalli Super Thermal Power Project (DSTPP), Stage-I (2×800 MW), NTPC Limited, Odisha	G C Naveen,.Balachander, A I Theresraj, G Gopinath and H S Venkatesh	Completed
52	RB-16-04	Monitoring of blast induced vibration at two identified locations (Phase-III), Darlipalli Super Thermal Power Project (DSTPP), Stage-I (2×800 MW), NTPC Limited, Odisha	G C Naveen, R Balachander, A I Theresraj, G Gopinath and H S Venkatesh	Completed

53	RB-16-02, 16-03, 16-05 & 16-06	Study on vibration and air overpressure for the blast conducted to construct unit 3 & 4 of Kudankulam nuclear power plant, Kudankulam, Tamil Nadu	G Gopinath, Balachander, A I Theresraj, G C Naveen and. H. S. Venkatesh	Completed
54	RB-16-08	Monitoring of machine vibration at Kadubesanahalli project, Kalyani Developers, Bangalore	G Gopinath, R Balachander, G C Naveen, A I Theresraj,and H S Venkatesh	Completed
55	RB-16-07	To ascertain the feasibility of a proposed twin tunnel for missing line of Mumbai Pune Expressway, Mumbai.	G Gopinath, R Balachander, G C Naveen, A I Theresraj and H S Venkatesh	On-going
56	RB-16-09	Monitoring of blast induced vibration at two identified locations (Phase-III), Darlipalli Super Thermal Power Project (DSTPP), Stage-I (2×800 MW), NTPC Limited, Odisha - Extension-I	G C Naveen, G Gopinath, R Balachander, A I Theresraj and H S Venkatesh	On-going
SEISMOTECTONIC CELL				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
57	EE-14-02	Evaluation of Light House Lineament related with Jaithapur Nuclear Power Plant, through trench studies, Ratnagiri, Maharashtra.	Biju John, Yogendra Singh, Divyalakshmi K S, Carter R M Tamilarasan K and A Rajan Babu	On-going
58	EE-15-01-r	Geological and geomorphic characterization of the frontal thrust fault at central and northeast Himalaya.	Biju John (collaborative project with JNCASR and IISc)	On-going
59	ST-16-01	Seismotectonic Evaluation (Feasibility) of the Proposed Nuclear Power Project Site at Gugulapalli, Nellore District, Andhra Pradesh	Biju John, Yogendra Singh, Divyalakshmi K S and A Rajan Babu	On-going
60	ST-16-02	Seismotectonic Evaluation (feasibility Study) for the Proposed Nuclear Power Project Site at Tummalapenta, Chennyapalem &Karedu, in Andhra Pradesh	Biju John, Yogendra Singh, Divyalakshmi K S, Tamilarasan K, Carter RM and A Rajan Babu	On-going
MICROSEISMIC AND ENGINEERING SEISMOLOGY DEPARTMENT				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
61	MS-11-01B	Installation and monitoring for two years at TVHPP Tapovan- Vishanughat Project	Sivakumar Cherukuri and Vikalp Kumar	On-going
62	ES-15-01-r	Continuance of operation and maintenance of the broad band seismological observatory at KGF	Sivakumar Cherukuri and Vikalp Kumar	On-going
63	MS-16-01	Stability monitoring of power hose cavern of Tala hydro power plant using microseismic (1st Jan-31st Dec,2017)	Sivakumar Cherukuri and Vikalp Kumar	On-going

ENVIRONMENTAL AND EXPLORATION GEOPHYSICS DEPARTMENT				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
64	ES-12-02-r	Estimation of seismic hazard in and around the mined out areas of Kolar Gold Fields.	Balasubramaniam, Goverdhan K, Praveena Das Jennifer and T Amrith Renaldy,	On-going
CENTRE FOR TESTING SERVICES-ROCK FRACTURE MECHANICS				
Sl. No.	**Project No.**	**Title of Project**	**Persons Involved**	**Status**
65	RF-16-01	Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of location-II, Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu. SECON.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	Completed
66	RF-15-03	Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of Dr. B.R.A. PranahithaChevella Lift Irrigation Scheme, Package-12-Mega Engineering and Infrastructure Limited (MEIL).	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	Completed
67	GC-15-06	Determination of Physico mechanical properties for design of stoping parameters for Mansar mine, MOIL ltd.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	Completed
68	RF-15-02	Laboratory Geotechnical Investigations on Rock Core Samples for optimizing of stoping parameters, of Hutti, Uti, and Hirabuddini Gold Mines, HGML.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	On-going
69	RF-16-02	Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of Dr. B.R.A. PranahithaChevella Lift Irrigation Scheme, Package-11, Mega Engineering and Infrastructure Limited.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	On-going
70	RF-16-03	Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of Dr. B.R.A. PranahithaChevella Lift Irrigation Scheme, Package-8, Mega Engineering and Infrastructure Limited.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	On-going
71	RF-16-04 (ONGC)	Laboratory Geotechnical Investigations on Rock Core Samples of Mumbai offshore, A& AA Basin, Jorhat (Regional Geoscience Laboratory, Sivasagar), and Kauvery Basin, Karikal, from COD Basement Exploration, ONGC Ltd, Mumbai.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	On-going
72	RF-16-05 (ONGC)	Laboratory Geotechnical Investigations on Rock Core Samples (Shale) of Geleki area of Assam Asset, Sivasagar, from Institute of Drilling Technology, ONGC, Dehradun.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	On-going
73	RF-16-06 (ONGC)	Laboratory Geotechnical Investigations on Rock Core Samples (Shale) of KG-98/2 area of KG_PG Basin, from Geodata Processing & Interpretation Centre (GEOPIC), ONGC, Dehradun.	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	On-going

CENTRE FOR TESTING SERVICES-MATERIAL TESTING LABORATORY				
Sl. No.	**Project No.**	**Clients**	**Persons Involved**	**Types of tests conducted**
74	CTS N-16-01	M/s Arulmigu Dhandayuthapani SwamyThirukoil, Palani, Tamil Nadu.	A Rajan Babu, S Udaya Kumar, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, J Raja, S Babu, S Thobias and Y Naveen Anandan	MPT & UT
75	ND-16-1Ac	M/s Hindustan Zinc Limited (HZL) – RajpuraDariba Mines, Rajasthan.	A Rajan Babu, SagayaBenady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Thobias, Y Naveen Anandan, S Babu, and S Arvind Kumar	MPT, UT & WRD
76	ND-16-1Bc	M/s Hindustan Zinc Limited (HZL) - Zawar group of Mines, Rajasthan.	A. Rajan Babu, SagayaBenady, Vivek Dominic Savio, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S.Thobias, Y. Naveen Anandan, S. Babu, and S. Arvind Kumar	MPT, UT & WRD
77	ND-16-02	M/s National Mineral Development Corporation Limited (OCSL Plant), Chhattisgarh.	A. Rajan Babu, G D Raju, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D. Prashanth Kumar, Syed Asghar, S.Thobias, Y. Naveen Anandan, S. Babu, S. Arvind Kumar and D. Vinod Kumar	VI, MPT, UT, LT & WRD
78	ND-16-03	M/s Shaft Sinkers Mauritius (SSM), Rajasthan.	A. Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D. Prashanth Kumar, Syed Asghar,	MPT, UT & WRD

			S.Thobias, Y. Naveen Anandan, S. Babu, S. Arvind Kumar and D. Vinod Kumar	
79	ND-16-04	M/s Hindustan Copper Limited (HCL) – Khetri&Kolihan Mines, Rajasthan.	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 and D. Vinod Kumar	UT & WRD
80	ND-16-06	M/s National Aluminium Company Limited (NALCO), Odisha.	A. Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D. Prashanth Kumar, Syed Asghar, S.Thobias, Y. Naveen Anandan, S. Babu, and S. Arvind Kumar	WRD
81	ND-16-07	M/s Jagson International Limited (Jakhu ropeway), Shimla, Himachal Pradesh	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 and D. Vinod Kumar	VI, LT, UT, IRT & WRD
82	ND-16-08	M/s Shaft Sinkers Mauritius (SSM), Rajasthan.	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 and D. Vinod Kumar	MPT, UT & WRD
83	ND-16-9Ac	M/s Hindustan Zinc Limited (HZL) – RajpuraDariba Mines, Rajasthan.	A. Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor,	MPT, UT & WRD

			D. Prashanth Kumar, Syed Asghar, S.Thobias, Y. Naveen Anandan, S. Babu, and S. Arvind Kumar	
84	ND-16-9Bc	M/s Hindustan Zinc Limited (HZL) - Zawar group of Mines, Rajasthan.	A. Rajan Babu, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D. Prashanth Kumar, Syed Asghar, S.Thobias, Y. Naveen Anandan, S. Babu, and S. Arvind Kumar	MPT, UT & WRD
85	ND-16-10	M/s ArulmiguDhandayuthapaniSwamyThirukoil, Palani, Rajasthan.	A. Rajan Babu, S. Udaya Kumar, Sagaya Benady, Vivek Dominic Savio, Royston Angelo Victor, D. Prashanth Kumar, Syed Asghar, J. Raja, S. Babu, S.Thobias and Y. Naveen Anandan	VI, MPT, UT & IRT

Annexure-7

LIST OF PUBLICATIONS

	ENGINEERING GEOLOGY
Sl. No.	**TITLE**
1	A.K. Naithani, Prasnna Jain, L.G. Singh, J.K. Jain, Vikas Palaye, M.K. Nema, N. Madhusudana Rao and Arvind Shrivastava, 2016: *Geotechnical evaluation of tower foundation and pond floor of natural draught cooling tower: a case study from Atomic Power Project*. Proceedings Sixth Annual Rock Conference INDOROCK 2016, pp 1-11.
2	A.K. Naithani, Prasnna Jain, Rabi Bhusan, J.K. Jain and P.C. Nawani, 2016: *Geological mapping of foundation floor for nuclear building of Rajasthan Atomic Power Project, Rawatbhata, India*. Special Publication of the Geological Society of India No. 4, pp 111-118 (DOI: 10.17491/cgsi/2016/95903).
3	D.S. Rawat, A.K. Naithani, Rajesh Patel and P.A. Samuel, 2016: *Prediction of adverse geological features based on the construction stage geological mapping: a case study of underground cavern, Karimnagar, Telangana State, India.* Indian Journal of Power and River Valley Development, vol. 66, Nos. 7&8, pp 103-109, .
4	Manoj Kumar, Jitendra Prasad and A.K. Naithani, 2016: *Classification and selection methodology for temporary support systems for underground structures.* Proceedings of Recent Advances in Rock Engineering (RARE 2016), Published by Atlantis Press, Paris, pp 191-198, (DOI: 10.2991/rare-16.2016.31).
5	LG Singh, AK Naithani, Devendra Singh Rawat and Prasnna Jain, 2016: *Engineering geological consideration of a deep pump house foundation floor: case study of lift irrigation scheme, India.* Proceedings of Recent Advances in Rock Engineering (RARE 2016), Published by Atlantis Press, Paris, pp 253-260, (DOI: 10.2991/rare-16.2016.40).
6	DS Rawat, AK Naithani, LG Singh, Prasnna Jain, Rajesh Patel, K Ravindra Nath and RNS Babu, 2016: *Tunneling through adverse geological conditions in granitic terrain.* Proceedings of Recent Advances in Rock Engineering (RARE 2016), Published by Atlantis Press, Paris, pp 261-265, (DOI: 10.2991/rare-16.2016.41).
7	Prasnna Jain, AK Naithani, Rabi Bhusan, LG Singh, DS Rawat, A Shrivastava, NM Rao, JK Jain and PC Nawani, 2016: *Engineering geological and geotechnical assessment of floor of control building of nuclear reactors-7&8 of Rajasthan Atomic Power Project, Rawatbhata, India*. Proceedings of Recent Advances in Rock Engineering (RARE 2016), Published by Atlantis Press, Paris, pp 408-412, (DOI: 10.2991/rare-16.2016.64).
8	A.K. Naithani, J.K. Jain, Prasnna Jain, L.G. Singh, and Rabi Bhusan, 2017: *Engineering geological investigations of a nuclear building foundation – a case study from atomic power project, India.* Geosciences Research, vol. 2, no. 1, pp 14-21, Isaac Scientific Publishing, (DOI: 10.22606/gr.2017.21003).
9	A.K. Naithani, 2017: *Geotechnical investigations and support design of underground pump house cavern – a case study from lift irrigation project.* Geotechnical and Geological Engineering, Springer Publ. (in press).
10	AK Naithani, LG Singh and Prasnna Jain, 2017: *Rock mass characterization and support design for underground additional surge pool cavern – a case study, India.* Geomaterials, Scientific Research Publishing (in press).
	ENGINEERING GEOPHYSICS
Sl. No.	**TITLE**
11	S Nelliat, B. Butchi Babu, PC Jha, YV Sivaram and SN Verma; *Borehole GPR investigations from underground for mapping the extension of old working at a Pb-Zn Mine in Rajasthan, India;* Proceedings of RARE-2016, doi:10.2991/rare-16.2016.82; Advances in Engineering Research; Vol.91, Atlantis Press, Amsterdam
12	B Butchi Babu, PC Jha, S Nelliat and YV Sivaram; *Foundation evaluation of a barrage using geophysical and geotechnical investigations;* Proceedings of RARE-2016, doi:10.2991/rare-16.2016.91; Advances in Engineering Research; Vol.91, Atlantis Press, Amsterdam
13	VR Balasubramaniam, PC Jha, B Butchi Babu, S Nelliat, YV Sivaram and K Goverdhan; *Influence of geophysical judgement and software parameters on interpretation of*

	*seismic sectio*n International Conference on Recent Advances in Rock Engineering (RARE-2016), Bengaluru 2016 (pp - 233-237)
	GEOTECHNICAL ENGINEERING
Sl. No.	**TITLE**
14	Subrahmanyam, D.S., Shyam, G., Vamshidhar, K. and Vikram, S. *Influence of topography on In-situ stress parameter at the proposed powerhouse sites of Rupaligad Re-regulating Project, Nepal,* International Conference on Recent Advances in Rock Engineering - Atlantis Press ISSN 2352-5401, doi: 10.2991/rare-16.2016.63 2016, pp 404-407.
15	Biju John, Rajan Babu A, Subrahmanyam D.S., Yogendra Singh, Divyalakshmi, K.S., and Nelliat S., *Seismicity of Kerala: An update,* International Conference on Recent Advances in Rock Engineering - Atlantis Press ISSN 2352-5401, doi: 10.2991/rare-16.2016.63 2016, pp 404-407.
16	*Vikram, S*. Subrahmanyam, D.S., Dheeraj Kumar, *Role of stress regime in deep mining conditions, International Conference on Deep Excavation, Energy Resources and Production,* Dept. of Mining Engineering, Indian Institute of Technology Kharagpur, 2017, pp 46.
17	Subrahmanyam, D.S., Shyam, G., Vamshidhar, K., and Vikram Shankar., *Influence of In situ stress on the alignment of head race tunnel due to the intersection of anticlines at one of the hydroelectric projects.* Tunneling Association of India (Paper accepted)
	GRUND CONTROL CELL
Sl. No.	**TITLE**
18	G D Raju , Prasnna Jain, V Venkateswarlu and A Rajan Babu "*Optimisation of stoping parameters for a cut and fill stope at Chikla mine of MOIL Ltd – A case study"* – International conference on Recent Advances in Rock Engineering (RARE 2016), Bangalore. 16-18, November 2016.
19	Ajay Ghade, KK Rao, Vijaykumar & G D Raju; "*Rock mechanics investigations at Tummalapalle Uranium Mine of UCIL*".- – International conference on Recent Advances in Rock Engineering (RARE 2016), Bangalore. 16-18, November 2016.
20	Bhardwaj Pandit, L.Shivakumar Babu & G D Raju; "*Robust geotechnical design of rock bolts for stability of rock slopes using response surface* – International conference on Recent Advances in Rock Engineering (RARE 2016), Bangalore. 16-18, November 2016.
	SLOPE STABILITY CELL
Sl. No.	**TITLE**
21	Kumar Reddy, S and Rajan Babu A. 2016. '*Stability analysis of a waste dump in Chromite mine: Existing state and planned heightening'*, Proceedings of 3rd International conference on Earth Sciences and Engineering, 17-18 June, 2016, Coimbatore.
22	Kumar Reddy, S and Rajan Babu A. 2016. '*Stability analysis of an open pit slope in a Chromite mine*', Proceedings of International conference on Recent Advances in Rock Engineering, 16-18 Nov, 2016, Bangalore.
23	Kumar Reddy, S and Rajan Babu A. 2017. '*Numerical stability analysis of an open pit mine slope by FLAC/SLOPE- A case study'*, Proceedings of conference on Numerical modeling in geomechanics, 3-4 March, 2017, IIT-Roorkee.
24	A. Rajan Babu, GC Naveen and SS Meena, *A novel grading methodology and recovery assessment technique for dimensional stone production*. Recent Advances in Rock Engineering, RARE 2016, Atlantis Publication, pp-455 – 460.
	NUMERICAL MODELING, GROUND CONTROL, INSTRUMENTATION AND MONITORING
Sl. No.	**TITLE**
25	Sripad, R.N., and Sastry, V.R., 2017, "*Assessment of stability of large caverns in Himalayas using 3D Numerical Modelling"*
26	Siva Prasad B.N.V. & Jayantu S., 2016, *"Evaluation of Strata Behaviour in Blasting Gallery Panel in Underground Coal Mines – A Case Study*", International Symposium on New Equipment, New Technology, Management & Safety in Mining & Mineral Based Industries, 11-12 May 2016, Bhubaneshwar.

27	Siva Prasad B.N.V, Murthy V.M.S.R. & Pandey S.K., 2016*, "Investigations on Rock Drillability Applied to Underground Mine Development vis-à-vis Drill Selection*", International Conference on Recent Advances in Rock Engineering (RARE), 16-18 November 2016, Bengaluru.
28	Rabi Bhusan, Sripad R. N., Vijay Sekar B.H., Sudhakar K. & Aditya M., 2016, "*Stability analysis of shafts in the proposed deepening in Zawar Mines*", International Conference on Recent Advances in Rock Engineering (RARE), 16-18 November 2016, Bengaluru.
29	Siva Prasad B.N.V & Murthy V.M.S.R., 2016, "*Prediction of Penetration Rates of Mechanised Drill Rigs in Hard Rock Underground Mines – Some Field Investigations*", *Int. Journal on Tunnelling and Underground Space Technology* (Under Review).
	ROCK BLASTING AND EXCAVATION ENGINEERING DEPARTMENT
Sl. No.	**TITLE**
30	R. Balachander, H. S. Venkatesh and G. Gopinath, "Tunnel Excavation on the Abutment of an existing Dam" *The Journal of Explosives Engineering, July/Aug. 2016, pp 28-35*
31	H. S. Venkatesh and G. Gopinath, "*Approach for operation and expansion of quarries prone for blast vibration*" International Conference on Recent Advances in Rock engineering (RARE), 16-18 November, 2016, Bengaluru, pp 425-428
32	G C Naveen, R Balachander, G Gopinath and H S Venkatesh, "*Controlled blasting in proximity to urban residential structures*" International Conference on Recent Advances in Rock engineering (RARE), 16-18 November, 2016, Bengaluru, pp 429-436
33	G Gopinath and H S Venkatesh and T Rajendra Babu, "*Prespliting for final wall rock control at spillway in Indira sagar polavaram project"* International Conference on Recent Advances in Rock engineering (RARE), 16-18 November, 2016, Bengaluru, pp 437-442
34	G C Naveen, R Balachander and G Gopinath, *"Controlled blast induced damage for deep surface excavation in highly geologically varying strata*", International Seminar NXGN MIFU, 15-17 Feb 2017, Vigyan Bhawan, New Delhi, , pp 201-208
	ENVIRONMENTAL AND EXPLORATION GEOPHYSICS
Sl. No.	**TITLE**
35	VR Balasubramaniam, PC Jha, B Butchi Babu, S Nelliat, YV Sivaram and K Goverdhan, 2016. *Influence of geophysical judgement and software parameters on interpretation of seismic section,* Proc. of the international conference on Recent Advances in Rock Engineering (RARE-2016), Nov. 16-18, Bengaluru, India, 233-237.
36	Praveena Das Jennifer, VR Balasubramaniam, K Goverdhan and GP Ganapathy, 2016. *Overview of seismic monitoring and assessment of seismic hazard based on a decade of seismic events,* Proc. of the international conference on Recent Advances in Rock Engineering (RARE-2016), Nov. 16-18, Bengaluru, India, 238-245.
37	Amrith Renaldy and Prasnna Jain, 2017. *Slope stability analysis of a limestone mine,* Proc. of the international conference on NexGen Technologies for Mining and Fuel Industries (NxGnMiFu), Feb. 15-17, New Delhi, India, 167-172.
	SEISMOTECTONIC CELL
Sl. No.	**TITLE**
38	Biju John, 2016 *Issues pertaining to active fault identification in cratonic regions: example from Peninsular India,* 7th international INQUA Meeting Paleoseismology, Active Tectonics and Archeoseismology, held at Creston, Colorado, in May 2016.
39	Yogendra Singh, Biju John, G.P. Ganapathy, A. George, S. Harisanth, K.S. Divyalakshmi, S. Kesavan, 2016 *Geomorphic observations from southwestern terminus of Palghat Gap, South India and their tectonic implications.* Journal of Earth System Science, vol. 125, No. 4, pp. 821–839.
40	Rajendran C.P. Biju John and Rajendran K. and Jaishri Sanwal, 2016. *Liquefaction record of the great 1934 earthquake predecessors from the north Bihar alluvial plains of India.* Journal of Seismology Vol. 20, pp 733–745
41	Biju John, A Rajan Babu, DS Subrahmanyam, Yogendra Singh, KS Divyalakshmi, E. Praseeda, Pijush Samui and GP Ganapathy, 2016 *Seismicity of Kerala: An update,* RARE 2016 Published by Atlantis Press pp. 217-220.

42	Yogendra Singh, Biju John and G.P. Ganapathy 2016 *Geomorphic studies for identification of active fault: observations from smaller river basins, South India*, RARE 2016 Published by Atlantis Press pp. 221-226.
43	Yogendra Singh and Biju John, 2017 *Neotectonic evidences from north western terminus of Periyar fault.* Presented in the National seminar on Shear zones and Crustal Blocks of southern India Vol 4, P 13.
44	Rajendran, C. P. Biju John, Anandasabari, K., Jaishri Sanwal, Kusala Rajendran, Pankaj Kumar and S. Chopra, 2017 *On the paleoseismic evidence of 1803 earthquake rupture (or lack of it) along the frontal thrust of the Kumaun Himalaya.* Communicated to Tectonophysics.
MICROSEISMICS AND ENGINEERING SEISMOLOGY	
Sl. No.	**TITLE**
45	"*Microseimsics for powerhouse cavern's stability evaluation*" RARE, NIRM November 16-18 2017

Annexure- 8

NEWS LETTER

ENGINEERING GEOLOGY DEPARTMENT

- Dr AK Naithani is a nominated committee member formed by Archaeological Survey of India to study the deterioration of stone members of shore temple, Mallapuram, Kanchipuram District, T.N.
- Dr AK Naithani regularly attended TEC meetings at NDMA Bhawan, New Delhi. He is a permanent member of Technical Evaluation Committee (TEC) of National Disaster Management Authority (NDMA), Govt. of India for the evaluation of Detailed Project Reports on Landslide Mitigation submitted by State Governments to be funded under "Centrally Sponsored Umbrella Pilot Scheme to Demonstrate Benefits of landslide mitigation". During this period he has reviewed 17 Detail Project Reports of Sikkim, Mizoram, Goa, Nagaland and Uttarkhand States and three revised DPR of Mizoram and Uttarakhand States.
- Dr AK Naithani is a nominated member of the Advisory Board of M/s Geo Constech Pvt. Ltd, New Delhi.
- Dr AK Naithani submitted a note on the request of NECL regarding the feasibility of underground pump house complex of Palamur Ranga Reddy Lift Irrigation Project – Package-1, T.S.
- Dr AK Naithani submitted a note on the request of I & CAD Department, Telangana State on slips in side slopes of R.F. Main Canal of Sri Komaram Bhem Medium Irrigation Project, Adilabad District of Telangana State.
- Dr AK Naithani submitted a note on the request of MEIL regarding the support system of delivery mains of Pranahitha - Chevella Sujala Sravanthi Lift Irrigation Scheme (PCSSLIS) – Package 8 (PCSSLIS-P8), Karimnagar District, Telangana State.
- Dr AK Naithani delivered a lecture on "Mitigation Measures for Landslides - A Case Study" on 27th July 2016 at KGF in a training course on "Controlled Blasting and Rock Mechanics" Organized by NIRM for the BRO Engineers at KGF during 25 to 30 July 2016.
- Dr AK Naithani delivered two lectures on "RMR – a system for characterizing rock mass classification" on 30th January and 14th February 2017 at Bengaluru in a training program on "Strata Control" Organized by NIRM for the SECL Officials at Bengaluru and KGF during January and February 2017.
- Dr AK Naithani, Dr. DS Rawat, Dr LG Singh and Prasnna Jain attended Geological Society of India monthly Scientific Lectures at Geological Survey of India, Bengaluru.
- Dr AK Naithani and Dr Prasnna Jain attended sixth Annual Rock Conference INDOROCK 2016 jointly organized by IIT Bombay and Indian Society of Rock Mechanics and Tunnelling Technology from 17th to 18th June 2016 at IIT Bombat and presented a technical paper. Dr Naithani was also a member of technical committee for this conference.
- Dr AK Naithani attended seminar on "Development in Geosciences in the Past Decade – Emerging Trends for the Future and Impact on Society" organized by Department of Geology and Geophysics, IIT Kharagpur from 21st to 23rd October 2016 at IIT Kharagpur and presented a technical paper.
- Dr AK Naithani attended two workshos on 1) Mohr Circle Simplified and 2) Modern Methods of Fabric Analysis in Deformed Rocks organized by Department of Geology and Geophysics, IIT Kharagpur from 21st to 23rd October 2016 at IIT Kharagpur.
- Dr AK Naithani attended 58th Annual General Body Meeting of the Geological Society of India at IIT Kharagpur on 23rd October 2016.

ENVIRONMENTAL AND EXPLORATION GEOPHYSICS DEPARTMENT

- Dr VR Balasubramaniam, Scientist-V and Head, EEGD, participated in the international conference, RARE-2016, organised by NIRM. He was one of the lead responsibles in the editorial committee that compiled the proceedings volume.

- Mr Goverdhan Kantepudi, Scientist-I, EEGD participated in the international conference, RARE-2016, organised by NIRM. He was also member of the editorial committee that compiled the conference proceedings volume.

- Mrs Praveena Das Jennifer, Scientist-II, EEGD participated in the international conference, RARE-2016, organised by NIRM. She contributed significantly to various important backend processes and was also member of the editorial committee that compiled the conference proceedings volume.
- Mr Amrith Renaldy, Scientist-II, EEGD participated in the international conference, RARE-2016, organised by NIRM. He contributed in development of conference website and as member of editorial committee.
- Dr VR Balasubramaniam, visited HGML mines for evaluating feasibility of microseismic monitoring in the deeper level of mines in and around active working regions.

GEOTECHNICAL ENGINEERING DEPARTMENT

- Mr. G Shyam has delivered a lecture on Strata Control for the South Eastern Coal Fields as part of the training programme at NIRM Bengaluru from 30th January-3rd February 2017 and 13th-17th February 2017.
- Mr. K Vamshidhar has delivered a lecture on Strata Control for the South Eastern Coal Fields as part of the training programme at NIRM Bengaluru from 30th January-3rd February 2017 and 13th-17th February 2017.
- Mr. S Vikram has delivered a lecture on Strata Control for the South Eastern Coal Fields as part of the training programme at NIRM Bengaluru from 30th January-3rd February 2017 and 13th-17th February 2017.

NUMERICAL MODELING, GROUND CONTROL, INSTRUMENTATION AND MONITORING DEPARTMENT

- Mr. Sripad R Naik delivered an invited talk on “Instrumentation in Mining” at ‘SPECTRUM 2017’ Golden Jubilee celebration of Goa Collage of Engineering, 16th March, 2017.
- Mr. Sripad R Naik delivered an invited talk on “Application of Numerical Modelling in Tunnel and caverns” and “Instrumentation in Tunnel and caverns and its utility” at Training Course organized by Regional Training Institute, GSI, Northern Region, Dehardun on 26th November, 2016.

ROCK BLASTING AND EXCAVATION ENGINEERING DEPARTMENT

- Dr. H. S. Venkatesh attended meetings as Member, State High Level Committee to study the issues with regard to quarrying activities vis-à-vis safety of Yeleswaram dam, East Godavari District, Govt. of Andhra Pradesh.
- Dr. H. S. Venkatesh is continuing and attending meetings as Expert Committee Member representing NIRM in the Expert Body (Dr. B P Das Committee 2015) as an expert in Blasting & Tunnelling constituted by MoEF&CC, Govt. of India as per the order of the Hon’ble Supreme Court to make a detailed study as per ToR prescribed in the order with regard to environmental degradation due to Hydroelectric power projects (existing and under construction) in the river basins of Alaknanda, Bhagirathi and their tributaries
- Dr. H. S. Venkatesh participated MEAI meetings as a council member, Bangalore Chapter.
- Dr. H. S. Venkatesh participated as Member, Organising Committees – National & International Conferences.
- Dr. H. S. Venkatesh participated as expert member in the State level committee on Palamuru-Ranga Reddy irrigation project committee, Govt. of Telangana, Hyderabad on 11-12 July 2016
- Dr. H. S. Venkatesh organised, RARE-2016 an International Conference on Recent Advances in Rock Engineering, 16-18 November, 2016, Bengaluru

- Dr. H. S. Venkatesh, A I Theresraj, G Gopinath, G C Naveen and R Balachander have International Conference on Recent Advances in Rock Engineering (RARE- 2016), 16-18 November, 2016, Bengaluru
- Dr. H. S. Venkatesh and G. Gopinath visited Tunga Bhadra dam related to the excavation of Mini Hydel project on 08/12/2016
- Dr. H. S. Venkatesh, G Gopinath, G C Naveen and R Balachander have attended International Seminar NXGN MIFU, 15-17 Feb 2017, Vigyan Bhawan, New Delhi

- G Gopinath guided Engineering students on “Monitoring of ground vibration due to blasting near railway line-A case study” for their Engineering project.
- G C Naveen submitted a Technical note on controlled blasting to The Executive Engineer, Anakkayam SHEP, KSEB, Kerala
- G Gopinath attended MAGNUM 2016 as a chief guest and delivered special lecture on Blasting at Acharya Institute of Technology, Bangalore, 26.10.2016

SEISMOTECTONIC CELL

- Mr. Yogendra Singh and Dr. Divyalakshmi K. S. attended site selection subcommittee meeting for locating the Gogulapalli site. The meeting was held with NPCIL, AMD and APGENCO officials at Nellore on 26-04-2016 and 27-04-2016.
- Dr. Biju John and Mr. Yogendra Singh attended a site selection committee meeting at Nellore from 3-8-2016 and 4-8-2016.
- Dr. Biju John and Mr. Yogendra Singh attended site selection committee meeting at Mumbai from 29-9-2016 and 30-9-2016.

SLOPE STABILITY CELL

- Dr SK Reddy guided the students of Dr TTIT, KGF, the project on “Geotechnical studies in ISMOIR Mines” for the final year BE (Mining) students.
- Dr SK Reddy guided the students of NITK, Surathkal, for their one month internship training programme on "Slope Stability Studies".
- Delivered lecture for training program on strata control for SECL officials on ‘Types of Instruments’, 16 February 2017, Bangalore.
- Guest lecture on ‘Rock Engineering’ in Jain college, 28 February 2017, Kolar Gold Fields.
- Dr SK Reddy guiding the final year BE (Mining) students of Dr TTIT, KGF, the project on “Movement and surveying of opencast mine slopes by radar”.

Annexure – 9

NIRM STAFF ON ROLL
(as on 31.03.2017)

Director: Dr V Venkateswarlu

Departments & Regular Staff

Engineering Geology	
Dr AK Naithani	
Dr Devendra Singh Rawat	
Dr L Gopeshwor Singh	
Dr Prasnna Jain	
Engineering Geophysics	
Dr PC Jha	
Dr Sandeep Nelliat	
Mr Butchi Babu Bongu	
Mr YV Sivaram	
Mr Shashi Nath Verma	
Geotechnical Engineering	
Dr D S Subrahmanyam	
Mr G Shyam	
Mr K Vamshidhar	
Mr Vikram S	
Mr Shashidhara KN	
Ground Control & Slope Stability Cell	
Dr S Kumar Reddy	
Mr Bharath Kumar A Y	
Mr N Selvaraj	
Numerical Modelling	
Mr Sripad R Naik	
Dr Rabi Bhusan	
Mr BH Vijay Sekhar	
Mr K Sudhakar	
Mr Aditya Mishra	
Mr BNV Siva Prasad	
Rock Blasting & Excavation Engineering	
Dr HS Venkatesh	
Mr G Gopinath	
Mr GC Naveen	
Mr AI Theresraj	
Mr R Balachander	
Project Monitoring Cell	
Dr V Venkateswarlu (add. charge)	
Mr Sultan Singh Meena	
Mr A Vijaya Kumar	

Seismotectonic cell	
	Dr Biju John
	Dr K S Divyalakshmi
	Mr Yogendra Singh
Microseismic & Engineering Seismology	
	Mr. Sivakumar Cherukuri
	Mr Vikalp Kumar
Environmental & Exploration Geophysics	
	Dr VR Balasubramaniam
	Mr T Amrith Renaldy
	Mrs Praveena Das Jennifer
	Mr Goverdhan Kantepudi
Centre for Testing Sercices	
	Mr A Rajan Babu
	Dr G Doraswamy Raju
	Mr S Udayakumar
	Mr D Joseph
	Mr Sagaya Benady
	Mr J Raja
	Mr Royston Angelo Victor
	Mr D Prashanth Kumar
	Mr Syed Asghar
	Mr R Prabhu
	Mr S Babu
Administration	
	Mr AN Nagarajan
	Mr S Ravi
	Mr JV Sastry
	Mrs S Lourdu Mary
	Mr N Jothiappa
	Mrs Janaki Bhavani P
Drivers	
	Mr P Venkata Reddy
	Mr K Manjunath
Staff resigned during the Year	
	Mr Ashok Kumar
Staff retired during the Year	
	Mrs CV Lalitha

NIRM organised and conducted a training programme for officials of M/s South Eastern Coalfields Limited (SECL) on Strata Control and instrumentation for underground coal mines, at NIRM, HO, Bengaluru in the month of January and February of 2017.

National Institute of Rock Mechanics

The National Institute of Rock Mechanics is a research organization set up under Ministry of Mines, with an objective to support and provide innovative approaches in the fields of Rock Mechanics and Ground Control for sustainable development in the fields of mining and civil engineering excavations. Over a period of time, rock mechanics is being increasingly applied for the design of excavations to improve the safety and stability in not only mines but in a variety of excavations in rock and NIRM has been supporting the sustainable development of the country as well as extending the expert services to other nations.

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