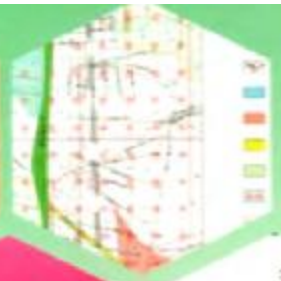
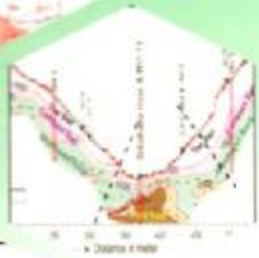
Engineering Geology



Engineering Geophysics



Geotechnical Engineering

Rock Blasting & Excavation Engineering

Numerical Modelling

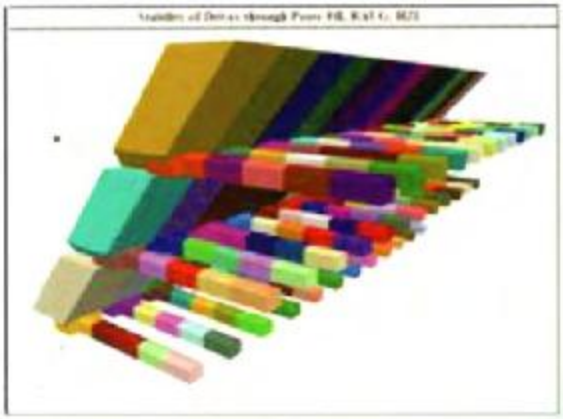
Centre for Testing Services

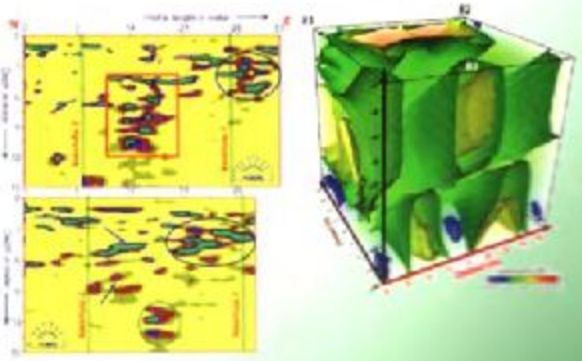
Environmental & Exploration Geophysics

Microseismics and Engineering Seismology

Geomechanics and Ground Control

Annual Report 2017-18





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Group photograph of training officers from RVNL

ANNUAL REPORT
(2017-18)

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CONTENTS

DIRECTOR'S REPORT
(2017-18)

I am pleased to present the Annual Report of this Institute for the year 2017-18. 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 (power and infrastructure) for both government and industry sponsored projects. In continuation of these activities, the Institute was associated with over 60 projects during 2017-18 spread over four major sectors :

- Mining Sector
- Power Sector
- Infrastructure Sector
- Miscellaneous industries

Apart from them, both laboratory and in-situ testing services of material and rock samples were also done for these sectors.

Major Achievements

During the year 2017-18, NIRM completed 50 sponsored projects, and work on about 17 other projects has been continuing. This year, our scientists have published 38 technical papers in international journals / national journals / conferences. During the year, NIRM received Rs. 636 lacs towards non-plan grant-in-aid from the Ministry of Mines, generated internal revenue to the tune of Rs. 640 lacs from completed projects with a cash flow of around 1312 lacs.

As part of information dissemination and skill development exercise, NIRM conducted two training courses during 2017-18 - one each for the Engineers of the Rail Vikas Nigam Ltd and other for the Mumbai Rail Vikash Corporation Ltd. The highlights of major R&D activities during 2017-18 are enumerated below.

Mining Sector

NIRM has made significant contribution to the development of safe and economic practices for coal, metal and opencast mines under difficult geomining conditions. During the year 2017-18, investigations were carried out for 12 mining projects which included three S&T projects for metal and coal mines, two modelling projects for HZL mines and three projects related to mining methods for MOIL. In addition slope stability studies were done for four opencast mines/ quarries.

The major areas of work include establishing a credible geophysical method for mapping a subsidence-prone area by surface geophysical survey; determination of in-situ stress upto a depth of 600m in the mines of SCCL for roof hazard maps for future mining activity and seismic hazard analysis for the remnant mining-induced-seismicity of BGML mines at KGF. All these projects were sponsored under S&T programme.

Mining methods for sub-level stoping under critical conditions were devised for Munar, Chikla and Balaghat Mines, stability studies for barrier pillars in the Thumalpalli mines of UCIL was done by Numerical model and empirical data, design for safe extraction of rib and crown pillars at Balria mines (HZL) by Numerical modelling and mining of remnant ore after paste-filling and driving through paste fill was studied by Numerical modelling for the RAUG mines (HZL).

Pit slope stability studies were done for the Kaliapani Chromite mines (Odisha) and Krishna Limetsone mines (TN), bench design for stable slope was investigated for a granite quarry (TN) and CGP Iron ore Mines (Goa).

Power Sector

NIRM has made significant contribution to the development of Power sector. During the year 2017-18, investigations were carried out for 21 power sector projects which include eight from Nuclear Power, twelve from hydel power and one from Thermal power.

Seismotectonics studies for site characterisation for three upcoming nuclear power plants in Andhra Pradesh; lineament mapping for Jaitapur NPP and investigation for suspected geothermal activities reported at Kundankulam NPP site were successfully completed. Guidance for controlled blasting for the expansion phase of Kundankulam NPP is being continued. In addition, guided blasting at the Rawatbhata site and geological mapping for the foundation pond floors and pump houses of Natural Draft Cooling Towers of RAPP were also completed successfully. Cross-hole testing for engineered foundation design was done at a mock up site for the GHAV Project in Haryana.

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). Instrumentation data analysis for stability of caverns and structures of various hydel projects of MHPA, PHPA, THPA (all in Bhutan) SSNNL, SJVNL and NJPC were done. Guidance for controlled blasting for various excavations of PHPA-I and PHPA-II projects are being continued. Numerical modelling studies for the stability and support design for butterfly valve chamber of MHPA Shaft as well as shaft and power house of Naitwar-Mori Project of SJVNL were completed. Determination of safe bearing capacity by in-situ Plate load & Foot load tests was done for the pothead yard of PHPA-II project at Bhutan. Site characterisation for fixing one of the two alternate dam axes for the Sillahalla hydel project of TANGEDCO was done by geophysical method. Guidance for controlled blasting is being continue for the Darlipalli Super Thermal Power Project at Odisha.

Infrastructure Sector

The Institute was involved in investing complex site investigation problems related to various infrastructure projects related to irrigation projects, marine projects, housing, road, metro and drinking water projects. During the year 2017-18, investigations were carried out for 14 infrastructure sector projects which include eight from irrigation projects, two from marine projects and one each for housing, road, metro and drinking water.

During this year, NIRM continued the comprehensive investigations of major Lift Irrigation Scheme in Telangana State. Detailed geological mapping were done for Pacakage-6, 10 and 12 of Kaleshwaram (KLIS) project. In addition, the in-situ stress determination was done for PRLIS Lift-II & II as well as for package-16. 3D Numerical Modelling and Instrumentation data analysis were done for the pump house and surge pool caverns of KLIS project (package-11). Blast vibration studies were done for various components of the MGKLIS project.

Guidance for controlled blasting for maximising extraction of armour rocks were provided for two crucial marine projects viz. Gopalpur Port in Odisha and Varsha Project in AP where breakwater construction is planned.

For the NMRCL metro rail network, vibration-induced-instability for the heritage Ambazari dam at Nagpur and Mapping for possible sub-surface water flow path leading to

collapse of approach road in prestigious Tata Promont housing society at Bangalore were carried out by geophysical methods. Geological mapping for the foundation of dam/barrage and the in-situ geotechnical test for shear strength of rock & rock/concrete interface for the drinking water facility (at BWT) were done. Feasibility studies for the controlled blasting excavation for the remnant portion of Mumbai-Pune expressway between Khapoli & Singad was also taken up.

Miscellaneous Sector

Apart from key work areas of Mining, Power and Infrastructure sector, the Institute was involved in site investigation by geophysical method (using GPR) for the future exploration work of ASI at Vadnagar (Gujrat), safety of heritage Bahubali Statue in Karnataka against vibration-induced-damage due to proposed installation of support lifts during Maha-Mastabhiseka Parva and analysis of damage vis-à-vis suggestion for conservation measures post-flooding of heritage Belum Caves (natural) damaged following cyclone in Andhra Pradesh. Involvement in such works of public interest earns a great repute to the Institute.

Testing Services

With an accredited test laboratory, NIRM has carried out in-situ testing of mining components in the mines of SCCL, SAIL, HZL, HCL, HGML and NALCO. Apart from them, in-situ testing of various mining components was done for M/s Shaft Sinkers and other service providers. Laboratory testing of ropes, material and rock samples for various physico-mechanical properties were also done for various industries including ONGC, Varsha project and various mining companies.

Acknowledgements

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 by assigning various sponsored projects.

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 sponsoring 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.

* * *

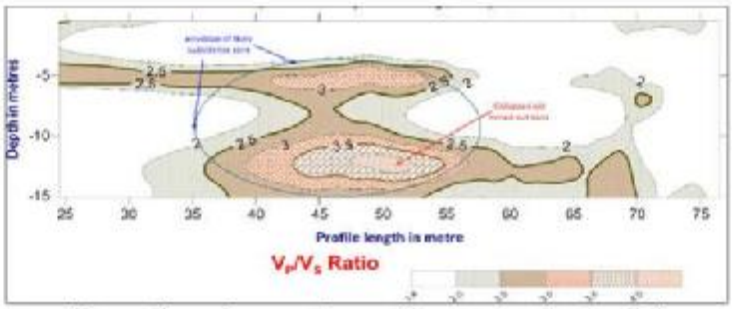
1. Mining Sector

National Institute of Rock Mechanics provides its R&D support and expertise to the mining industry (surface and underground), power industry (hydel, thermal and nuclear) and infrastructure projects (rail, road, metro, irrigation, marine, urban construction etc.) by carrying out varieties of investigations in the area of rock engineering and rock mechanics.

Key areas of activities of the Institute involve numerical modelling, excavation engineering, controlled blasting, seismology, slope stability, site characterisation (including geological, geophysical and geotechnical investigations), laboratory testing of rock samples, wire ropes and other mining accessories and NDT testing (both at lab and in-situ).

During this year 12 projects were taken up in the mining sector, out of which two were from coal mines, seven from metal mines and three others from open cast mines (granite, limestone and iron ore quarries). While investigations were completed and final report submitted for six of them, four other are being continued and for the remaining two, either data processing is in progress or an interim report is submitted.

» Under an S&T project on development of a viable surface geophysical technique for mapping a potential settling environment (subsidence prone zone), investigation was taken up in the old coal mining areas of ECL. Geophysical surveys using both Multichannel Analysis of Surface Waves (MASW) and seismic refraction technique were done in a subsidence prone area at Jobagram under Jamadoba area.



Formation of anomalous pattern around potential subsidence zone as seen in the plot of V_P/V_S with depth

A contour plot was made with V_P/V_S against depth. An abnormal high ratio of V_P/Vs over old mined out region confirmed the presence of an impending subsidence with its focus at 5-7m depth at the time of survey. True to expectation, within a month entire area witnessed a massive subsidence with 3m trough at centre.

» In yet another S&T project, investigation for assessing the horizontal stress field in the deeper horizons and development of roof hazard maps of coal resources in SCCL command area was taken up. In-situ stress measurements was successfully completed in SCCL mines upto a depth of 600m, the first ever such deep-seated in-situ investigation carried out in India. Results of this study will be useful in devising safe mining practices in new mining regime. This experiment was widely reported in newspapers and local TV. Data analysis and preparation of the draft report is under progress.

SCCL goes for latest technology

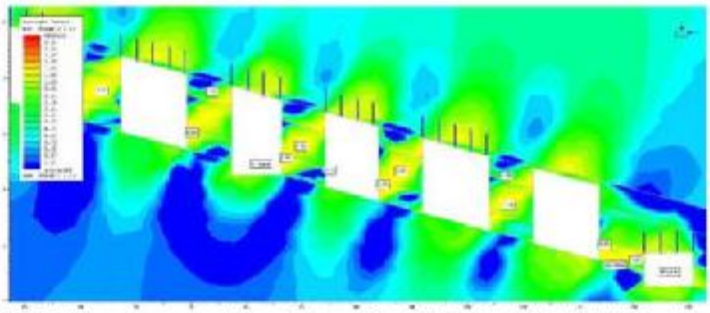
Uses tech imported from Australia and Germany to exploit coal reserves

Newspaper article covered in the Deccan Chronicle regarding NIRM work.

» In the Munsar, Chikla and Balaghat Mines of MOIL, the design of sub-level stoping with down the hole vertical drilling along with the stability and back filling was done with a view to optimise the stoping parameters by both empirical and numerical modelling. In Balaghat mines, additional study was done for (a) the feasibility of conversion of in-situ rib pillar to post pillar, (b) deciding the dimensions of post pillars and placement of post pillars of varying

widths; and (c) placement of cable bolts & roof bolts. Empirical study was done by testing rock samples for their physico-mechanical, geo-mechanical properties and RMR/Barton's Q-value. Based on empirical study and instrumentation data analysis for Chikla mines, recommendations were made following which the stope was mined up to 12m from -270L. Remaining excavation is expected to get completed in another 2 years. Further investigation is in progress for other mines.

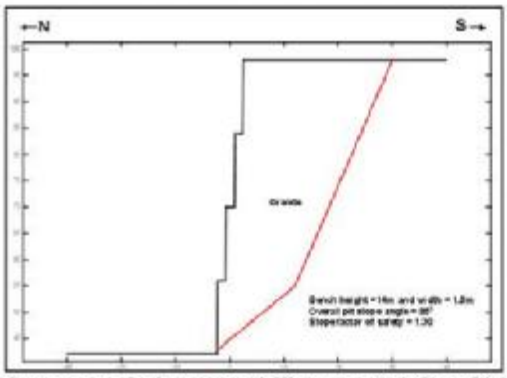
» In the Tummalapalli Uranium Mine of UCIL investigation was done for the long term stability of the main return airways and the barrier pillars adjacent to the main declines. Representative rock blocks were collected from the underground for determining physico-mechanical properties of these rocks in the laboratory. Based on test results and other input data from the mines, the stress analysis using numerical modelling was done



FoS Values around the pillars after FW, Parting & HW lode mining without backfilling

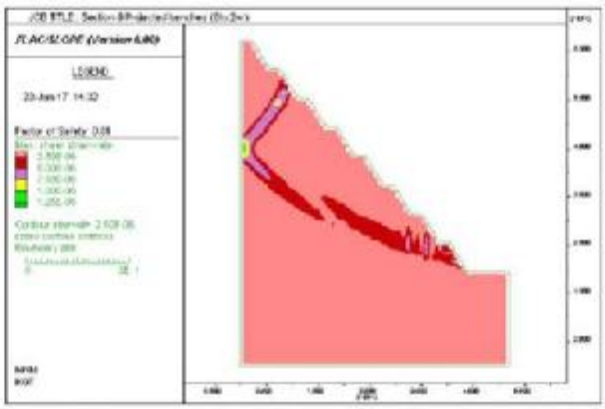
(a) to review the existing pillar sizes for factor of safety and extraction ratio,
(b) to evaluate the stability of the pillars so formed and
(c) to evaluate the stability of the remnant pillars and the rooms with and without backfilling.
An interim report detailing various recommendations was submitted to the mine management.

» Three case specific investigations were done for the slope stability studies at various quarries. In first case, investigation was done to optimize the bench parameters and design of final pit slope stability of GV Granites quarry in Naganur village, Karur (TN). The extraction at the moment is being carried out at a depth of about 20 m but the mining lease is up to 56 m depth of workings. The future workings of quarry up to 56 m depth needs plan to optimize the bench parameters and design of final pit slope stability for safe working conditions. After detailed field investigations, final report incorporating recommendations for bench parameters and final pit slope stability was submitted to the quarry owner.



Suggested slope stability model for GV Granite quarry based on GALENA model results

Second case study was done for the Copila Gaichem Paul Iron ore mine of M/s. Fomento Industrial Private Limited at Sigao in South Goa. The area consists of a big broad hill, which is flat on top running in almost NW-SE direction. The hill slopes gradually towards north and west resulting in a valley on the western side adjacent to the lease boundary. The mine is having common boundary with the Sesagoa mine. In order to optimise the mineral resources towards common boundary with other mine, the mine management required optimum design of bench parameters and ultimate slope angle of the pit.



One of two suggested alternatives for slope stability based on numerical modelling results (6m height by 2m width benches)

Accordingly, geotechnical studies were conducted in this mine. Based on numerical modelling

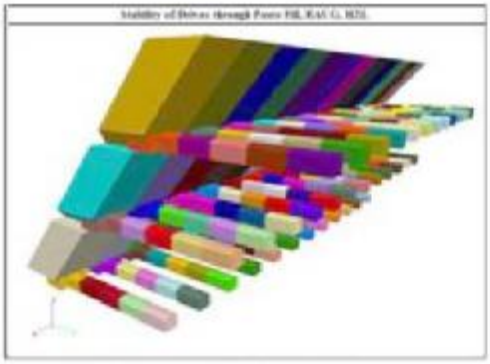
studies using the geotechnical parameters, recommendations for optimum design of bench parameters and ultimate slope angle were submitted in the final report.

Third case study was done for the pit stability monitoring towards north side and design of final pit slope of Krishna Limestone Mine in Ramayanpatti, Tirunelveli (TN). On both sides of Krishna mines lease area, i.e. East and West side, the mines belonging to India Cements Ltd., are in operation. The rock mass in this region is observed to be poor to a depth of about 40 m. In this mine, a slope failure had occurred in May 2003 towards the North side covering a length of about 250 m. Therefore, the stability of area/slopes is being investigated by monitoring in the pit towards north face. One interim report covering recommendations for deformations in pit and strengthening of the strata is submitted. Monitoring is still continuing by using total station instrument.

» In the Kaliapani Chromite Mine of M/s Balasore Alloys Limited, a study was taken up for the stability of the pit slopes form the existing working depth of 142 m to 182 m with critical geometrical conditions (i.e. two internal dumps either side of the pit and two common boundaries with other mines), and suggest suitable slope design parameters. This mine is having two internal dumps towards north and south directions, and shares its boundaries with M/s IMFA Ltd. on east side and M/s Jindal Steel on west side. Investigation work is in progress by the end of this reporting period.

Aerial view of the Kaliapani Chromite Mine showing dumps on its boundary.

» In the Rampura Agucha Underground Mine (RAUG), the mine officials need to determine the feasibility of underhand mining method. To undergo underhand mining, the blast boreholes required to be drilled downwards from crown level of the stope. To access the crown level, the paste filled drives need to be excavated by drilling and blasting operations. Therefore, it was necessary to ensure stability of these drives until the drilling and blasting activities of the stope were completed. The backfill plays an important role in transferring of stress from hangwall to footwall and thus an alteration required in strength parameters of backfill need to be studied scientifically before implementation. For this study, dynamic numerical modelling was carried out for the model stopes and essential parameters were calculated using the input provided by the mine officials. From the numerical modelling results, it can be predicted that the drives excavated through paste fill would be stable after drilling and blasting operations to further carry out downward drilling for underhand mining. The modelling results were calibrated using the blast vibration data as provided by the mine officials. Based on our recommendations, Stope N210 was mined by underhand mining.



FLAC3D model showing stopes, plugs and tunnels

The displacements at the location of the stope was monitored by using MPBX installed at the center roof, the stope, and the footwall. After the blast, the location was inspected. No significant changes in displacement was found in the reading of MPBX. The tell-tales installed at the location showed no major displacements in the fill column. Moreover, no fill material was detected while mucking. This indicated that the fill column was stable and the same was shown in results of numerical modelling. Based on the numerical modelling results, it was suggested that a 4.8mX4.8m excavation required a double fibercrete with wire mesh *(50 mm*

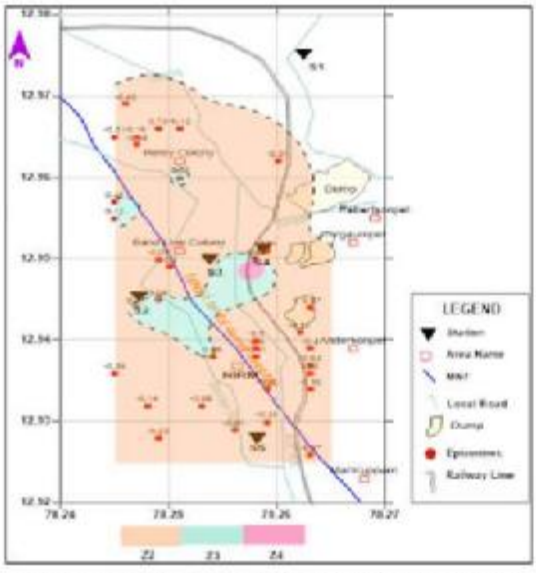
fibercrete followed by wire mesh and 50 mm fibercrete again) along with 2.4 m long split sets at 1.0mx1.0m spacing. Similarly systematic instrumentation plan was suggested from -180mRL to -230mRL. In was also suggested to update the geological mapping and geotechnical mapping according to Indian Standard IS 11315 to delineate the discontinuities and quantify parameters for calculation of Q and RMR values.

» In the Baroi Mines of HZL, the strain-softening constitutive model was utilised to determine the post-failure behaviour of ore, hangwall and footwall. From the numerical modelling results, it can be predicted that it is safe to extract some pillars without backfilling the open stopes. Keeping in view of stability of surrounding rib pillars, it is recommended that the nearby crown and sill pillars and Hangwall be closely monitored using stress meters and MPBX. As low confinement in the backfill may affect the stability of nearby workings, the stability of the mine was also studied using backfilling of existing open stopes followed by extraction of target pillars. In the numerical model, there was no evidence for significant surface subsidence post extraction of recommended pillars.

» In the Balaria Mines of HZL, it was anticipated by the mine management that extraction of some of the pillars (rib and crown pillars) with or without filling may affect the stability of mines. Therefore, numerical modelling studies were conducted to identify such pillars and to check for global stability post extraction. Based on the numerical modelling analysis, it was recommended to extract few pillars which were not affecting the stability of the mine at the local as well as the global level. It was also recommended to regularly monitor the backfill as it may affect the stability of nearby workings due to low confinement. Thus, all suggested pillars except those in old workings or nearby failed pillars may be extracted if the open stopes are paste filled.

In order to review the ground control and the geotechnical monitoring practices in the Balaria mines, various documents, plans, sections, data etc. related to the above study including GCMP were thoroughly checked. Anchorage testing of rock bolts was also done during the underground visit. It was found that the implementation of GCMP in the mine had standardized most of the procedures related to ground control. It was noticed that the GCMP was not reviewed periodically. Therefore, it was recommended to review the GCMP at regular intervals to ensure that it meets the current ground control conditions and practices.

» An S &T Project is being carried out since June 2016 for estimation of the seismic hazard in and around the old gold mines of BGML at Kolar Gold Fields (KGF) in Karnataka. As part of this study, the seismic activities in and around the mined-out areas was monitored round the clock with five station seismic network installed in the northern, central and southern zones of the mining area spanning between 12.98–12.92N, 78.24-78.27E to identify the potential zones of hazards due remnant seismicity induced due to old abandoned mines. The main objective of this project is to monitor the seismic activities in the top 200 m of the old mining regime so as to identify and locate the seismic events that could be potentially hazardous for the surface structures and activity. Continuous data was acquired using triaxial velocity transducers which had built-in electronics for pre-processing and storage of data. The gathered data were processed and analysed for seismic events in the mining area. P and S wave phase picking, frequency analysis, computation of various source parameters like



Map showing Seismic Hazard Index of the old mining area

event depth, distance, stress drop, the ground motion parameters like Peak Ground Velocity (PGV) and Peak Ground Acceleration (PGA) were computed. The seismic monitoring data revealed occurrence of 35 low magnitude events (-0.82 to 1.05 on Richter Scale). Equivalent coda scale magnitude was -1.0 to 0.9. The PGV maximum was found to be 0.54 cm/s and PGA maximum was 0.059.

All the source parameters were comparatively analysed and found that barring a couple of events in the top 200m, most of the events were in deeper levels. Hence the hazard level in the mining area was predominantly low. As the stress build-up in the rockmass are transient and could migrate from one to other location, the hazard index too is expected to migrate, which requires continuous monitoring.

» As part of the calibration exercise for newly procured Portable Seismic Recorder System (PSRS), it was deployed for recording blasting at a quarry. Four systems with eight sensors were installed at a stone quarry at Korchanur village, Tekal, Malur (Karnataka). The combinations of sensors were deployed to understand the ground response of the vibration generated by explosives source (blasting) in the high frequency and low frequency range. It was observed that the vibration data record of the PSRS and the blasting seismograph were coherent confirming the calibration of the equipment.

Deployment of Portable Seismic Recorder Systems and Minimate seismograph for a calibration study at a stone quarry.

The blasting seismograph data revealed that the vibration, air overpressure and flyrock distance monitored during the present study were within the permissible limits. They followed the same trend as observed during a prior study carried out in 2006 by NIRM at the same quarry. This validating the site specific predictor equation developed earlier for that quarry.

2. Power Sector

Extending our expertise by way of providing consultancy services to the power sector is one of key areas wherein various departments extended their services in solving the site specific problem and carried out crucial investigations for the design and development. Financially, power sector is the backbone of the NIRM and accounts for 60% of the revenue earning.

During this year 21 projects were taken up in the power sector, out of which eight were for nuclear power, twelve for hydroelectric power and one for thermal power. Most of the studies were related to the construction stage guidance for safe practice and/or site characterisation for the design implementation. While investigation was completed and final report submitted for thirteen of them, investigation or data processing is being continued for the remaining eight.

» 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 were carried out. The investigations included engineering geological mapping on 1:100 scale of the foundation strata at foundation levels of NDCT 7A, 7B (Fig. 1), 8A and 8B pond floor and pump houses of 7 and 8, identification of geological defects and recommendations of suitable engineering measures. Classification of rock mass using Rock Mass Rating was done. Based on engineering geological investigations, review of laboratory analysis and in-situ permeability tests results, recommendations for the treatment of foundations were given.

Geological plan map of NDCT-7B pond floor, RAPP, Rajasthan

» Nuclear Fuel Complex (NFC) is constructing a nuclear fuel complex at Rawatbhata, Kota. As part of this work, hard rock has to be excavated for the construction of foundation and grading to a depth of 1 to 4 m by drilling and blasting methods. Blasting need be carried out close to the upcoming structures belonging to NFC and towards the existing structures of Rajasthan Atomic Power Plant. NIRM guided the controlled blast for the excavation of foundation and grading at different project components.

The NFC main gate building which is under construction is located around 200m and stores and site office building about 800m. The HT line is passing at a distance of about 300 m from the nearest excavation boundary line. The vibration data generated were regressed to derive the site specific predictor equation and used for arriving safe maximum charge per delay. The permissible level of vibration of 10mm/s as stipulated by project authorities was adhered to for the all excavations. In order to ensure the safety of all the structures, the lowest value of the safe maximum charge per delay was suggested as

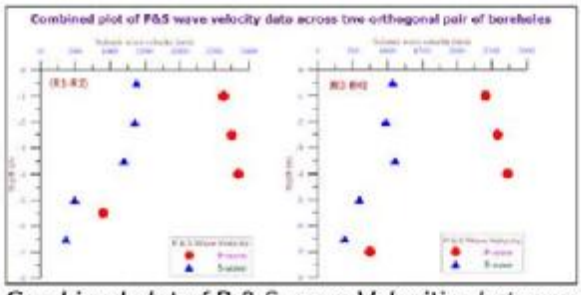
(i) 10 mm/s for civil structures,
(ii) 3 mm/s for structures containing electrical and electronic equipment's, and
(iii) permissible level for concrete/hardening concrete.

Self-explanatory graphs depicting the relationship between PPV (mm/s), maximum charge per delay (kg) and distance (m) were presented as a ready reckoner for future blasts. The blast design parameters for opening of bench blasts and production blasts were suggested for future excavation.

» Nuclear Power Corporation of India Limited (NPCIL) intends to set up nuclear power plant at Gorakhpur Village of Fatehabad District, Haryana. This project is under feasibility stage during which various types of tests are proposed by NPCIL to validate the design parameters. Testing the efficacy of a soil-cement mix, to be used in the foundation, is one of such tests in which cross-hole seismic test was to done for checking the improvement in the P and S wave velocity in the mix and its overall effects on the Poisson's ratio. A mock-up test site was created with 5mX5mX5m soil-cement mix compacted to 95% of the maximum density according to the standard Proctor method. The plan of cross-hole test was laid as per ASTM D4428 standard, which prescribes an array of five boreholes which includes one source borehole (S) and two pair of receiver boreholes (R) drilled in orthogonal directions with the source borehole at the origin. All boreholes were cased with PVC pipe with bottom closed.

Before starting the cross-hole seismic test, the deviation of boreholes (from vertical) was surveyed at every 0.5m interval. Using the borehole deviation data, exact borehole separation at every logged point was determined. The cross-hole travel times for P and S wave were determined by placing the P-wave source in source borehole and two sets of receivers in one arm of the boreholes, i.e., R1 and R2. Subsequently receivers were placed in the second arm and travel time data was determined for R3 and R4. Same exercise was repeated with the S-wave source also.

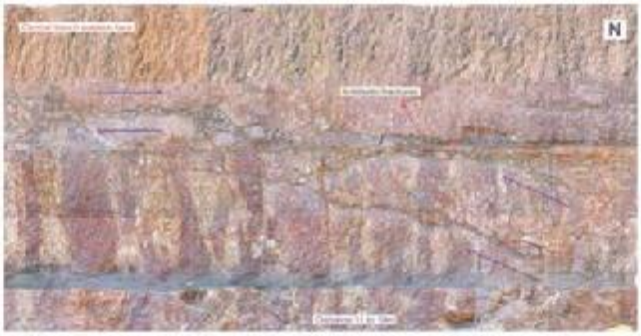
Using the corrected separation between boreholes at each point of measurement, the velocity of P and S wave between R1-R2 as well R3-R4 was computed at each point of measurement. This combined plot of P and S-wave velocity across R1-R2 and R3-R4 showed that the average seismic wave velocity in the soil-cement mix area was 2500m/sec for P-waves and 1350m/sec for S-waves. The Poisson's ratio (v) of the compacted medium was 0.38-0.39.



Combined plot of P & S-wave Velocities between -R2 & R3-R4

» For identifying deformational features for light house lineament at Jaitapur Nuclear Power Plant, investigation was done by thorough mapping by digging one of the largest trench (100mX29mX26m) in the world. Contrary to findings of the previous study, it was observed that no normal fault was present within the trench area. However, the studies identified 6-8m thick laterite zone showing at least two episodes of deformation after ending laterization process. No leaching or goethite formation was observed across the fractures generated by second deformation. The nature of many of the south dipping veins indicated that the cracks which facilitated the veins were formed by the relative movement of the blocks on either side. The nature of fracture fillings (forceful injection) during the second deformation phase indicated the dynamic nature of the deformation episode. Small scale movement mapped across the dyke boundary and intense fracturing observed in the clay indicated that the deformation might be younger than alteration/weathering process at this zone.

The small scale reverse movements observed at multiple locations within the laminated clay and below may be an indication of dragging by overlying block. The mapping also observed antithetic fractures at the southern side opposite to the overall movement observed in the trench. The inferred folding of laminated clay and associated deformation in goethite veins indicated that the deformation might be associated with the compressive forces.

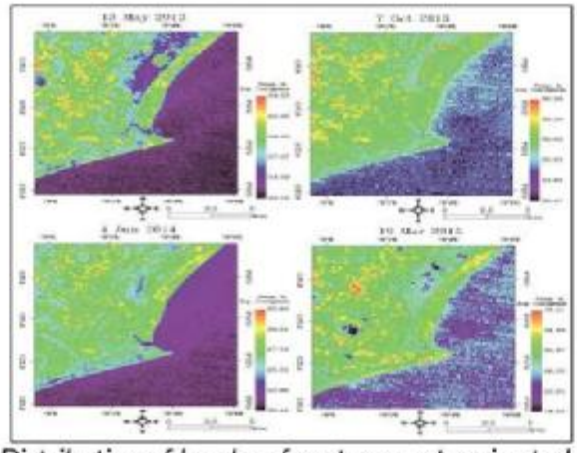


Development of antithetic fractures in the southern side of the trench

» **NPCIL** is constructing additional units 3 & 4 near the existing units 1 & 2 of Kudankulam Nuclear Power Plant (KNPP), Tamilnadu. As part of the construction of Unit 3 & 4, excavations by safe blasting practices had to be carried out for the construction of pump houses adjacent to the green and matured concrete structures of unit 3 and 4. Accordingly, a method statement was submitted which comprised the tentative blast designs, permissible limits of ground vibration for civil structures, industrial structures, concrete of different age etc. Fifteen trial blasts were carried out and ground vibrations and air overpressure were monitored by deploying six seismographs at different locations in consultation with project authorities. Analysis of blast monitored data and preparation of final report is under preparation.

Preparation of charging of holes for bench blasting

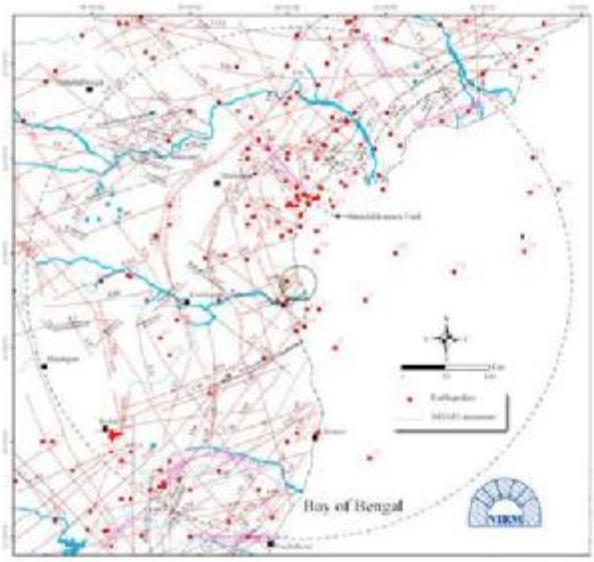
» **F**ollowing the report of suspected geothermal activity reported at Manappad located 44 km northeast of KNPP, NPCIL approached NIRM to evaluate the incidence. The suspected feature was identified as a depression surrounded by circular rim (9ft diameter) of sand mixed with shells. The circular rim was exposed above the water level. The thickness of clay was less inside the depression and the bottom appeared to be hard. The study area was identified after interaction with local people and based on the morphology of the suspected feature. To ascertain the geothermal activity, NIRM carried out analysis of last ten years of the remote sensing data of the area through thermal bands. For identifying precipitation from deep seated geothermal fluids leading to intra fracture zones, water samples were collected from the nearby wells and Investigated. Monitoring using thermal bands matched with the temperature recorded in the region; the studies of fracture zones did not show any precipitation of secondary minerals. The suspected spot was further verified using temperature profiles but no abnormal temperature was observed over 10 years. Geochemical studies confirmed no anomalies in nearby wells. Thus the studies confirmed the absence of any suspected geothermal activity in Manappad.



Distribution of Land surface temperature in study area in year 2012, 2013, 2014, 2015 as calculated from thermal bands.

» **T**he proposed Nuclear Power Project around Gogulapalli is located in the Nellore district of AP and falls in the seismic zone III. The proposed location is a low lying land, having elevation less than 10 m msl. There are eight lineaments/faults reported in this region. The present study identified seven lineaments within the 20 km radius. Detailed geological studies indicated few slip planes in the N-S trending quartzitic hillock in the western side of the study area. The joints were open and slickensides were also observed along the plane. Near Sriharikota, a westward dipping sheared plane trending N-S was observed in the quartzite rocks. Field observations indicated that the trend of the prominent joint/shear observed in the basement was consistent with the trend of lineament N5. Lineaments N1, N3, N6 and N7 did not show any surface signature of faulting.

The Ongole region which is located in the north east of the proposed site, had witnessed some earthquakes in the past 30 years. The present study updated earthquake catalogue for 300 km radius of the site from various sources for the preparation of seismotectonic map. Further investigation is on.



Final 300 km Seismotectonic Map for the proposed Gogulappalli site

» Three additional sites were proposed by NPCIL for preliminary seismotectonic studies for the Nuclear Power Plant. These sites are at Karedu, Chennayapalem and Tummalapenta (all in AP). The proposed study area for the three sites is falling in seismic zone III and the Ongole region, which witnessed seismicity during the last 30 years, is located in the north of them. During the field investigation it was found that 50% - 70% area is covered with alluvium. The hard rock is exposed in very small ridges. The maximum height of the ridges was 40 m. Along the lineament N5 near Palukuru village a shear plane was observed in the direction N320°. Thick Gondwana formations were identified in the northwest of Karedu site. The top layers of this formation appeared to be folded in the vicinity of N11. Final seismotectonic map and final report is under preparation. Site selection studies carried out by NIRM at the east coast of India in Andhra Pradesh was reported in various news reports *(Times of India, 24 Jun 2017; Indian Defence Update, 13 Aug 2017; and The Hans India, 13 Aug 2017).*

West dipping fault observed in the direction of lineament N 8.

» At Punatsangchhu-II hydroelectric project (PHP) in Bhutan, it is proposed to construct a pothead yard at the right bank of Punatsangcchu river near the dead-end transmission line tower location on the underlying soil strata consisting of silty, less clayey soil with intermittent boulders. For this purpose, determination of safe bearing capacity by Plate load & Foot load tests was detemined. Safe bearing capacity parameter is essential for the design of foundation. Field investigation is completed and the final report is under preparation.

Field setup for measuring of safe bearing capacity

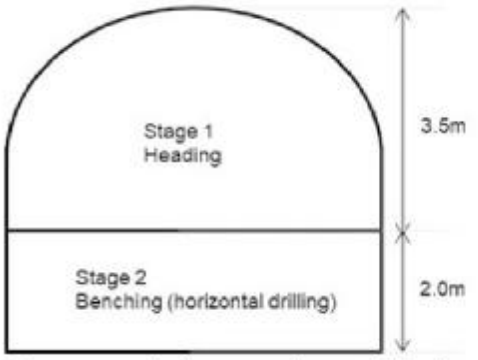
» The modulus of deformation of rock mass is an important engineering parameter required for the analysing the sliding stability of the dam structure and design of rock structures. Such study was required for Goriganga-IIIA hydel project, where in-situ testing for determination of modulus of deformation of the rock mass was carried out in the vicinity of proposed powerhouse site. Based on the results of the investigations, the recommended orientation of

the underground powerhouse was N20°. It was recommended that the long axis of the underground Desilting chamber may be oriented along N 20°. The deformability modulus of rock mass at the proposed Desilting Chamber indicated the rock type to be in the Fair category (Class-III).

» Another project is being carried out at PHP for analysis of the instrumentation data and for assistance in the installation & monitoring of instruments at C#3 Package. A resident scientist is posted at the site for overall monitoring of geotechnical and geodetic instrumentation works. A 3D instrumentation model incorporating global positioning, geological structures, over-break sections and actual positions of instruments was developed exclusively for PHP-II. Layouts and sections of excavation sequence for different components of the PHC were constructed. Guidelines were given for installation and monitoring of different instruments at site. Detailed direct and derived analysis for different caverns of the PHP on regular basis was done. Critical or stressed zones in different components of the PHP were identified and the project authorities were informed for taking necessary remedial measures. Detailed reports were submitted cavern wise.

» In order to fill the cavity at PHP, it was proposed to excavate a tunnel of 6m x 6m from the surface near pothead yard and to connect with the downstream surge chamber. As the excavation of the tunnel had to be carried out by controlled blasting, M/S WAPCOS requested NIRM to technically guide the controlled blasting operations and the monitoring of ground vibration for the remaining excavation. Accordingly a reconnaissance survey was carried out at the rock fall location in downstream surge chamber, transformer cavern and the location was identified for making a connecting tunnel to the surge chamber. Initially, the flaws in the design of the existing blasting practices was noted.

Cosnidering the gelocical and ground condition, the full face blast carried out earlier was replaced with heading and benching. The suggested modification in the design yielded good results, even the monitored blast vibration was far below the permissible limit. Since there was no room for drilling vertical holes by the boomers for excavating the bench portion, drilling of horizontal holes was suggested. Horizontal blast holes permitted better breakage to the invert and more precise control over the final contour of the tunnel. Excavation of tunnel was successfully completed with the suggested modified blasting design.



Recommended stages of tunnel blasting

» The Mangdechhu Hydroelectric Project Authority (MHPA) at Bhutan implemented an extensive instrumentation plan during the excavation of the caverns. It was requested by the MHPA to compare the instrumented data with the numerical modelling results and suggest modification of the support system, required if any, for the overall stability of excavations. Accordingly, 3D modelling results were compared with the MPBX data at the anchor depths. The numerical model was able to depict the overall behaviour of the surrounding rock mass vis-à-vis the behaviour of caverns and other cross tunnels. The model results showed that the rib sections provided in the roof and supports in the form of rock bolts in the crown and walls of the powerhouse cavern were adequate. The results also showed that the thickness of SFRS of 250mm was adequate for the control of rock mass movement. At bus ducts, stitching the pillars with rock bolts proved effective in improving the factor of safety of the pillar in between the powerhouse and the transformer hall cavern.

Scope of installing additional instruments for long term monitoring may be explored after all the construction activities in the caverns are completed,. Analysis of the instrument data shall be carried out on regular basis. In future caverns, MPBX depth may be extended to at least

equal to the width of the caverns. Since the depth of the deepest anchor is very crucial in the analysis of the MPBX data, depth shall be as deep as possible particularly on the outer walls in case of multiple caverns. Time lag between the excavation and the supporting as well as installation of instruments should be minimized in future so that crucial information in the initial stages are not lost.

Stability analysis of the Butterfly Valve Chamber (BVC) of MHPA was carried out using 3D Numerical Modelling with FLAC 3D. Modelling results revealed that the RCC raft was countering the higher displacements at the invert and was a necessary support measure. The maximum displacement was observed at the invert, below the RCC raft of the BVC floor where the fractured rock mass (shear zone) was present. Effect of consolidation grouting in the rock mass surrounding the BVC was incorporated in the model. It was found that there was notable improvement in the strength properties after grouting. It was recommended that displacements, load on supports, crack widths and pore pressure surrounding the BVC must be measured with the help of instruments and these data should be monitored regularly in order to assess the stability of the BVC.

» NIRM established a network of control points in the surrounding of the Sardar Sarovar concrete gravity dam using DGPS. Monitoring points were installed on the dam blocks at the crest level. NIRM started the monitoring from both banks of the river depending on the least distance and visibility of the prism points on the dam blocks. The monitoring was continued for almost five years as there were inconsistencies in readings at few points. These were due to common problems associated with the measurement of large distances manually using total station. Current study of geodetic monitoring proved these limitations while measuring the large distances manually using total station. It was recommended to go for advanced automatic geodetic monitoring systems using Global Navigation Satellite System (GNSS) and advanced automatic total stations from established total station manufacturers. SSNNL requested NIRM to suggest additional monitoring points on the overflow blocks. This work will be taken up later. Effort should be made to get the site specific meteorological data to correlate the observed variations.

The behaviour of underground powerhouse of Sardar Sarovar project is also being monitored by NIRM since the year 2000. Based on the instrumentation data, it was found that the MRMPBX's at the underground powerhouse showed stable trend during the period. The surface MRMPBX data confirmed that the area between the crown and surface was stable and no movement was currently taking place. Geological sections were examined at locations where the displacement exceeded 4mm. It was found that all these anchors are located in agglomerate rock and near to the shear zone. Hence, further monitoring should focus on the measurements in this area to observe the trend.

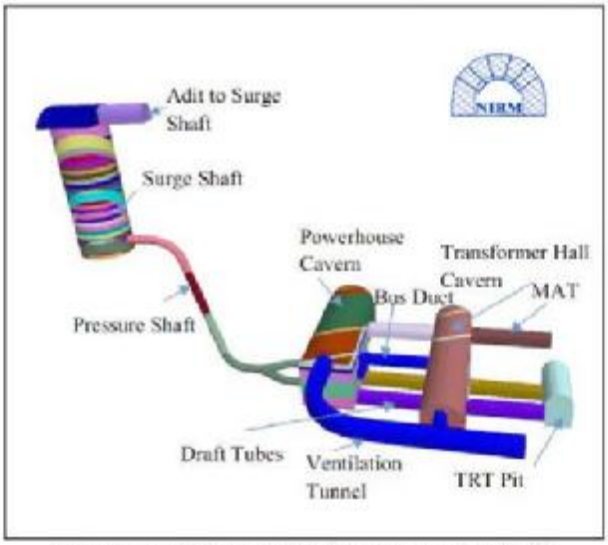
» At Tala Hydroelectric Project in Bhutan, currently about 150 instruments are being monitored at powerhouse complex, surge shaft and pressure shaft butterfly valve chamber. Based on the analysis of instruments data it was noted that the total convergence during the operational period (3950 days) varied from 23 to 44 mm. Load on the rock bolts was increasing at some of the locations, particularly at 150 u/s at EL 506 (an increase of 9.72 tons). It can be concluded that the caverns were undergoing time dependent deformations and stress induced deformations due to its close proximity to the Main Central Thrust. Back analysis study using 3D numerical modelling done by NIRM indicated that more bolts were likely to fail. Monitoring of the powerhouse complex and surrounding rock mass using micro-seismic monitoring, being done by NIRM, should aid the assessment of the stability of the cavern in the near future.

» NIRM is carrying out the data analysis of instruments in the powerhouse, the desilting chambers and the dam of the Nathpa Jhakri Hydroelectric Project, Himachal Pradesh since its commissioning. During the current year, it was found that the readings of both the anchors at

RD 92 Crown at Powerhouse Cavern were fluctuating. Negligible relative displacement between 4m and 6m anchors indicated that, the displacement was taking place between surface and 4m anchor. No anomalous trend was observed in any other instrumented data of powerhouse cavern. Even in the desilting chambers, pore water pressures did not show any abnormal pore pressure changes. Analysis of the instrumentation data of the dam indicated that the values indicated by most of the instruments were within the design limits. Analysis of the strains near S3 and S5 indicated that the strains due to factors other than loading might be causing increase in stress at this location. Therefore, it was recommended to carry out geophysical investigations near the area to find out the likely reasons.

» NIRM carried out 3D numerical modelling studies at surge shaft and powerhouse complex of the Naitwar Mori hydro power project belonging to M/s. Satluj Jal Vidyut Ltd. (SJVNL) to evaluate the efficacy of the proposed support system. The support design was done based on the 3D modelling results. Extensive studies were done using continuum models in FLAC-3D.

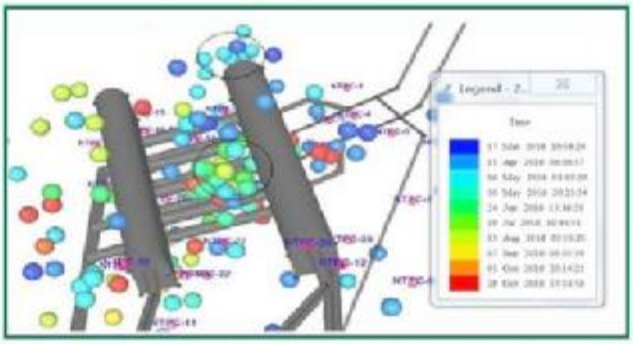
Based on Numerical modelling studies, it was recommended to adopt controlled blasting techniques for the excavation of the surge shaft, the powerhouse cavern and the transformer hall cavern. At intersections where surge shaft excavation falls in fractured rock and shear zone, consolidation grouting should be carried out to a depth of about 9m to improve the rock mass parameters. Similarly, consolidation grouting to a depth of 9m may be carried out for increasing the stability of areas where sheared zone material intersects the powerhouse cavern. The length of rock bolts may be increased to about 8m near the junctions of unit penstocks, draft tube tunnels and at other tunnel junctions.



3D view of the model showing surge shaft, powerhouse and transformer hall cavern.

» Microseismic monitoring system was installed at the powerhouse of Tapovan Vishnugad Hydropower project (TVHPP), NTPC Ltd., using a network of thirty geophone stations. During the monitoring period, the acquired data consisted of a lot of coherent and incoherent noises in and around the network due to the construction activity, rockmass sliding, electrical wiring activity etc. which was filtered out. At the end 178 microseismic events with high S/N ratio were mapped on the 3D cavern plan of the powerhouse. Most of the events had taken place at the cross section of the biotite schist and the shear seam which resulted in a high displacement in this area as compared to other areas of the powerhouse.

The temporal variation of the microseismic activity along with the cumulative apparent volume showed two significant cluster of events at the end of the machine hall and in the downstream wall of the machine hall (around bus duct 1). No block movement was observed in the strata during the monitoring period and the structure appears to be stable. Maximum apparent stress and seismic moment were 1.91 bar and $39.81*10^9$ Nm respectively.

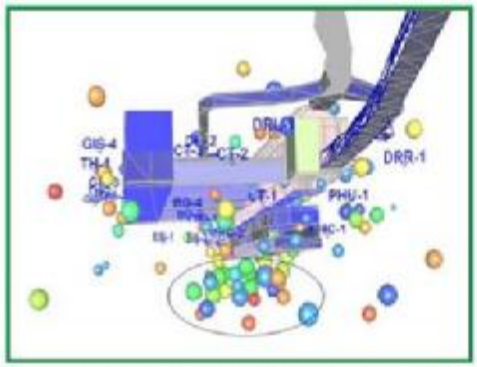


Spatio-temporal distribution of microseismic events

» Microseismic monitoring with thirty geophone stations, eight data acquisition units, data

communication hub and data server is being continued since Sept 2013at the powerhouse of Tala Hydropower Plant, Bhutan. During the year, 117 microseismic events with high S/N ratio are mapped on the 3D cavern plan of the powerhouse.

The spatial and temporal variation of the seismic source parameter and their variations had been studied to evaluate the stability of the powerhouse cavern and to estimate the seismic hazard. Except for one minor event cluster found during June-July 2017, no other clusters observed during the monitoring period. The microseismic events detected during this period had local magnitude in the range of-3.6 to 0. Maximum displacement zone was between RD 100m to 130m. Failure of two rockbolts between Jan-March 2018 had been correlated with the microseismic events but no precursory cluster of events or other pattern were noticed around the rockbolt failure location.



Microseismic events plotted on the plan of the powerhouse of THPshowing formation of a cluster zone

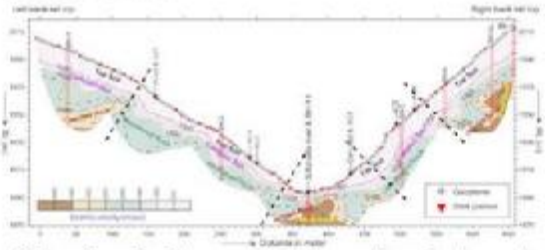
A total of forty five number of microseismic events occurred in the first quarter of 2018. There was a high displacement zone around RD 65 m in the upstream wall of the machine hall but there no significant apparent stress zone formed within the monitored area.

» NIRM carried out field investigations and controlled blasting method of rock excavation for phase-I of the Darlipalli Super Thermal Power Project (DSTPP) of NTPC at Odisha. In Phase-II, ninety one blasts were monitored and in phase-III 383 blasts were monitored from (September, 2016 to January, 2017). The blasting operations were carried out in TP-4, TP-5, Block-7, Block-11, Crusher house, Block-10, MC Building, etc for excavation of hard rock. All the monitored blasts were safe with respect to blast vibrations and flyrock at the structures.

During Phase-III (extension-I) period 648 blasts were monitored. During Phase-III (Extension-II) period, 779 blasts were monitored in various distances from the blast locations and the monitoring locations were selected in such a way that they were towards the structure. All the monitored blasts were safe with respect to blast vibrations and flyrock at the structures. A sample site photograph showing of blast vibration towards Panchali Chowk is shown in the adjacent column.

» Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) is planning to construct Sillahalla dam as an 'Energy Augmentation' scheme in the Nilgiris District, Tamil Nadu. Due to ambiguity in the drilling data outcome, TANGEDCO requested for Seismic Refraction Survey to be conducted along the abutment of the two alternate axes of the proposed dam to map the rock level along the line of survey as well as to indicate any geological pitfalls. The required depth of investigation was 30-35m.

Accordingly, the seismic refraction survey was done at the project site. The first dam axis (L1) line was covered in seven segments (each 115m long) and the second/alternate dam axis (L2) line was covered with five segments (each 115m long) along the abutment alignment. In addition survey along seven across (transverse) lines, each of 115 m, was carried out at various elevations as shown by dotted lines.



Seismic velocity section along the abutment of the first dam axis line (L1)

Of them, three survey lines were on the left bank, three on the right bank and one line below

the water fall on the left bank. Seismic velocity section along first dam axis line L1 is shown here. Along this line, the presence of jointed and hard rock layers were mapped in very small stretch whereas along L2 line stretches with hard rock portions were longer. Comparing both sections, it was suggested that L2 was the better alternative for the dam axis.

3. Infrastructure Sector

Apart from key work areas of Mining and Power sector, which accounts for 80% of the revenue of the Institute, NIRM extends its R&D support and expertise to the Infrastructure industry also which includes Irrigation and Marine projects, Drinking water, Urban housing and Metro and Rail/Road projects. During this year 14 projects were taken up in the infrastructure sector, out of which eight were irrigation projects, two marine projects and remaining one each from drinking water, housing, road and metro projects. While investigation was completed for twelve projects and final report was submitted for ten of them and interim report was submitted for two others. For the remaining two projects, investigations are being continued.

» A dam for drinking water storage across Markandaya River at Yargol in Bangarpet Taluk of Karnataka is being constructed by Karnataka Urban Water Supply and Sewerage Board (KUWSSB). This project will cater to the drinking water needs of 45 en-route villages and 3 towns namely Kolar, Bangarpet and Malur of Kolar district, which are having the recurring drought problems and shortage of drinking water. Construction stage engineering geological foundation mapping was carried out in which geological mapping on 1:200 scale was done for the foundation strata of dam and housing chamber for a total area of approx. 16695 sq.m. Based on detailed engineering geological investigations, suitable engineering measures for the treatment of foundation including grouting pattern (curtain and consolidated) were recommended.

Foundation geological mapping of the dam area (Dam block 9 and 10)

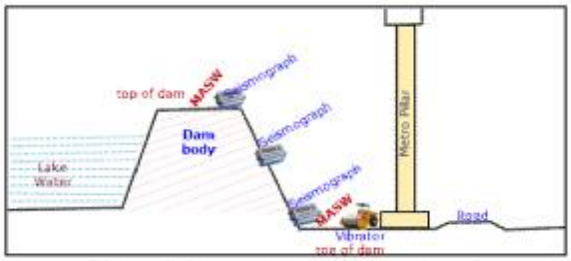
» The shear strength parameters of rock mass and rock/concrete interface are the utmost important parameters used in the design of dam. Due to variation of rock mass properties at different sites, the measurement of in-situ shear parameters at each site is essential. At the proposed dam site at Yargol, the rock mass interface and the concrete to rock mass interface peak cohesion (C) were determined as 0.85 MPa and 0.46 MPa; the inter frictional angle (ϕ) were 59° and & 47° respectively. A moderately higher cohesion and friction angle of the rock mass at the proposed dam axis suggested very good quality of rock.

Direct shear test being carried out at the Yargol dam project

» Nagpur Metro Rail network has its East-West corridor passing close to Ambazari Lake. This dam being a heritage structure, construction within 200m is not permitted unless any train-vibration-induced threat to the stability of this dam is ruled out. Accordingly, a comprehensive survey was done using induced vibration to analyse the impact of the vibration on the stability of the dam. A vibratory road compactor was used in the steady state mode to simulate the sustained vibration at the toe of the dam similar to running of metro train.

Various vibration-induced parameters like Peak Frequency, Peak Particle Velocity (PPV) and Peak Ground Acceleration (PGA) due to the impact of this simulated vibration on the dam body was measured simultaneously at toe, middle and top of the dam. In addition, the impact of traffic plying on road at peak hours in terms of PPV and predominant frequency both at the top and toe of the dam and the shear wave velocity section of the dam body (from top) as well as its foundation (from toe) was determined by the active MASW method.

Free vibration of the dam body was used to determine its natural frequency. The shear wave velocity (obtained by MASW survey) on the top of dam body reflected a well compacted soil till 15m depth and that at the toe indicated that the dam body was strongly founded on the weathered and jointed rock which was present all along at 9-10m depth.



Plan of the proposed survey work

The vibration data in terms of PPV, PFR and PGA values for the vibratory source (sustained vibration), indicated that these parameters fall off by almost 50% from toe to the top of dam with their average value on the top of dam being 1mm/sec, 0.08g and 25 Hz. The natural frequency of the dam body was 15 Hz as against peak frequency response (PFR) of 25 Hz (from simulated vibration) of the dam body. There was virtually no vibratory impact on the dam body with the present spate of traffic density on the adjoining road. Thus by analyzing these vibration-induced dynamic parameters on a section of the dam body, it was concluded that the structure of the dam was quite competent to sustain the vibratory impact from the sustained vibratory source like metro train movement.

» Kaleswaram lift irrigation project in Telangana state is under construction to cater to the needs of the drinking water and to support irrigation needs of the six districts of northern part of Telangana state. For package-6 of this lift irrigation project, engineering geological mapping (3-D and face mapping) and rock mass assessment for support system as per design of twin tunnels (RMT and LMT) was carried out by NIRM. Similar investigation was done for the underground pump house, the transformer cavern, the surge pool, the delivery mains and the escape tunnel. The scope of the work included rock matrix description, rock discontinuity orientation and description, ground water condition, rock mass quality assessment and recommendations for permanent support based on rock support categories *(as mentioned in basic engineering design)* after every drill and blast-mucking-scaling cycle. During this period all the draft tubes, delivery mains and vertical shafts were excavated in fair to good rock mass category as per tunnelling quality index 'Q'. The floor region was fresh to slightly weathered (WI – WII) but prominent vertical and inclined joints were present. To overcome the problem of differential settlement and make foundation monolith, appropriate treatment plan including the grouting was recommended based on the structural features.

» In package -10 of the Kaleshwaram lift irrigation project, NIRM carried out engineering geological foundation mapping of surge pool and pump house cavities and geological investigations for delivery main shafts (horizontal and vertical) and ventilation shafts. The geological/geotechnical mapping of the above-mentioned underground caverns was done as and when they were excavated. Estimation of the rock mass quality (Q) and recommendations for suitable engineering measures based on Q-value and site geological conditions were made.

In order to evaluate the design basis foundation parameters, engineering geological mappings (on 1:200 scale) of pump pits 1, 2, 3 and 4 were carried out. The primary purpose of the mapping was to provide a permanent record of geological conditions during the excavation. This map will be used to assess the requirement of any ground improvement. Classification of rock mass using Rock Mass Rating (RMR, [Bieniawski (1989]) was done and recommendations for the treatment of foundation including the grouting patterns are being given.

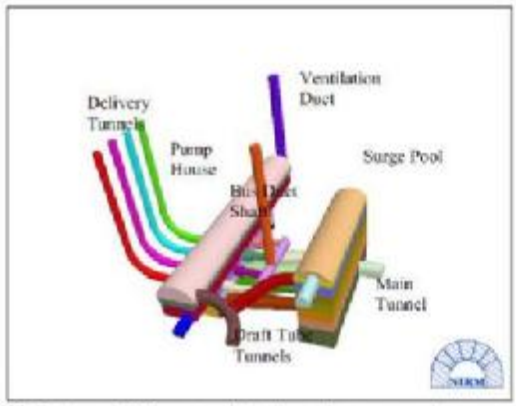
» In Package-11 of the Kaleshwaram Lift Irrigation Scheme, a tunnel and an underground pump house complex are to be constructed; this also includes Imamabad reservoir. The engineering geological foundation mapping of surge pool and pump house cavities and geological investigations for delivery main shaft and ventilation shafts, estimation of the rock mass quality were carried out by NIRM.

Engineering geological mappings (on 1:200 scale) of pump pits 1, 2, 3 and 4 were carried out. All the lithological and structural features were observed and mapped using total station equipment. This mapping will be used to assess the requirement of any ground improvement and in making better interpretation of post-construction foundation instrumentation data. Rock Mass Rating (RMR, [Bieniawski (1989]) was done. Based on rock mass rating and site conditions, recommendations for the treatment of foundation were given.

Cleaning of the pump pit-1 foundation area for engineering geological mapping

» The instrumentation layouts and specifications of instruments has been provided by NIRM for the pump house and surge pool of package-11 of KLIS. In all twenty two MPBX and ten load cells were installed in crown and walls. Based on the analysis of instrumentation data recommendation for support design for the surge pool and pump house were submitted in the final report. At a later stage Bus duct shaft has been proposed above draft tube tunnels. M/s MEIL requested NIRM to check its stability and its effect on the surge pool and pump house. 3D continuum model was constructed with the actual geometry of the pump house, surge pool, draft tubes, bus duct, delivery tunnels and intake tunnel.

Based on the modelling results, it was recommended to provide 25mm diameter, 4m long fully grouted rock bolts (Fe 500) at 2m center to center staggered in horizontal bus duct tunnels invert for improving the rock strength between bus duct and draft tube tunnels. Proper scaling has to be carried out in walls and crown of the bus duct and draft tube tunnels and support has to be provided immediately. Steel ribs ISMB 150 at 1m centre to centre spacing has to be provided for a length of 5m at the junction of pump house and draft tube tunnels. Rock bolts of length 8m may be considered near the junction of bus ducts and draft tube tunnels with the walls of pump house.



3D view of the model showing pump house, surge pool and other tunnels

» In package-12 of Kaleshwaram lift irrigation scheme, the Engineering geological investigation of deep underground pump house complex is being carried out. The investigation includes foundation mapping of surge pool, transformer cavern and pump house cavities and geological evaluation for draft tubes, bus ducts, deliver main shaft and ventilation shafts. The foundation of pump pits 1, 2, 4, 5, 6, 7 and 8 were mapped on 1: 200 scale after the final excavation. Detailed examination of rock types in each grid was carried out which included mineralogical composition, texture, classification and nomenclature and degree of weathering. Fracture filling taken place in the study site were examined and recorded. The attitude and structure of the rock, fracture and joint pattern present in the floor was determined and recorded.

ISRM (1978) classification for weathered rock mass was used to characterize the rock mass into different grade. All the discontinuities in the rock mass within the zone of influence of the foundation were identified and mapped using total station equipment. Classification of rock mass using Rock mass rating of Bieniawski (1989) was done. Bearing capacity of the foundation was evaluated based on the rock type and rock mass rating. Based on detailed engineering geological investigations and analysis of the collected data, recommendations for the treatment of foundations are being given.

Geological mapping and collection of joint data of the foundation of pump pits

» Under Palamuru–Rangareddy Lift Irrigation Scheme under lift-II and lift-III, it is proposed to construct an underground complex. Water will be lifted from the Veeranjaneya reservoir at Yedula to Venkatadri reservoir at Vatem for irrigation and drinking water purpose in Mahabubnagar and Rangareddy districts of Telangana. As part of various field investigations, NIRM determined the *in situ* stress parameters at the vicinity of underground pump house for its best orientation. The *In-situ* stress measurements were conducted in four zones from 30 to 130m depth of the borehole (Fig. 10) of lift –II and lift-III. The recommended orientation of the underground pump house is N 30° for lift-II and N 50° for the underground pump house.

» As an integral part of the lift Irrigation scheme under stage-IV Package-16 of the Palamuru-Rangareddy Lift Irrigation scheme, it is proposed to construct an underground pump house complex and the water will be lifted from Kurumarthyraya reservoir to proposed Udandapur reservoir near Udandapur in Mahabubnagar district. This project aims to irrigate upland areas of Mahabubnagar, Rangareddy, and Nalgonda districts and in addition provide drinking water facility to enroute villages, Hyderabad city and industrial areas. For the design of underground pump-house the *in-situ* stress parameters are of utmost importance.

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, NIRM was assigned the work to determine the *in situ* stress parameters at the vicinity of underground pump house for its best orientation. The *In-situ* stress measurements were conducted in four zones from 47 to 111 m depth of the borehole. Based on in-situ data, the recommended orientation of the underground pump house is N 40°.

Lowering of hydraulic fracturing equipment with NQ rods

» Mahatma Gandhi Kalwakurthy Lift Irrigation (MGKLI) scheme in Telangana State is proposed to provide irrigation and drinking water facility to the chronically drought affected upland areas in the parts of erstwhile Kollapur, Nagrkurnool, Achampet and Kalwakurthy constituencies of Mahabubnagar district by lifting water from from Neelam Sanjiva Reddy Sagar Project. As part of it, an intake structure needs to be constructed at Km 2.07 near the tunnel entry of stage -1 pumping station at Regumangadda, Yellur village of MGKLI scheme. For this purpose rock portion needs to be excavated by drilling and blasting for which NIRM was asked to provide its services. NIRM has been carrying out blasting studies at various projects and monitored blast vibrations. A huge repository of data with regard to vibrations and blast designs is available with NIRM. Data relevant to the current project site was

segregated and analysed to ascertain the feasibility of foundation excavation for intake structure at the proposed site by drilling and blasting.

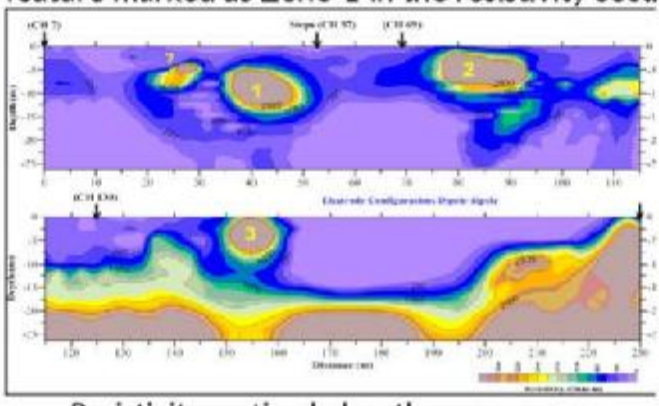
A reconnaissance survey was conducted at the location. The vibration limits were established based on our earlier recommendations in similar situations and from the global practices. Thus, a generalized predictor equation was derived and safe peak particle velocity for civil structures, tunnel, rock mass was established. It was concluded that controlled blasting was possible at the proposed intake structure location close to the completed tunnel located at chainage 2.07 km of the first stage of the pump house.

View at the tunnel portal (water level above the crown of the tunnel)

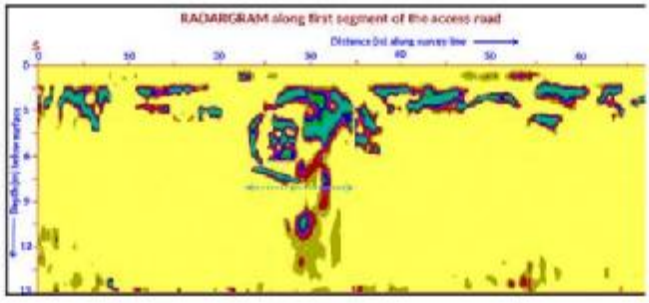
» Tata Promont is a luxury apartment complex being developed over Hanumagiri hill at Hosakerehalli in the city of Bengaluru (Bangalore). There is a Hosakerehalli Lake right below Hanumagiri hill. Water from this hill used to flow into the lake through the feeder canals/ subsurface flow path. As a part of construction exercise, access road to the apartment complex was laid by back-filling the slope portion. During the year 2016, some section of this road developed cracks and there was an incidence of undercutting of the subsurface soil.

Tell-tale effect of the failure of the access road during rainy season presumably due to under-cutting of soil

Following request from the project authorities to examine the reason behind this failure, it was proposed to carry out the seismic and GPR survey along the 100 m stretch on the road with a view to examine whether the problem is due to leakage around the subsurface drainage pipe or due to blocking of any hidden water-flow channel . The lines for surface survey were located at two places, i.e., (1) on the ramp area West of the access road and (2) on the access road itself. Since entire tar road is laid by filling up the slope to the extent of 5-15m thick soil, only GPR survey could be carried out on the tar road. To trace the continuity/ extension of the water flow path traced on the GPR section, resistivity imaging and seismic refraction survey was done on the ramp area. Three conspicuous high resistivity pockets within this fill-up zone were identified. In the GPR section of first segment, a well-marked feature appeared between 25-35m chainage at 1.5-7.0m depth. This can be correlated to the feature marked as Zone-1 in the resistivity section.



Resistivity section below the ramp area



First segment GPR section on road (Chainage 0-70 m)

Comprehensive analysis of the geophysical survey data indicated presence of three sub-surface stream with their locations as under:

Identity	Chainage	Width	Depth range
Stream-1	35-50 m	Over 15 m	5-10 m
Stream-2	75-90 m	Over 15 m	2-7 m
Stream-3	150-160 m	Over 10 m	0.5-6.5 m

In order to arrest further deterioration of the access road in subsequent rainy seasons, proper guided flow-path need to be devised and provided.

» **M**aharashtra State Road Development Corporation (MSRDC) has constructed Mumbai Pune Expressway of which a section of the road alignment between Khopoli and Sinhgad University was not completed due to issues related to environmental clearances. Construction of this missing link consists of construction of twin tunnels, over bridge, viaducts and capacity augmentation of the corridor. In order to ascertain the feasibility of construction of tunnels, MSRDC approached NIRM.

The ground vibration data collected at similar projects using 38 mm hole diameter and 45 mm hole diameter were analyzed. The generalized predictor equation for data using 45 mm diameter holes were found conservative and same was presented in this case. Based on the DGMS norms, a ground vibration limit of 10 mm/s was recommended as safe peak particle velocity for civil structures. Based on the earlier works of NIRM (blasting close to bridges/dams), a safe peak particle velocity of 25 mm/s is recommended for the Lonavla barrage and 100 mm/s for the Bushi Dam. Though the permissible vibration limit for civil structures is 10 mm/s based on DGMS standards, the derived generalized predictor equation was used to calculate the safe maximum charge per delay for different distances by taking 5 mm/s as permissible limit (to increase the factor of safety).

It was concluded that by adopting controlled blasting, excavation of twin tunnels at the missing link of Mumbai Pune Express Highway was possible. Also it was suggested to excavate the tunnel 1 and 2 by three stages as

Stage I - Pilot heading,
Stage II – Side Slashing/Arch enlargement &
Stage III – vertical benching.

The tentative blast designs using smooth wall techniques wherever applicable was prepared for all the stages of excavation.

Location of various civil structures with reference to the proposed twin-tunnel alignment

The recommended hole diameter for the tunnel excavation is 45 mm using cartridged slurry/emulsion explosives with shock tube initiation system. It is recommended that during actual construction of the twin tunnels, a site specific ground vibration study should be carried out and ground vibration should be monitored regularly for all the blasts. As the stability of the proposed tunnels under Lonavala Lake depends on many parameters and it is the domain of Support Design Engineers, the same was not discussed during plan of blasting.

» **T**he Government of Odisha decided to develop the non-functional fair weather port to an all-weather direct berthing port at Gopalpur. M/S Gopalpur Ports Ltd (GPL) is developing this port. GPL constructed a breakwater partially but it was damaged during the Phailin Cyclone in 2013. Now GPL wanted to renovate of the damaged breakwater. To reconstruct the breakwater, it requires about 2.8 million tons of eight different graded material of 1 kg to 6000 kg size.

In 2013, GPL operated three quarries for the construction of breakwater; they planned to operate the same quarries this time again. In order to maximise the output of the graded material from blasting, the management of the implementing agencies approached NIRM to provide

technical advice on armour stone blasting for the construction of breakwater.

After a preliminary site visit and detailed discussions with project authorities, a method statement was submitted incorporating the details of blast design parameters for armour rock for the construction of breakwater. Keeping the site constraints in view, 115 mm hole dia was considered for arriving at the tentative blast design. Design for each quarry is given which shall be field tested and modified during the next field visit. However, it was strongly recommended to use 89 mm drill holes and 50 mm dia. cartridged explosives for better results. The trial blast yielded 44% of armour stone against 18% which was earlier obtained in the Quarry No. 1 by the quarry team. The suggested tentative blast designs will be field tested in the next field investigation. Further modifications will be carried out depending on the site conditions. The ground vibration recorded is well within permissible levels. An interim report was submitted during February 2018. At Quarry No. 2 and 3, trial blasts shall be carried out after development works to form proper benches. Fragment size distribution shall be analysed using image processing technique after carrying out further field studies at the quarries. To achieve the excavation target, the management shall be advised to open multiple faces in different benches and accordingly increase the equipment deployment.

» Indian Navy is constructing Varsha Project naval base near Vishakhapatnam. As part of this work about 3 km break water is to be constructed. To construct the break water, it requires about 7.8 million tons of eight different graded material of 1 kg to 10 MT size and aggregates of about 5.5 MT. To maximise the output of the graded material from blasting, the Navayuga Engineering Company Ltd, Vishakhapatnam (the implementing agency) approached NIRM to provide technical advice on armour stone blasting for the construction of breakwater. Subsequently, site visit to the existing quarries was made and excavation plan was discussed with the project authorities. Based on the observations, it was noted that the quarry needs technical inputs to maximise the production of armour stone and minimise the deterioration due to inappropriate blasting. The client accepted our proposal and awarded scientific study at their site. The field study will be started once the quarries are ready for trial blasts.

4. Testing Services

Apart from field investigation, NIRM has DGMS approved testing laboratory for testing of material and rope samples. Both destructive testing at laboratory for wire and rope samples and Non-Destructive Testing (NDT) at site for various mining equipment and accessories like winders, wire-rope and shaft components are done at site. Apart from them, the Institute has well established rock testing facility where both preparation and testing of rock samples for various physico-mechanical properties are done as per ISRM standard. The fracture mechanics set-up at Institute determines both static and dynamic properties of rock joints.

During this year, testing services were extended to six major mining companies including HZL, HCL, NALCO, HGML, SCCL and SAIL. Rock testing services were extended to two irrigation projects (KL-8 & KL-11) as well as for ONGC and one marine project.

» HZL Mines, Rajasthan

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. An MOU for a period of three was signed between M/s SSM and NIRM for providing test services. During this year NDT testing such as magnetic particle tests and ultrasonic tests were conducted to determine surface, sub-surface and internal flaws on 190kW stage winder vital components, 5200HP kibble winder vital components, suspension gear parts, 3750kW production koepe winder vital components, 800kW service koepe winder vital components, 15 T winch vital components (2 Nos.), new sheave pulley shafts (3 Nos.) and spare suspension gear parts.

The NDT results on winder/winch vital components, stage attachments and kibble attachments indicated that they were free from surface, sub-surface and internal flaws. Based on the test results of NDT, it was concluded that all the tested components were free from surface, sub-surface and internal flaws. M/s Shaft Sinker's Mauritius Ltd also requested to conduct prototype tests. Proto-type proof load test and NDT on suspension device of cage and skip were conducted to determine it designed payload and NDT on the components to determine surface, sub-surface and internal flaws.

NDT on winder/winch vital components & kibble attachments

This test was carried out on fork link assembly 2 Nos., Swivel 2 Nos., Wedge type cappel 2 Nos., Fork link with pin 2 Nos. and Hydraulic adjustable link 2 Nos. All the tested components such as fork link assembly, swivel, wedge type capple, fork link with pins and hydraulic adjustable link of Cage & Skip sustained its proof load.

After the completion proof load test, the entire suspension device of cage and skip side were subjected to magnetic particle test to identify anomalies. The components of Cage & Skip were tested in accordance with ASME (IS 5334-1981). The test results revealed that the components were free from surface and sub-surface flaws. The components of cage & skip were tested in accordance with ASTM E -114-95. The scanned results indicated that the tested components were free from internal flaws. Proto-type break load test on suspension device of cage and skip were conducted to determine the designed break load.

Break Load on suspension device of production and service shaft, M/s SSM

The components of fork link assembly, swivel , wedge type capple, fork link with pins and hydraulic adjustable link of Cage & Skip were tested in accordance with IS standard (IS: 3626–2001 & IS: 6594–2001). They were found within the permissible limit at the applied breaking load (Safe working load x 10 times).

For Rajpura-Dariba mines of HZL, an MOU is signed for Non-Destructive Testing (NDT) to be conducted on winders and associated components for a period of two years. 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 of 236kW cage winder suspension gear parts at Main shaft, 740kW skip winder suspension gear parts at Main shaft and 225kW cage winder suspension gear parts at Auxiliary shaft. 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.

NDT on suspension gear parts, Rajpura Dariba Mines

The inspected wire ropes included Ø32mm FLC cage ropes – 2 Nos. at Auxiliary shaft, Ø18mm FLC cage ropes –5Nos. at Main shaft and Ø24mm FLC skip ropes – 4Nos. at Main shaft. A fatigue crack was noticed on N1 skip rope of Main shaft which lies at a distance of 350m to 400m from the cappel end. The scanned length of other skip ropes (N2, N3, & N4), cage ropes (E1, E2, E3, E4 & E5) at Main shaft and cage & counter weight side rope at Auxiliary shaft 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).

Zawar Group of Mines of HZL comprises 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 of 383HP cage winder suspension gear parts at Balaria mine, 560HP skip winder suspension gear parts and 70HP cage winder suspension gear parts at Zawar Mala mine, 236HP cage winder suspension gear parts at West Mochia mine, 400HP skip winder suspension gear parts and 200HP cage winder suspension gear parts at Central Mochia mine and Chain pulley blocks. The test results of NDT on cage suspension gear sets and chain pulley blocks indicated that they were free from surface, sub-surface and internal flaws.

There are 17 Nos. of wire ropes at Zawar Group of Mines used for men and material hoisting. The wire ropes were subjected to defectograph tests.The details of the tested wire ropes are Ø32mm FLC cage ropes – 2Nos. of Balaria mine, Ø16mm FLC cage ropes – 2Nos. and Ø30mm FLC skip ropes – 2Nos. of Zawarmala mine, Ø20mm FLC cage ropes – 3Nos. of West

Mochia mine, Ø24mm FLC skip ropes – 4Nos. and Ø16mm FLC cage ropes – 4Nos. of Central Mochia mine.

NDT on winder suspension gear parts & chain pulley blocks, Zawar Group of Mines, HZL.

Inspection of wire ropes, Zawar group of mines, HZL

The test results 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).

» Hindustan Copper Limited, Rajasthan

M/s Hindustan Copper Limited (HCL) is a public sector undertaking under Ministry of Mines. As a statutory requirement, the winders and all their associated vital components need to be periodically evaluated for their fitness. Accordingly, 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 on 1600kW cage winder vital parts, suspension gear parts and Ø51mm langs lay 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.) of Kolihan Mine; 800HP koepe skip winder vital parts, suspension gear parts and Ø24mm FLC E2 skip rope (01No.); Ø16mm FLC rope at '0' mRL (01No.) and Ø19mm FLC rope at 184 mRL (01No.) of Kolihan Mine.

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. As regards to non-destructive tests conducted on all the wire ropes, the results revealed that the tested wire ropes were free from local faults (LF) such as pitting, corrosion and broken wires and also there was no loss of metallic cross-sectional area (LMA).

» National Aluminium Company Limited, Damanjodi, Odisha

M/s National Aluminum Company Limited (NALCO) a public sector enterprise under the Ministry of Mines. 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 14.66 Km 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 need to be periodically checked for their fitness. M/s NALCO requested NIRM to evaluate the operational cable belt drive ropes. The length of each rope (left side and right side) is 30km, which is made up of five ropes measuring 6km each and joined (spliced). Wire rope defectography studies were carried out on the cable belt drive ropes and the scanned strip charts were analyzed.

Inspection of cable belt drive ropes, NALCO

Based on the tests carried out on the cable belt drive ropes (Left and Right), it was concluded that the left side rope which was installed during April 2015 had undergone wear. Also fatigue cracks and few broken wires were noticed. The left side rope was found to have uniform wear throughout the length of rope. The right side rope was found to be deteriorated and characterized with excessive wear. The percentage reduction in diameter of left side rope is 6.66% and that of right side rope is 8.03%. As the reduction in diameter of both the ropes is well below 10%, the ropes can be continued for 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 that the right side rope needs a careful handling and regular monitoring with caution. It was also recommended to introduce non-metallic liners on the deflection pulley grooves to reduce excessive wear. It was suggested that the ropes should be subjected to periodic tensile tests to know the minimum breaking force. Therefore specimen samples of the rope from every spliced region may be sent to NIRM for determination of tensile strength.

» Singareni Collieries Company Limited, Telangana

The project sites of M/s Singareni Collieries Company Limited (SCCL) are located at different parts of Telangana state. The operations at all the mines are carried out through shafts run by winders. M/s SCCL requested NIRM to carry out non-destructive testing on various mining machineries. Accordingly NDT on winder vital components, suspension gear parts and wire rope defectography were done at Ramagundam, Yellandu and Kothagudem areas. Using MPT and UT, NDT was carried out on the winder vital components and suspension gear parts of 350HP cage winder at GDK-10 incline, Ramagundem Area, 285kW cage winder at PVK-5B, Kothagudem Area, 285kW Cage winder at VK-7 incline, Kothagudem Area and 400HP cage winder at 21 incline, Yellandu Area

The wire ropes used for operating the cages were also inspected using wire rope defectograph equipment on 32mm FLC ropes – 02 Nos. at GDK-10 incline, 32mm FLC ropes – 02 Nos. at PVK-5B, 32mm, FLC ropes – 02 Nos. at VK-7 and 32mm FLC ropes – 02 Nos. at 21 incline. All the tests were completed successfully. Based on the tests conducted on winder vital components and suspension gear parts, it was concluded that all the tested components were free from surface, sub-surface and internal flaws. As regards to non-destructive tests conducted on cage wire ropes, the results 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).

To access the fitness of the Hear gear structures, M/s SCCL requested NIRM to take up the NDT works and structural audit on all the four head gears steel structures at Ramagundem, Yellandu and Kothagudem areas of mines. NIRM conducted the required tests using NDT techniques on the steel structures of the head gears. The study was conducted using various NDT techniques such as visual inspection, ultrasonic test, ultrasonic pulse velocity, infrared thermography, vibration analysis, rebound hammer, load test using total station survey and thickness measurement gauge.

The results of visual inspection on the identified steel structures indicated that all of them were in good condition. To avoid rust, paint with anti-rust should be applied periodically. Ultrasonic test on all the foundation bolts of head gear steel structures were free from internal flaws and their integrity appeared good. As a qualitative assessment test, ultrasonic pulse velocity test was conducted on different locations of the concrete foundations of steel structures. The measured values of pulse velocity on concrete foundations of the identified structures were in the range of 3.5 to 4.5km/s. Hence the concrete was classified under 'Good' grade concrete as per velocity criterion prescribed in IS 13311 (Part I): 1992.

Structural stability audit on head gear structures at M/s SCCL, Telangana

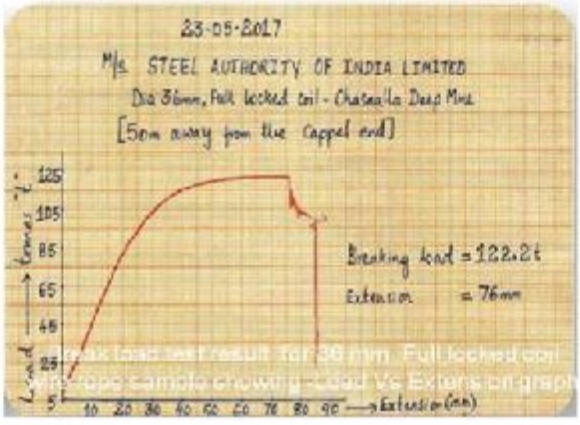
Infrared thermography study on the stressed zones of gantry steel structures and concrete foundations of gantry steel structures showed that there was no thermal anomaly. This indicated that no significant stress zones were present on the steel structures and the concrete foundations were free from voids, cracks, moisture and de-lamination.

Vibration levels at different loads on top of the head gear and on the foundations were measured (Class V Machines). The observed velocity did not exceed 28mm/s (as per the vibration standards) which indicated the severity of the vibration as 'Moderate'. The measured rebound values on the concrete foundations of the steel structures were found to be in the range of 38 to 44. As per IS 13311, part-2:1992, BS: 6089-81 & BS: 1881: Part-202 from table 4, the quality of the concrete was between 'Good and Very Good grades'. The thickness measured at different locations of the steel structure matched with its original thickness.

» Steel Authority India Ltd., Jharkhand

Investigation on fatal accident on suspension gear attachments (cage suspension gear parts) and wire ropes of Chasnalla Mine of M/s SAIL, Jharkhand was carried out at the Material Testing Laboratory of NIRM.

Apart from destructive tests, Material Testing Laboratory is also providing services in the field of non-destructive tests. During the financial year 2017-18, eight NDT projects were taken up. Apart from these tests, Calibration test on 200 t load cell unit was carried out for BEML.



Destructive tests on steel wire ropes were carried out to determine their residual life. Destructive test included comprehensive test (tensile, torsion & reverse bend test on individual wires) and tensile test on complete wire rope sample. During the fiscal year, testing laboratory had carried out testing of 106 steel wire ropes of diameters ranging from 16 mm to 51 mm.

» Hutti, Hirabuddini and Uti gold mines, HGML, Raichur, Karnataka

For Hutti Gold Mines, uniaxial compression tests were carried out on both dry and saturated samples for the determination of compressive strength, Young's Modulus and Poisson's ratio. A total of 12 samples were tested and it was observed that the UCS varied from 67 MPa to 334 MPa for dry samples, whereas it ranged from 101 MPa to 348 MPa for saturated samples. The Young's modulus was ranging from 38.17 GPa to 118.28 GPa for dry samples whereas it was 50 GPa to 102 GPa for samples tested with saturated conditions. The Poisson's ratio for dry and saturated samples varied from 0.24 to 0.32 and 0.19 to 0.31 respectively. Tensile tests were carried out on both dry and saturated samples prepared from the host rock and Ore rock. A total of 20 samples were tested and it was observed that the tensile strength for dry samples varied from 17 MPa to 36.8 MPa whereas for saturated samples it was ranging from 17.4 MPa to 34.4 MPa. Triaxial compression tests were carried out on both dry and saturated samples for the determination of cohesion, friction angles and constant "m". Tests were carried out on 12 samples. It was observed that the cohesion and friction angle varied from 26.39 MPa to 60.34 MPa and 41.85° to 48.69° respectively for dry samples. For saturated samples the cohesion and friction angle varied from 28.13 MPa to 56.08 MPa and 41.28^0 to 48.76^0 respectively.

Samples having joint were tested in MTS compression testing machine. The normal load and the deformation were measured to calculate the normal stiffness of joints. Shear tests were carried out in the Direct Shear Testing machine for different samples from different locations at different normal stress to determine the peak shear stress and shear stiffness.

For Hirabuddinni Gold Mines, laboratory geotechnical investigations were carried out on the rock core samples received from Ore Body, LHW and LFW. The samples were tested under uniaxial and triaxial stress conditions for the determination of UCS, Tensile strength, Young's modulus, Cohesion and Friction angle. UCS and Young's Modulus were determined for 6 samples tested from Foot Wall, Hanging Wall and Ore Body. The UCS value varied from 177 MPa to 417 MPa, where as the Young's modulus ranged from 57.54 GPa to 124.39 GPa. The Poisson's ratio varied from 0.21 to 0.24. The tensile strength was determined for core samples from different boreholes of Ore Body, Hanging Wall and Foot Wall. A total of 12 samples were tested under dry and saturated conditions. Triaxial compression tests were carried out on 6 samples for the determination of cohesion and friction angles. The values of cohesion for samples varied from 24.36 MPa to 93.00 MPa and the values of Friction angle ranges from 41.31 to 50.56 degrees.

For Uti Gold Mines, laboratory geotechnical investigations were carried out on the rock core samples received from Foot Wall, Hanging Wall and Mineralized zone of UGM-14 and UGM-25, Load no.4. UCS and Young's Modulus were determined for 3 samples tested from foot-wall, hanging-wall and mineralised zone. The UCS varied from 203 MPa to 258 MPa, whereas the Young's modulus ranged from 80 GPa to 86 GPa. Brazilian tests were conducted on 6 samples from foot wall, hanging wall and mineralized zone for the determination of tensile strength. Triaxial compression tests were carried out on 3 samples for the determination of cohesion and friction angles. The values of cohesion for samples varied from 29.91 MPa to 59.85MPa and the values of friction angle ranges from 47.25 to 50.17 degrees.

» Kaleshwaram Lift Irrigation Scheme (KLIS), Package-8, Telangana

Laboratory geotechnical investigations were carried out on the rock core samples belonging to KLIS, Package-8 for the purpose of support Design for the Underground Surge Pool and Pump House. The core samples were received from 9 boreholes of the pump house loose fall area, for determining physico mechanical properties.

The scope of work included determination of bulk density, tensile strength, uniaxial

compressive strength, Young's modulus and Poisson's ratio, cohesion and friction angle from triaxial compression test (Multiple failure method).

Tests were carried out as per ISRM suggested methods on the prepared test specimens both under dry & saturated conditions to determine various physico mechanical properties.

» Kaleshwaram Lift Irrigation Scheme (KLIS), Package-11, Telangana

Laboratory geotechnical investigations were carried out on the rock core samples belonging to the Underground Surge Pool and Pump House, KLIS, Package-11 for the purpose of support design. The core samples were received from the Pump house loose fall area, for determining physico mechanical properties.

The scope of work included determination of bulk density, uniaxial compressive strength with elastic constants, cohesion and friction angle from triaxial compression test, normal and shear stiffness of Joints on both dry and saturated samples of surge pool and Pump house.

Test specimens were prepared from the selected core samples and tests were carried out as per ISRM methods.

» Oil and Natural Gas Corporation Limited

The Oil and Natural Gas Commission (ONGC) is in the process of drilling deep boreholes for exploration purpose. The Institute of Drilling Technology (IDT) Dehradun, and Centre of Delivery (COD), Basement exploration, Mumbai (subsidiaries of ONGC) requested NIRM to carry out laboratory geotechnical investigations on core samples from wellbores of Geleki area of Assam Asset, Sivasagar and from wellbores of Mumbai Offshore area, Cauvery Basin and A&AA Basin. The test results will form input parameters for geo-mechanical modelling of wellbore stability to be carried out by IDT and COD.

The scope of work included determination of Density P & S-wave velocity, Uniaxial compressive strength, Young's modulus and Poisson's ratio & Cohesion and Friction angle from triaxial compression test (Multiple failure method). Test specimens were prepared and all the tests were carried out as per ISRM suggested methods. Test reports were submitted.

» P1 Project, Vizag, Andhra Pradesh

L & T constructions, Vizag, requested NIRM to carryout Geotechnical investigations on rock core samples of P1 project, collected from 8 different boreholes viz. NBH 13, 14, 15, 31, 39,40, 45, & 6A/1. The samples for various tests were prepared and tested as per ASTM / IS / ISRM standards.

The scope of work included determination of physico-mechanical properties such as density and porosity, specific gravity and absorption, dynamic modulus, Schmidt rebound hardness, slake durability index and water content, uniaxial compressive strength, Young's modulus, Poisson's ratio from uniaxial compression test, cohesion and friction angle from triaxial compression test, tensile strength from Brazilian test method and Point load strength index.

Samples were tested under both dry and saturated conditions depending upon the availability of core samples from each borehole. In general the values for the samples tested under dry condition were higher than those tested under saturated conditions. Triaxial compression tests were carried out at various confinements (2.0 MPa to 10 MPa) and failure stress, Cohesion and Friction angle were determined.

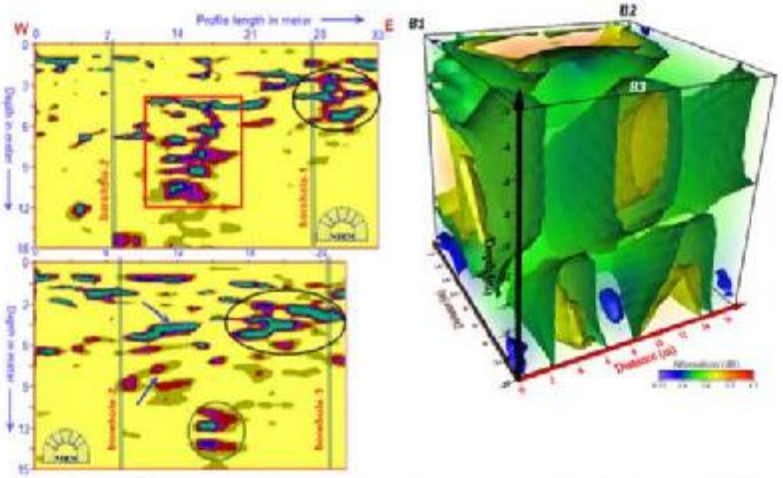
Borehole wise physical and mechanical properties were determined and presented for the better understanding and interpretation of the results.

5. Miscellaneous Sector

Apart from key work areas of Mining, Power and Infrastructure sector, NIRM extends its R&D support and expertise to other allied areas which include Archaeological Survey of India where conservation of heritage structure against vibration induced damage or exploration of new excavation sites is necessary. Means for conservation of other heritage structure against damage by forces of nature or other forces is also investigated. Three such projects were taken up during this year out of which two belonging to ASI has been completed and investigation is in progress for the other one.

» Vadnagar located in the Mehsana district of Gujarat state is a heritage site of old Buddhist monastery. Excavations at Vadanagar in 2006 by archaeological department of Gujarat had found trace of a major Buddhist monastery. The same was later discovered by the Archaeological Survey of India (ASI) also at other nearby places. In order to explore extension of such old settlement elsewhere, ASI requested GPR survey in some virgin area. Accordingly the campus of municipal Girls' Primary school at Vadnagar and areas around old excavations were selected for this exercise. NIRM carried out both surface GPR survey and GPR tomography in the school campus and surface GPR survey at other places. Three boreholes of 20m depth were drilled by ASI in a triangular array in the school campus and three sets of cross-hole tomography were done between them.

The GPR tomogram from these measurements indicated rocky strata in the centre extending upto 6m depth and the same re-appeared at 14-15m depth. The central vacant portion appeared filled by loose soil or debris with central space open where a reverse pattern of contour closure was mapped. Features revealed from interpretation of various tomograms were found in the surface survey section also. For a better understanding of the implication of various features, the three tomograms were combined into a 3-D section.



Surface GPR section in the school campus and 3-D plot of GPR tomogram indicating a buried collapsed structure from a shallow depth of 4-15m. This section shows 3D view of buried structure from school side

This revealed a collapsed buried structure in the school campus area. Manifestations of these features in the tomographic sections need to be confirmed by actual excavation.

» Shravanabelagola is one of the holiest shrines of Jains where world's tallest monolithic statue (Grey Granite) of Bahubali installed in 981 AD is worshipped. This 58.8 feet tall statue is carved out on Vindhyagiri hill of Hassan District, Karnataka. Masthaka-abhisheka of this statue is done once in 12 years and is considered as the most auspicious events where lacs of pilgrims attend the month long function. The scaffolding and platform to perform Abhisheka is being provided by the Karnataka State Government through M/S Layher and Company.

In order to transport men and material to the elevated platform it was proposed to erect two lifts for man riding and one for materials. As the statue and all other iconic places here come under the Archaeological Survey of India (ASI), the Superintendent of ASI, Bengaluru had apprehensions with regard to influence of vibrations on the statue due to the operation of these temporary lifts at a distance of just 15m behind the statue and the ability of load

bearing capacity of the rockmass at the proposed lifts location. Keeping this in view, the organizers of Jain community approached NIRM with a request to visit the site and assist technically on the issues flagged by ASI, Bengaluru so as to enable the experts and concerned departments to arrive at a consensus decision.

Subsequently the team from NIRM visited the site and carried out various field studies. Electronic Schmidt hammer rebound tests were carried out and strength of the foundation rock was determined. The strata for testing was selected at random and tested for rebound reading. Uniaxial Compressive Strength (UCS) was determined based on ISRM suggested method (Adnan Aydin, 2008). The UCS at three representative locations namely exposed rock behind statue was 181 MPa; exposed rock by the side of statue was 234 MPa and in the nearby area it was 312 MPa. These values of UCS were very high and proved that the rock was very competent and can take high loads.

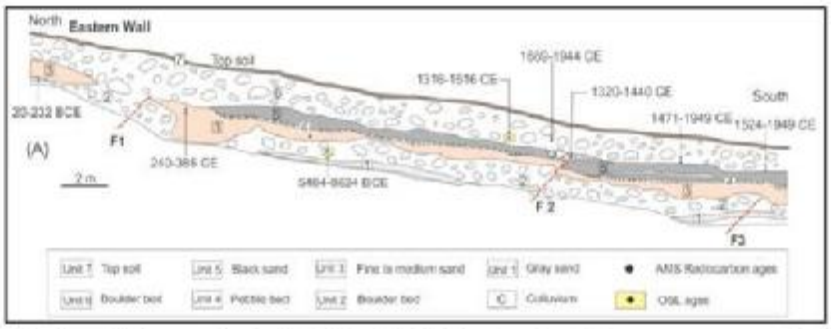
Testing of rock by Schmidt hammer in the nearby area

As per specifications of the lifts, the actual load transfer is 18 kN/m^2 (0.018MPa) and 76 kN/m^2 (0.076MPa) on the foundation rock. Since the rock mass at Vindhyagiri hill is massive and there are no distinct discontinuities and the UCS of granite in general is more than 100 MPa, the transferred load is insignificant compared to the safe bearing capacity of the rock (as determined from UCS as per IS code 12070–1987).

Microprocessor-based portable seismograph was used for monitoring vibration. The threshold limit of the geophone was set to a minimum level of 0.130 mm/s. The seismograph didn't pick any vibration even at this very low sensitive level which revealed that the ambient vibration levels were insignificant surrounding the statue. Therefore it is opined that by inducting three lifts into the current systems of operation at the proposed location shall in any way alter the above vibration levels. However, it is suggested that vibration levels be measured during a trial run of the lift to ascertain the vibration levels.

NIRM apprised of the outcome field study to the concerned officials. Outcome of this study enabled GoK to permit the operation of the lifts.

» An S&T project was taken up on geological and geomorphic characterization of the frontal thrust fault at central and northeast Himalaya. The potential threat of great earthquakes from the Himalayan sources is a major scientific and societal concern. The study conducted paleo-seismological studies in the selected locations within the central Himalaya to determine ages, sizes and the extent of the earthquake ruptures.



Eastern wall of the trench at MohanaKhola, Bihar and Calibrated and modelled ages of each of organic samples collected from the wall

During this period, detailed field investigations were carried out at Mohanakola, in the frontal belt of Himalaya and Bathouli. A 35-meter long trench with a depth of 3 to 4 m and width of 2 m was excavated at the foot of the frontal Himalayan thrust. The trench exposed three major sedimentary units - a lower sandy facies, middle bed of boulders, cobbles, gravels and

pebbles with some sand and an upper sandy-silty unit. The top of the upper sand-silt unit was marked by a depositional unconformity and then continued by landslide debris. The scarp was formed by a 30- to 60-m-high strath terrace capped by middle to late Holocene fluvial gravels, probably associated with a tributary channel.

The scarp represented uplifted inset terraces, associated with a tributary channel that drained the high terrace, across the MFT. As a part of identifying paleo-liquefaction features sand dikes were exposed near Bathouli. Stratigraphically controlled samples were collected from these trenches to bracket the event. Results of these investigations are expected to provide information on the timing of Himalayan earthquakes of the past.

» Belum Caves in Andhra Pradesh extend around 8 km near the Belum village. These natural caves are carved out in the lime stone deposits and has significant geological importance. The cave was flooded due to heavy rain in the month of October, 2017. NIRM has undertaken c geological studies for assessing the stability of the caves. Objectives of the studies include :

(a) geological mapping of the caves paths, roof as well as wall
(b) identify the most unstable areas in the caves, and
(c) find out the direction of the water flow and source with help of the available data.

During field visit it was observed that bedding joints were open at a few locations due to flooding, some boulders were displaced from their earlier location and few toppling of the cave walls were also observed. No proper ventilation was provided in the caves. Surface geological observations were taken around the caves. Three major sink holes were identified which might be connected with the main caves. The surface holes are mostly controlled by the joint and the radial flow pattern was observed in the exposed rock on surface near the caves.

Holes developed along the joint in the limestone

6. Human Resource Development

As a part of HRD exercise, NIRM conducts training programme for executives from the industry. During this year, two such programs were conducted.

» First training programme was conducted on "Tunnelling Technology" for the Engineers of the Rail Vikash Nigam Ltd." at NIRM, Bengaluru HO from 3rd-7thJuly, 2017.

» Second training programme was conducted on "Tunnelling Technology" for the Officers of the Mumbai Rail Vikash Vorporation Ltd. at NIRM, Bengaluru HO from 3rd-7thJuly, 2017.

» Celebration of 75th Anniversary of"Quit India Movement"

On the occasion of the 75th anniversary of "Quit India Movement", National Institute of Rock Mechanics organized Swachchh Bharat drive and plantation of trees in and around NIRM HO during 16th-30th August, 2017. All the employees participated in the cleaning exercise and planted trees in the campus.

Cleaning of office premise by employee

Plantation of trees

Group photo of NIRM employee on the occasion of Swachh Bharat Drive

» Celebration of Hindi Fortnight

The Hindi fortnight was successfully organized from 14.09.17 to 28.09.17 in the office. On this occasion various competitions such as essay writing, standard noting, word-matching, and poetry recitation were organized to encourage employees and to enhance the use of Hindi language. All the officials and employees participated enthusiastically. Prize was distributed to performing employees in the program. In the closing ceremony, the Official Language Officer highlighted the importance of the official language. All Heads of Departments also expressed their views. The Director said that every Indian should value Hindi language and take advantage of economic advancement in the country. He emphasized that Hindi as Official Language is the key to our identity in the future.

Participation of NIRM staff in competitions and award of individual prizes to winners

» Celebration Of 3rd International Day of Yoga

In continuation of the tradition of participating in the worldwide programme on International Day of Yoga, NIRM celebrated IDY-2017 by conducting Yoga Session in the NIRM office premises. The yoga session was organised on 21-06-2017, from 9:30 am to 10:45 am with the participation of all the Scientists and Staff of NIRM HO (Bengaluru) and NIRM RO (KGF).

At Bengaluru, the Yoga Session was conducted by the local Yoga exponent Sanyasi Devanand, Yoga Guru from Atma Darshan Ashram, Bengaluru. At KGF office Yoga session was conducted by the Yoga Guru from Prajapita Brahma Kumaris Ishwariya Vishwa Vidyalaya.

Reiterating the essence of Yoga, Yoga Guru emphasized was on Kshama (attitude of forgiveness) and Maitri (attitude of friendliness). This was advised in daily practice of inner tranquil that will ensure smooth and healthy working atmosphere. Yoga Gurus also delivered short speech on the benefits of yoga and urged all the employees to make yoga a daily practice in their lives. During interactive session, clarifications and explanations of queries made by staff were given by the Yoga Guru. The Yoga Guru gave useful practical tips and suggestions to enable the employees practice at home and as well as at places where they travel for their duties.

Practice of asana and pranayama under the guidance of Yoga Guru

ANNUAL ACCOUNTS

G. Manjunath & Co
Chartered Accountants

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 2018, 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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No. 300/C, I Floor, 36th Cross, 9th A Main, 5th Block Jayanagar, Bengaluru - 560041
Ph: 080-26534010 Cell: +91 94483 64010 e-mail: ca@gmanjunath.com, gmanjunath.ca@gmail.com

Basis for qualified opinion

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

ii. *Physical verification of fixed assets with tagging of fixed assets are yet to be carried out as described in item No.4 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 2018;
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 18,2018

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 2018.

1. ACCOUNTING POLICIES :-

A. Background:

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

Basis of Preparation:

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

B. Fixed Assets:

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

C. Foreign Exchange Transactions:

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

D. Revenue Recognition:

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

E. Treatment of Government Grant:

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

The Capital Grant for 'Plan' received as per sanction order 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.

4. Fixed Assets are subject to physical verification and identification tagging. The process of updating of the fixed assets register is underway and is pending completion.

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. The accumulated interest earned on the Fixed deposits of Institute Development fund for Rs.70.80 lakhs transferred to corpus fund i.e. Institute Development Fund during the year 2017-18

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 Institute has sought confirmation of balance from the parties, some of which is yet to be acknowledged by them.

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

Uma.H.R
Finance & Accounts Officer

Dr.H.S.Venkatesh 19/9/18
Director

Member
Governing Body

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

Place: Bangalore
Date:

G. MANJUNATH & CO. FRN 001995S Chartered Accountants

CA.G.MANJUNATH & CO
Proprietor
(MRN: 027968)

NATIONAL INSTITUTE OF ROCK MECHANICS

BANGALORE

CONSOLIDATED BALANCE SHEET AS AT 31ST MARCH 2018

(Amount in Rs)

Sl. No.	Liabilities	Sch No.	Balance as on 31-03-2018	Balance as on 31-03-2017	Sl. No.	Assets	Sch No	Balance as on 31-03-2018	Balance as on 31-03-2017
1	**CAPITAL FUND**	1							
	a) Capital Reserve		32,44,334	32,44,334	1	**FIXED ASSETS**	7	5,01,89,985	2,86,48,945
	b) Internal Capital Reserve		2,50,42,413	2,50,42,413					
					2	**INVESTMENTS**	8		
2	**OTHER CAPITAL FUNDS**	2				a) Fixed Deposits - Institute Development Fund		5,30,80,024	4,60,00,000
	a) Deferred Government Grant		8,21,03,201	8,26,27,845		b) Short term deposits against project advances received from clients		13,95,88,665	12,54,80,053
	b) Institute's Development Fund		5,30,80,024	4,60,00,000				-	
					3	**CURRENT ASSETS, LOANS & ADVANCES**			
3	**CURRENT LIABILITIES**					Deposits	9	5,35,628	6,35,628
					4	**Loans and advances**			
	a) Sundry Creditors - Staff	3	24,49,488	22,07,821		a) Advances - Staff	10	17,54,890	9,58,092
	b) Sundry Creditors - Others	4	2,12,06,063	1,21,62,277		b) Advances - Suppliers	11	1,49,68,046	4,22,06,272
	c) Project Advaces Received	5	20,50,39,519	18,40,99,555		Other Current Assets	12	3,01,32,681	3,42,25,321
	d) Provisions	6	1,78,75,318	1,67,19,049		Expenses on Ongoing Projects	13	6,22,97,218	5,08,05,690
						Sundry Debtors	14	3,95,18,987	1,87,09,167
					5	**Current Assets**	15		
						a) Cash in Hand		-	36,859
						b) Cash at Bank		1,11,39,594	1,15,06,716
4	Significant accounting policies & Notes on Accounts	29				c) closing Stock		-	-
					6	**Income & Expenditure A/c. (Dr)**	16	68,34,642	1,28,90,551
	TOTAL		**41,00,40,360**	**37,21,03,294**		**TOTAL**		**41,00,40,360**	**37,21,03,294**

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

For National Institute of Rock Mechanics

(Uma.H.R)
Finance & Accounts Officer

(Dr. H.S.Venkatesh)
Director

Member
Governing Body

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

(CA G.Manjunath)
MRN : 027968

Place : Bangalore
Date :18-9-2018

NATIONAL INSTITUTE OF ROCK MECHANICS
BANGALORE

CONSOLIDATED INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING ON 31st MARCH 2018

(Amount in Rs)

Sl. No.	Expenditure	Sch No	2017-18	2016-17	Sl. No.	Income	Sch No	2017-18	2016-17
1	Administrative Expenses	17	1,11,13,254	71,69,577	1	Grant-in-Aid received from Ministry of Mines	24	6,36,00,000	5,94,00,000
2	Pay & Allowances	18	9,86,32,860	8,74,11,896	2	Amount Received Against Completed Projects	25	12,05,01,436	7,05,63,734
3	Travelling Expenditure	19	7,39,107	6,18,019	3	Interest Received	26	1,11,58,273	1,44,12,440
4	Upkeep of Assets	20	5,82,502	9,82,321	4	Miscellaneous Income	27	13,03,508	3,56,904
5	Expenditure on Completed Projects	21	5,55,94,761	2,78,97,222	5	Withdrawal of Depreciation	28	5,24,644	5,24,644
5	Depreciation on Fixed Assets	7	90,62,174	80,26,547					
6	Prior Period Expenses	22	-	66,916					
7	Tax Expenses	23	82,27,270	52,65,479					
8	Excess of Income over Expenditure		1,31,35,933	78,19,745					
	Total:-		19,70,87,861	14,52,57,722		Total:-		19,70,87,861	14,52,57,722

The Schedules referred to above form an integral part of the Income and Expenditure Account

For National Institute of Rock Mechanics

(Uma.H.R)
Finance & Accounts Officer

(Dr. H.S.Venkatesh)
Director

Member
Governing Body

As per our Report of even date
For G Manjunath & Co
Chartered Accountants
FRN :0019958

(CA G.Manjunath)
MRN:027968

Place : Bangalore
Date : 18-9-2018

NATIONAL INSTITUTE OF ROCK MECHANICS
BANGALORE
Consolidated Receipts and Payments Account for the year ending on 31st March 2018

(Amount in Rs)

	Receipts	Amount		Payments	Amount
To	Opening Balance		By	TDS on Fixed Deposits	12,56,305
"	Cash	36,860	"	TDS on Project Receipts	57,58,793
"	Bank	1,15,06,714	"	Refund of EMD	2,49,500
"			"	Paid for Purchase of Lab Equipment	13,84,659
"	Grant - in - aid ((Non Plan)	6,36,00,000	"	Transfer to Fixed Deposits	20,69,52,748
"	Licence Fee Received	9,182	"	Prepaid Expenses - AMC & Insurance	3,931
"	Other Income Received	55,675	"	Advances to Others	69,82,573
"	Security Deposits Recovered	1,00,000	"	Administrative Expenses	1,09,91,388
"	Interest Received on Savings Bank Deposits	6,82,943	"	Salaries & Wages	9,95,55,143
"	Interest Received on Term Deposits	1,55,17,439	"	payment of retention money	2,00,000
"	Fixed Deposits Matured	18,57,64,112	"	payment of terminal benefits	1,36,013
"	Advance Received - Sponsored Projects	13,61,13,751	"	Advance to Staff	13,66,418
"	Advance Received - Centre for Testing service	34,71,450	"	Travelling Expenses	7,99,848
"	Other Advances Recovered	15,42,122	"	Up Keep of Assets	5,83,090
"	Income tax refund received with Interest	7,19,922	"	Imprest	10,000
			"	Project Contingency (B)	2,75,529
			"	Honorarium/ Incentive (Projects / MTL)	3,26,718
			"	Institute-Project Adjustment Account	1,66,13,556
			"	Advances - Capital Material (net)	1,28,35,796
			"	Expenditure on Running Projects	1,10,72,919
			"	Expenditure on sponsored Sponsored Projects	1,37,18,557
			"	Contigency - Centre for Testing Servcies	3,42,726
			"	Payment of GST & Service Tax	1,61,80,694
			"	Expenditure on Completed Sponsored Projects	3,83,670
			"	Closing Balance	
			"	Cash	
			"	Bank	1,11,39,595
	Total	**41,91,20,170**		**Total**	**41,91,20,170**

For National Institute of Rock Mechanics

(Uma.H.R)
Finance & Accounts Officer

(Dr. H.S.Venkatesh)
Director

Member
Governing Body

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

(CA G.Manjunath)
MRN : 027968

Place : Bangalore
Date :

Schedule - 7

NATIONAL INSTITUTE OF ROCK MECHANICS
Bangalore

CONSOLIDATED DEPRECIATION SCHEDULE FOR THE YEAR ENDING 31ST MARCH 2018

(Amount in Rs)

Name of the Assets	Rate of Depreciation %	Gross Block: Balance as on 01-04-2017	Gross Block: Assets Written off/Transferred	Gross Block: Purchases up to 30.09.2017	Gross Block: Purchases between 1.10.2017 to 31.12.2017	Gross Block: Purchases After 01.01.2018	Gross Block: Total as on 31.03.2018 (Total of Col 3 to Col 7)	Depreciation: Balance as on 01-04-2017	Depreciation: Depreciation written off	Depreciation: Depreciation for the year	Depreciation: Total Depreciation as on 31-03-2018 (Total of Col 9 to Col 11)	Net Block: As on 31-3-2018 (Col 8 - Col 12)	Net Block: As on 31-3-2017
1	2	3	4	5	6	7	8	9	10	11	12	13	13
Buildings	5	2,17,32,967	-				2,17,32,967	56,12,724	-	10,86,648	1,06,59,272	1,15,33,395	1,71,29,241
Plant & Machinery	7.5	3,32,40,834	-				3,32,40,834	3,29,44,179	-	2,96,555	3,32,40,734	100	[illegible]
Water Supply	5	3,28,926	-	-	-	-	3,28,926	3,28,826	-		3,28,826	100	100
Power supply	5	5,03,434	-	-	-	-	5,03,434	5,03,334	-		5,03,334	100	100
Furniture	5	45,68,296	-	-	17,772	-	45,83,068	29,62,082	-	2,28,756	31,90,838	13,92,230	16,06,174
Office Equipment	5	27,56,604	-	4,50,772	1,04,480	40,012	33,61,868	18,29,794	-	1,64,956	19,93,450	13,96,418	[illegible]
Vehicle	7.5	7,83,835	-	-	-	-	7,83,835	7,83,735	-		7,83,735	100	100
Laboratory Equipment	7.5	3,31,31,800	-	2,30,16,563	9,52,330	60,15,384	6,31,16,097	2,49,87,195	-	43,59,630	2,93,46,828	3,37,69,271	81,44,625
Technical Books	5	46,93,917	-	-	-	-	46,93,917	35,29,203	-	2,34,596	37,63,799	9,30,018	11,64,714
Computer Software	15	1,83,58,034	-	-	-	-	1,83,58,034	1,60,62,226	-	22,95,708	1,83,57,934	100	22,95,808
Computer Hardware	20	1,46,33,368	-	-	-	-	1,46,33,368	1,46,33,268	-		1,46,33,268	100	100
Conversion of Power line	5	17,99,459	-	-	-	-	17,99,459	14,24,384	-	89,973	15,14,357	2,85,102	3,75,075
Env Geo Tech Lab	7.5	21,13,400	-	-	-	-	21,13,400	17,61,602	-	1,58,506	19,20,108	1,93,292	3,51,798
PROJECT:													
Vehicle	7.5	19,68,620	-	-	-	-	19,68,620	6,04,385	-	1,47,647	7,52,032	12,16,588	13,64,235
Total:-		16,06,15,543	-	2,34,74,259	10,74,542	60,55,396	17,12,18,264	11,19,66,598	-	90,62,174	12,10,28,772	5,01,89,084	2,86,48,945
Advance for capital material purchase		-	-	-	-	-	-	-	-	-	-	-	-
(Previous year figures)		12,76,70,618	-	89,33,320	18,75,068	21,37,516	16,06,15,543	10,30,48,051	-	88,28,547	11,19,66,598	2,86,48,945	2,32,35,567

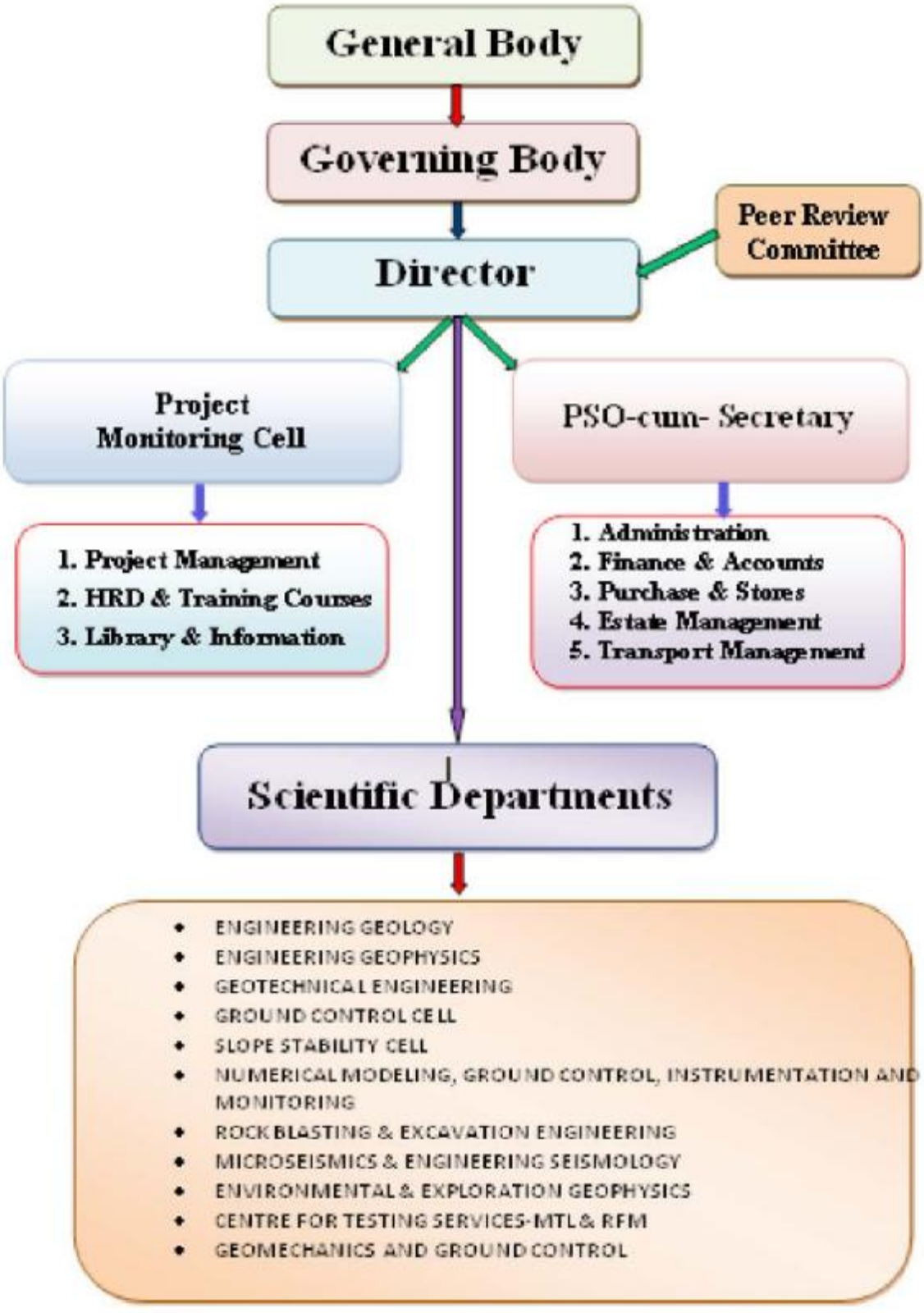
Note: 1. Items not put into use : NIL

2. Depreciation has been charged on Straight Line Method.

ANNEXURE
(1-8)

ANNEXURE-1

NIRM ORGANISATION CHART



ANNEXURE-2

MEMBERS OF THE GENERAL BODY	
Chairman	
Secretary (MOM) Ministry of Mines, Government of India, 3rd Floor, A Wing, Room No. 320, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi – 110 001.	
Members	
Additional Seceretary, Ministry of Mines, 3rd Floor, A Wing, Room No.327, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi - 110 001.	Member (D & R), Central Water Commission, Room No.401 (S), Sewa Bhavan, R.K.Puram, New Delhi - 110 066.
Joint Secretary & Financial Advisor, Ministry of Mines, 3rd Floor, A Wing, Room No.321, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi – 110 001	The Advisor (Projects), Ministry of Coal, 3rd Floor, A Wing, Shastri Bhavan, Dr.Rajendraprasad Road, New Delhi - 110 001
Joint Secretary / Economic Advisor, (in-charge NIRM) Ministry of Mines, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi – 110 001	The Executive Director (Mining) National Thermal Power Corporation, NTPC Bhawan, SCOPE Complex, Institutional Area, Lodhi Road,New Delhi - 110003 (Resigned as on date from NTPC)
Director General, Geological Survey of India, (GSI) No.27, Jawaharlal Nehru Road, Kolkata - 700 016.	Prof. Bharat B Dhar, Formerly:Director. CIMFR Director (R), AIU; Director (R&IC), Amity Univ. Advisor, HESRT&SD, D-20, Pamposh Enclave,New Delhi - 110 048.
The Controller General, Indian Bureau of Mines, Indira Bhavan, 22/1, Civil Lines, Nagpur - 440 001.	Prof. V.R.Shastry, Mining Engineering Department, National Institute of Technology, Surathkal - 575 025. Karnataka
Director General of Mines Safety, Hirapur, Dhanbad - 826 001. Jharkhand.	Shri.A.Sundaramurthy, Director General (Retd), GSI No.44, VV Nagar, 6th Street, Kolathur (PO), Chennai -600 099
Director, CIMFR, Central Institute of Mining & Fuel Research, Barwa Road, Dhanbad - 826 015.	Director, National Institute of Rock Mechanics Bengaluru-560070
Director Indian Institute of Technology (ISM), Dhanbad - 826 003.Jharkhand.	**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)
Director (Operations), Singareni Collieries Company Ltd., Kothagudem Collieries , Khammam Dist, Telangana – 507 101.	

ANNEXURE-3

MEMBERS OF THE GOVERNING BODY	
Chairman	
Secretary (MOM) Ministry of Mines, Government of India, 3rd Floor, A Wing, Room No. 320, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi – 110 001.	
Members	
Additional Seceretary, Ministry of Mines, 3rd Floor, A Wing, Room No.327, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi - 110 001.	Director Indian Institute of Technology (ISM), Dhanbad - 826 003.Jharkhand.
Joint Secretary & Financial Advisor, Ministry of Mines, 3rd Floor, A Wing, Room No.321, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi – 110 001	Director (Operations), Singareni Collieries Company Ltd., Kothagudem Collieries , Khammam Dist, Telangana – 507 101.
Joint Secretary / Economic Advisor, (in-charge NIRM) Ministry of Mines, Shastri Bhavan, Dr.Rajendra Prasad Road, New Delhi – 110 001	Prof. Bharat B Dhar, Formerly:Director. CIMFR Director (Research), AIU; Director (R&IC), Amity University, Advisor, HESRT&SD, D-20, Pamposh Enclave,New Delhi - 110 048.
Director General, Geological Survey of India, (GSI) No.27, Jawaharlal Nehru Road, Kolkata - 700 016.	Prof. V.R.Shastry, Mining Engineering Department, National Institute of Technology, Surathkal - 575 025. Karnataka
The Controller General, Indian Bureau of Mines, Indira Bhavan, 22/1, Civil Lines, Nagpur - 440 001.	Shri.A.Sundaramurthy, Director General (Retd), GSI No.44, VV Nagar, 6th Street, Kolathur (PO), Chennai -600 099
Director General of Mines Safety, Hirapur, Dhanbad - 826 001.Jharkhand.	Director, National Institute of Rock Mechanics Bengaluru-560070
Director, CIMFR, Central Institute of Mining & Fuel Research, Barwa Road, Dhanbad - 826 015.	**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-4

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 Mangalore – 575 025, Karnataka		
Members		
Shri A Sundaramoorthy, (retd. Director General , GSI), Chennai-600 099		The CE, (Designs(N&W)), Central Water Commission, 8th Floor, Seva Bhavan, RK Puram, New Delhi-110 066
Dy.Director General Directorate General of Mines Safety, South Zone, Koramangala, Bengaluru-560 034		Prof. T G Sitharam, Department of Civil Engineering, IISc, Bengaluru-560 001
Executive Director, (Mines/SME & Conveyor), Neyveli Lignite Corporation Ltd., Mine I & IA, Administrative Office, Block 26 Neyveli-607 803 (Tamil Nadu)		Director National Institute of Rock Mechanics, Banashakari 2nd Stage, Bengaluru-560 070
General Manager (R&D) The SCCL Kothagudem Collieries, Bhadrari Kothegudem-507 101, Telangana		**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)
Prof. VMSR Murthy, Professor and Head, Department of Mining Engineering IIT (ISM), Dhanbad-826 004		

ANNEXURE-5

SUPPORTING ORGANISATIONS & MAJOR CLIENTELE

Central Government Ministries & Departments

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

State Government

Andhra Pradesh Heavy Machinery and Engineering Limited (APHMEL)
Andhra Pradesh Power Generation Corporation (APGENCO)
Karnataka Power Corporation Limited (KPCL)
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

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)
WAPCOS Limited

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
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 PROJECTS

Sl. No.	Project No.	Title of Project	Persons Involved	Status
1	EG - 1701	Construction stage engineering geological foundation mapping of Yargol Gravity type concrete dam in Bangarpet Taluk of Karnataka State	AK Naithani, LG Singh & Prasnna Jain, DS Rawat	Completed
2	EG - 1702	Engineering geological investigations of Kaleshwaram – DBRAPCSS II Lift Irrigation Scheme Package-6, Karimnagar District, T.S. (April 2017 – September 2017)	AK Naithani	Completed
3	EG - 1703	Engineering geological investigations of Kaleshwaram – DBRAPCSS II Lift Irrigation Scheme Package-6, Karimnagar District, T.S (October 2017 - December 2017)	AK Naithani, DS Rawat, LG Singh & Prasnna Jain	Completed
4	GP - 1505	Cross-hole GPR survey for mapping probable extensions of old working at 200mRL of RD Mines, Dariba.	PC Jha, N Sandeep , Butchi Babu, YV Sivram and Shashinath Verma	Completed
5	GP - 1504	Cross-hole Seismic Tomography Survey for investigationof the foundation of S60 pillar of ChenabBridge, USBRL Project, J & K.	PC Jha, N Sandeep , Butchi Babu, YV Sivram and Shashinath Verma	Completed
6	GE-1605	Determination 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, KN Shashidhara	Completed
7	GE - 1702	Determination of *in-situ* stress parameters for the design of underground power house of Naitwar-Mori H.E. Project, Uttarakhand	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram, KN Shashidhara	Completed
8	GE-1703	Determination of various in-situ rock mass parameters at the proposed Desilting chamber and Powerhouse site of Goriganga-IIIA H.E. Project	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram, KN Shashidhara	Completed
9	GE - 1704	Determination of In-situ stress parameters at the proposed underground surge pool/pump house of Palamuru - Rangareddy lift-III Pumping station	DS Subrahmanyam, G Shyam, K Vamshidhar, S Vikram, KN Shashidhara	Completed
10	SS - 1602	Slope stability studies of Copila Gaichem Paul Iron ore mine, Sigao and Collem village, Dharbandora taluka, South Goa	G D Raju, S K Reddy A Rajan Babu & AY Bharath kumar	Completed
11	SS - 1701	Scientific studies to optimize the bench parameters and design of final pit slope stability of G V Granites quarry in Naganur village, Kulithalai Taluk, Karur dist., Tamil Nadu.	S K Reddy, A Rajan Babu, G D Raju, S Udaykumar &	Completed

			AY Bharath Kumar	
12	NM-1307	Slope Stability Analysis of Abutment Cut Slopes for Concrete Dam at Mangdechu Hydroelectric Project, Bhutan	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Completed
13	NM-1403	Stability Analysis of Rock Slopes for Pothead Yard at Mangdechhu Hydroelectric Project, Bhutan	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Completed
14	NM-1404	Deformation Monitoring of Underground Powerhouse Cavern of Sardar Sarovar Project	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Completed
15	NM-1501	Analysis of Instrumentation data of Powerhouse Complex and Desilting Chamber (April 1, 2015 to March 31, 2016), at Tala Hydel Project, Bhutan	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Completed
16	NM-1502	Analysis of instrumentation data of Machine Hall and Desilting Complex, NJHPS (2015-16)	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Completed
17	NM-1504	Pit Slope Stability of North - East benches of A.Narrain Mines, Chitradurga	Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Completed
18	NM-1601	Analysis of Data obtained from Normal Compression Test and Direct Shear Test: Specimen Collected over Indian Sub- Continent Region	Aditya Mishra, Uday Kumar, Rajan Babu, Sripad R Naik, Rabi Bhusan, BH Vijay Sekar & K Sudhakar	Ongoing
19	NM-1602	Analysis of Instrumentation data of Powerhouse Complex and Desilting Chamber (April 1, 2015 to March 31, 2016), at Tala Hydroelectric Project, Bhutan	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra	Completed
20	NM-1603	Support Design using 3D Numerical Modelling at Underground Surge Pool and Pump House of Pranahita Chevella Sujala Sravanthi Lift Irrigation Scheme Pkg-11	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra & BNV Siva Prasad	Completed
21	NM-1604	3D Numerical Modelling analysis of pump house and surge pool caverns of Kaleshwarm Project (PCLIS) Package -8	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra	Completed
22	NM-1606	Scientific Study to Assess the Stress and Displacement Limits at Zawar Mines, HZL	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra & BNV Siva Prasad	Completed
23	NM-1607	Validation of an In-house study at a Mine of Zawar Group of Mines, HZL	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra & BNV Siva Prasad	Completed
24	NM-1608	Analysis of Instrumentation data of Machine hall and Desilting Complex, NJHPS (2nd year)	BH Vijay Sekar, K Sudhakar, Rabi Bhusan, Aditya Mishra & Sripad R Naik	Ongoing
25	NM-1609	Establishing the Dimensions of Cap Rock and Estimating the Stoping Parameters for K Series and Northern Series of Lenses at Baroi Mine, HZL	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra & BNV Siva Prasad	Completed
26	GC-1503	Optimisation of stoping parameters and designing stopes below 20th level at Hutti Gold Mine, HGML	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra, BNV Siva	Completed

			Prasad& Amrith Renaldy	
27	GC-1504	Optimisation of stoping parameters and designing stopes at Uti and Hirabuddini, HGML	Sripad R Naik, K Sudhakar, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra, BNV Siva Prasad& Amrith Renaldy	Completed
28	NM 1702	3D Numerical Model Studies for Stress Analysis of Underground Powerhouse Complex and Underground Surge Shaft of Naitwar Mori Hydroelectric Project, Uttarakhand	Sripad R Naik, BNV Siva Prasad, K Sudhakar, Rabi Bhusan, BH Vijay Sekar & Aditya Mishra	Completed
29	NM-1705	Stability Analysis of Bus Duct Shaft above Draft Tube Tunnels using 3D Numerical Modelling – Pranahita Chevella Sujala Sravanthi Lift Irrigation SchemePackage-11, Telangana	Sripad R Naik, BH Vijay Sekar, Rabi Bhusan, Aditya Mishra & K Sudhakar	Completed
30	RB-1506	To ascertain the feasibility of a proposed twin tunnel for missing line of Mumbai Pune Expressway, Mumbai	G Gopinath, R Balachander, GC Naveen, Al Theresraj, Dr. HS Venkatesh	Completed
31	RB-1601	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)	GC Naveen, R Balachander, Al Theresraj, G Gopinath, Dr. HS Venkatesh	Completed
32	RB-1305	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 II) - Project No. RB 1704	GC Naveen, R Balachander, Al Theresraj, G Gopinath, Dr. HS Venkatesh	Completed
33	RB-1503	Technical guidance on controlled blasting for the excavations related to nuclear fuel complex and monitoring of ground vibration at nearby critical structures" Rawatbhata, Tata Projects Ltd. Rajasthan	G Gopinath, Al Theresraj, R. Balachander, GC. Naveen and Dr. HS. Venkatesh	Completed
34	RB-1505	To ascertain the feasibility of proposed tunnel portal excavation by blasting adjacent to intake structure, Regumangadda, Telangana	G. Gopinath, R. Balachander, GC. Naveen, A.I. Theresraj and Dr. HS. Venkatesh	Completed
35	MS-1101	Stability Monitoring using Nanoseismics/ Microseismics in the power house cavern at TVHPP, Joshimath (second year)	Sivakumar Cherukuri, Vikalp Kumar	Completed
36	MS-1601	Stability monitoring of the powerhouse of Tala hydropower plant using Microseismics monitoring	Sivakumar Cherukuri, Vikalp Kumar	Completed
37	ST-1601	Seismotectonic Evaluation (Feasibility) of the Proposed Nuclear Power Project Site at Gugulapalli, Nellore District, Andhra Pradesh	Biju John, Yogendra Singh, K.S. Divyalakshmi. and A Rajan Babu	Completed
38	ES-1201	Geothermal studies at Manappad and around Kudankulamarea	Biju John, Yogendra Singh, K.S. Divyalakshmi	completed
39	RF-1502	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	Completed
40	RF-1602	Laboratory Geotechnical Investigations on Rock Core Samples from Boreholes of Dr. B.R.A. PranahithaChevella Lift Irrigation Scheme,	S Udaya Kumar, G D Raju, D Joseph and A Rajan Babu	Completed

		Package-11, Mega Engineering and Infrastructure Limited.		
41	RF-1603	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 RajanBabu	Completed
42	RF-1604	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	Completed
43	RF-1605	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	Completed
44	RF-1606	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	Completed
45	ND-1505	NDE of vital components of winders / winches at Rampura Agucha Mines, HZL (main shaft - kibble winders)	A Rajan Babu, S Udaya Kumar, Sagaya Benady, Royston Angelo Victor, D Prashanth Kumar, Syed Asghar, S Babu	Completed
46	ND-161B	NDT on vital components of winders at Zawar group of mines		Completed
47	ND-1603	NDT on vital components of south ventilation shaft, RampuraAgucha Mines, HZL		Completed
48	ND-1607	NDT on Jakhu ropeway, Shimla		Completed
49	GC-1505	Rock mechanics studies below 100 m depth in east and weastsides, for both footwall an hangwallodes,of Tummalapalli Mine,UCIL	G D Raju, A Y Bharath Kumar and A Rajan Babu	Completed
50	GC-1506	Designing Stoping Parameters for Munsar Mine of MOIL Ltd.For-30'& below levels	G D Raju A Y Bharath Kumar and A Rajan Babu	Completed

ANNEXURE-7

LIST OF PUBLICATIONS

1	A.K. Naithani L.G. 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, vol. 7, pp. 64-82.
2	A.K. Naithani, 2017: Geotechnical investigations and support design of underground pump house cavern – a case study from lift irrigation project. Int. J. Geotechnical and Geological Engineering, Springer Publ., vol. 35 (5), pp. 2445-2453
3	A.K. Naithani, D.S. Rawat, L.G. Singh, and Prasnna Jain, 2017: Engineering geological investigation of deep open surge pool area of lift irrigation scheme - a case study from Telangana state, India. Journal of Rock Mechanics & Tunnelling Technology (JRMTT). vol.23 (2), pp. 91-100.
4	L.G. Singh, A.K. Naithani, Rajesh Patel, D.S. Rawat, PrasnnaJain and T.N. Singh, 2017: Engineering geological assessment of adverse conditions: a case study from road tunnel.Proceedings 7th Indian rock conference INDOROCK 2017, pp 493-502.
5	D.S. Rawat, A.K. Naithani, L.G. Singh, Prasnna Jain, Rajesh Patel, R.N.S. Babu and G.S. Rao, 2017: Assessment of rock mass for escape tunnel - a case study from lift irrigation project, Telangana State, India. Proceeding Engineering Geological Solutions for Sustainable Development (EGCON-2017) organized by Indian Society of Engineering Geology (ISEG), the India National Group of IAEG on 7th& 8th October 2017 at New Delhi, India.
6	R.N.S. Babu, R.K. Nath, D.S. Rawat, A.K. Naithani and G.S. Rao 2017: Geologically problematic band and its treatment on upstream wall of large underground surge pool cavern-a case study from lift irrigation scheme-Telangana State, India. Proceeding volume of Engineering geological solutions for sustainable development (EGCON-2017) organized by Indian Society of Engineering Geology (ISEG), the India National Group of IAEG on 7th& 8th October 2017 at New Delhi, India.
7	A. K. Naithani, L. G. Singh, Rawat, D.S. and Prasanna Jain, 2018: Engineering geological and geotechnical investigations for a pump house complex site – a case study from lift irrigation scheme. Journal Geological Society of India, Springer Publ., vol 91, pp 215-220.
8	A.K Naithani, D.S Rawat, L.G. Singh and Prasanna Jain, 2018: Assessment of the excavatability of rock based on rock mass quality: a case study from India. Int. J. Geotechnical and Geological Engineering, Springer Publ. (In press).
9	A.K. Naithani, L.G. Singh, Prasnna Jain and D.S Rawat, 2018: Geotechnical assessment of the foundation of housing chamber of Yaragol gravity dam. Karnataka state, India. Int. J. Nanoscience and Nanotechnology (In press).
10	A.K. Naithani, L.G. Singh, Prasnna Jain and D.S. Rawat, 2018: Engineering geological assessment of cut slope – a case study from hydroelectric project. Indian Landslide Journal (in Press).
11	A.K. Naithani, 2018: Empirical rock mass classifications for rock slope stability analysis – an overview. Himalayan Geology (Communicated).
12	Butchi Babu, B., Sandeep, N., Sivaram, Y.V., Jha, P.C. and Khan, P.K., 2017. Bridge pier foundation evaluation using cross
13	M. Prasad, P. C. Jha, S. G. Modani, M. Singh, Development of an Analyser for Flaw Characterisation Dimensional Stone Blocks using Transient Signals, International Journal of Electronics, Electrical and Computational System, Volume 6, Issue 5, May 2017; ISSN 2348
14	M. Prasad, P. C. Jha, S. G. Modani, M. Singh, Immunity of the source signature of a transient signal in flaw characterisation in spectral domain, International Journal of Engineering Technology, Management and Applied Sciences, May 2017, Volume 5,

	Issue 5, ISSN 2349
15	*Dr. DS Subrahmanyam, Mr. G. Shyam, Mr. K. Vamshidhar, and Mr. S. Vikram "Assessing the stress behavior on after excavation of central gullet at powerhouse cavern of Vishnugad Pipalkoti Hydroelectric project – a case study" Indorock-2017, 7th Indian rock conference, pp 208-213, - ISBN 81-86501-25-1, 25 – 27 October 2017.*
16	*Dr. DS Subrahmanyam, Mr. G Shyam, Mr. K Vamshidhar, and Mr. S Vikram "Hydraulic fracturing stress measurements in porous rock mass"paper accepted, Asian Rock Mechanics Symposium, Singapore, 29th -3rd November 2018.*
17	G D Raju, G G Manekar and Prasnna Jain; 2017: Conservation of Mineral resources by optimization of stoping parameters for a cut and fill stope at Chikla mine of MOIL Ltd: A case study. In the National seminar on "Conservation of Mineral resources; IBM, Nagpur, India.
18	G D Raju and Hani Mitri; 2018 "Rockbolt support behavior with regard to the rock mass modulus – A parametric study.In Canadian Geotechnical Journal – Abstract Submitted.
19	G D Raju, R Venugopala Rao, S Gangadhara and H S Venkatesh; 2018: Comparison of predicted and measured deformations for an underground cavern- a case study. In ARMS10 to be held in Singapore during November 2018: Full paper submitted
20	Kumar Reddy, S., James Paul., and Paul Prasanna Kumar, 2017. Application of slope stability radar in an opencast mine, Journal of Mining Engineers Association of Inida, Volume 19, No. 5, 10
21	Kumar Reddy, S and Rajan Babu A, 2017. Monitoring the movement of slopes in opencast mines, Proceedings of international conference on Advanced Engineering and Information Technology, 7
22	B H Vijay Sekar, K Sudhakar and Sripad R Naik, 2017,"Study on Pore Water Pressure Distribution in Underground Desilting Chambers in a Hydro
23	Siva Praasad BNV and VMSR Murthy, 2017 "Influence of rock abrasivity and bit wear on drill penetration rate", Proceedings Seventh Annual Rock Conference INDOROCK 2017, 25
24	Sripad R Naik, 2017 "Role of Instrumentation and Monitoring in Underground Excavations", A Keynote lecture, International Conference on "Underground Excavations in Difficult Ground Conditions: Issues & Challenges", 27
25	Sripad R Naik, 2017 "ThreeDimensional Numerical ModellingTechniques for Large UndergroundCaverns", A Keynote lecture, International Conference on "Engineering Geological Solutions for Sustainable Development (EGCON
26	Siva Prasad, BNV and VMSR Murthy, 2018 "Laboratory investigations into fracture propagation characteristics of rock material", AIP Conference Proceedings, International Symposium on Material Science and Engineering (ISMSE 2018), 19
27	Siva Prasad BNV and VMSR Murthy, 2018 "Laboratory investigations into fracture propagation characteristics of rock material", Remote presentation at International Symposium on Material Science and Engineering (ISMSE 2018), 19
28	H.S.Venkatesh, R.Balachander and G.Gopinath, 2017, "GROUND VIBRATION DUE TO BLASTING AND ITS ATTENUATION CHARACTERISTICS IN HIMALAYAN REGION", National Seminar on "Challenges in Planning, Investigation, Design, and Construction of Highway Tunnels In Himalayan Region" on 2-3, Nov 2017, Border Roads Organisation, Manekshaw Centre, Delhi Cantt-A, New Delhi
29	H.S.Venkatesh, R.Balachander and G.Gopinath, 2017 "Drilling and blasting of tunnels in Himalayan Geology Conference on Tunnelling in Himalayan Geology", 10-13 October 2017, Hotel Radisson Blu, Jammu, J&K. Status: Published
30	G.Gopinath, H.S.Venkatesh and R.Balachander, "Optimisation of Blast Design For An Armour Stone Quarry- A Case Study", 12th International Symposium in Rock Fragmentation by Blasting, Fragblast12, 11-13 June 2018, Lulea, Sweden – Status: Communicated
31	Goverdhan K, Balasubramaniam VR, Praveena Das Jennifer and Sivakumar C

	"Preliminary assessment of seismic hazard in old mining area using surface mounted seismic sensors"-published in Journal of Indian Geophysical Union (IGU)- under revised/review
32	Vikalp Kumar, Sivakumar Cherukuri and Nagendra Pratap Singh, 2017, "Stability Analysis of the Underground Powerhouse in Himalaya Region using Microseismic Monitoring", INDOROCK-2017: 7th Indian rock Conference, 25-27 October 2017, New Delhi.
33	Rajendran, C. P. Biju John, Anandasabari, K., JaishriSanwal, KusalaRajendran, Pankaj Kumar and S. Chopra, 2018 On the paleoseismic evidence of the 1803 earthquake rupture (or lack of it) along the frontal thrust of the Kumaun Himalaya.Tectonophysics 722, 227–234.
34	Biju John 2017. Importance of Geological Studies in Earthquake Hazard Assessment. In Integrating Disaster Science and Management: Global Case Studies in Mitigation and Recovery (Chapter Communicatedto Elsevier on request).
35	Biju John, Yogendra Singh, K.S. Divyalakshmi, K. Tamilarasan, C. Sivakumar 2018. Some observations on Fault related brittle deformation in Peninsular India in National seminar on Shear zones and Crustal Blocks of southern India. Vol 5, 5-6.
36	Joshi, D.D., G.C. Kandpal and Biju John, 2017.Active fault study in the Yamuna Tear Zone, GSI Spl. Publication No. 110. 40 P.
37	Yogendra Singh, Biju John, K.S. Divyalakshmi and G. P. Ganapathy, 2018Interconnected faults: Is this responsible for Seismicity of Kerala? National Seminar on Dynamics of Surface and Subsurface Geological Processes, Abstract Volume pp 82-83.
38	Divyalakshmi, K.S., Yogendra Singh and Biju John, Ongoing subtle tectonic activity in the Peninsular India: Observation from Peninsular India, National Seminar on Dynamics of Surface and Subsurface Geological Processes Abstract Volume , pp 161

ANNEXURE-8

NIRM STAFF ON ROLL

(as on 31.03.2018)

Director: ***Dr HS Venkatesh***

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Mr D Joseph
Mr Sagaya Benady
Mr J Raja
Mr Royston Angelo Victor
Mr D Prashanth Kumar
Mr Syed Asghar
Mr R Prabhu
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Mr T Amrith Renaldy
Mr Sultan Singh Meena
Dr Sandi Kumar Reddy
Mr Bharath Kumar AY
Mr. Aman Soni

Administration
Dr Sandeep Nelliat, COA (addl. Charge)
Mr S Ravi, PSO
Mrs. Uma HR, FAO
Mr JV Sastry
Mr N Jothiappa
Mrs Janaki Bhavani P
Mr. MP Adithya
Mrs. BS Shruthi

Drivers
Mr P Venkata Reddy
Mr K Manjunath

Staff retired during the Year
Dr V Venkateswarlu
Mr AN Nagarajan
Mrs S Lourdu Mary
Mr A Vijaya Kumar

Employees participating in Hindi usages competition during Hindi Pakhwada Celebration

Comprehensive structural stability audit in mines of SCCL

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