Curriculum Vitae

Name: Vemavarapu M.S.R.Murthy

Present Position: Professor(HAG) & Head
                            Centre of Rock Excavation Engg.
                            Department of Mining Engineering

Postal Address:
                   Indian Institute of Technology (Indian School of Mines),
                   Dhanbad, Jharkhand, India, PIN: 826004

E-Mail Address: vmsrmurthy@iitism.ac.in/vmsr_murthy@yahoo.com, www: iitism.ac.in
        Web of Science ResearcherID : F-4114-2019; Scopus AU-ID: 5719370198;ORCID: 0000-0002-1764-481X

Phone Number: **Mobile**: 9431124864; **Land Line**: 0326-2235445, 2235279

Date of Birth: 19.06.1965

Educational Qualifications:

Degree/ Examination	University/ Institution	Year	Discipline	Division/ Class	% of Marks	Rank in Board/ University
Ph.D.	Indian Institute of Technology (ISM), Dhanbad	1997	Mining Engineering	-	-	-
M.B.A.	G.S.College of Commerce & Economics, Nagpur	1990	Financial and Personnel	First	72	-
M.Tech.	Indian School of Mines, Dhanbad	1988	Mine Planning and Design	First with Dist.	4.9/5.0 OGPA	ISM Gold Medal
B.E.	V.N.I.T., Nagpur (formerly V.R.C.E.)	1986	Mining Engineering	First with Dist.	85	University Second
Intermediate	Board of Intermediate Education, Hyderabad	1982	Maths, Physics, Chemistry	First with Dist.	82	College First
S.S.C.	Board of Secondary Education, Hyderabad	1980	Maths, Science, English, Hindi	First with Dist.	83.5	District First

Present Scale of Pay: Level 15 (Central Scales)

Experience (Academic, Research and Administrative):

Academic Experience: about 25 years

University/ Organisation	Designation	From	To	Total Period	Nature of Experience
IIT(ISM) Dhanbad	Professor	05.11.08	Cont…	13 years	Teaching, Research and industry-sponsored projects
Indian School of Mines, Dhanbad	Associate Professor	05.11.04	04.11.08	4 years	Teaching, Research and industry-sponsored projects
Indian School of Mines, Dhanbad	Assistant Professor	14.08.97	04.11.04	7 years	Teaching, Research and industry-sponsored projects
R.K.N.E.College, Nagpur	Lecturer	01.07.88	27.08.89	1 year 2 months	Teaching

Research Experience: 8 Years

University/ Organisation	Designation	From	To	Total Period	Nature of Experience
Central Mining Research Institute, Dhanbad (at Nagpur)	Scientist'C'	28.08.94	13.08.97	3 years	Research and Consultancy
Central Mining Research Institute, Dhanbad (at Nagpur)	Scientist'B'	28.08.89	27.08.94	5 years	Research and Consultancy
Indian School of Mines, Dhanbad	Project Fellow	28.04.88	27.06.88	2 months	Mine Planning

Administrative Experience: 7 years 8 months

University/ Organisation	Designation	From	To	Total Period	Nature of Experience
IIT(ISM), Dhanbad	Head, Deptt. of Mining Engineering	01.11.16	31.10.19	3years	Management of Teaching (UG, PG), research (JRF), industry-sponsored research, Testing etc.
Indian School of Mines, Dhanbad	Dean	01.09.16	31.12.16	4 months	International Relations and Alumni Affairs
Indian School of Mines, Dhanbad	Associate Dean	01.04.12	31.08.16	4 Years 4 months	International Relations and Alumni Affairs

Training: Leadership for Academicians and Building World Class Universities Programme (LEAP-2018) jointy organised by IIT Kanpur and Nanyang Technological University, Singapore **(19.11.2018 to 08.12.2018).**

Number of Patents granted/applied for: In process (4 no.s)

Number and Names of reputed Awards/Recognitions:

- National Geoscience Award (2019) – Mining Technology
- ISM Gold Medal (PG studies), ISM, Dhanbad
- University 2nd in Engineering (Nagpur University-1986), VNIT, Nagpur
- Branch Topper (three years-1984, 1985, 1986), VRCE (now VNIT), Nagpur
- Halcrow Premium Award (UK)
- ISRMTT Awards for Best Papers
- Hindustan Zinc Limited Prize from Institution of Engineers (India)
- The Institute Prize from Institution of Engineers (India)
- Erasmus Fellow, India 4EUII Exchange, DIATI, Politecnico di Torino, Italy funded by European Commission
- Duo-India Fellowship- DIATI, Politecnico di Torino, Italy

No. of Ph.D. Guided : 13 (10 ongoing)
No. of Research Projects **:** 14(3 ongoing)
Number of Research Publications : 220
Number of Books Published/Edited : 3
Number of Industry-Sponsored Projects/EDPs : 196
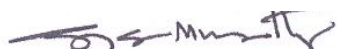**Number of Memberships in Societies** **:** 06

    Life Member:
- Indian Society of Rock Mechanics and Tunnelling Technology
- Mining Engg. Association of India
- Mining Geological and Metallurgical Institute of India
- Tunnelling Association of India (TAI-ITA)
- International Society for Rock Mechanics-India Group (CBIP)

    Fellow:
- Institution of Engineers (India),

(Annexure I : Summarises the significant contributions, achievements and their impacts in research, teaching and industry-problem solving)

Signature of Applicant   Date: 30.10.2022; Place: Dhanbad

A) Contributions and achievements

Following are the concepts, approaches, methods and systems established individually and through associated research group for enhancing deeper understanding of rock excavation technology, mining methods and tunnelling techniques:

- **Operating efficiency** of dragline equipment system vs **environmental and economic efficiency**

- Seismic effects in dragline bench blasting and **fragmentation/backbreak control**

- Thermal behaviour during **pick-rock interaction** and optimisation of **operating parameters** of surface miner

- Performance analysis of rotary blasthole drills through **machine vibration** and **coarseness index mapping**

- **Reliability modelling** of tunnel boring machines using Markov chains

- A new **rock mass rating methodology (RMR$_{dyn}$)** for support design in fragile coal mines.

- **Cuttability assessment of hard sandstone** for shearer overload prevention in a mechanized longwall mine (Jhanjhra, ECL).

- Predictive models using **machine learning algorithms (ANN) for throw distance in bench blasting,**

- **Estimation of production, pick and diesel consumption in cutting with surface miner and** indigenization of surface miner.

- Determining the **threshold peak particle velocity of roof rock** for rational explosive charging for improved safety and productivity in both coal and metal mines and tunnels

- Enhancing the **functional capability of indigenous diamond wire technology** for dimension stone cutting in India.

- **Asset management** through a **comprehensive nomogram for quick assessment** of performance of surface miners and also plan inventories.

- Predicting **risk, depth and size of pot-hole formation,** especially in shallow coal mines for safe mining.

- **Blast-induced pressure and time-based concepts** were developed to estimate **the fly-rock distance,** which is crucial **in defining the exclusion zone** in a mine for safe operation. Predictive models were also developed for back break and fragmentation through **near-field blast vibration dynamics.**

- Model combining rock, explosive and blast design parameters for **over break control in metal mines**. Aimed at **reducing dilution of ore** due to blast-induced overbreak. **Pull optimization** was also integrated subsequently.

- **Underwater drilling and blasting concepts and techniques** for **controlled blasting near marine structures** to complete deepening and widening of the ports (Vishakhapatnam), Intake channels for enhanced trade.

- Industry needs **a single window solution for research and modeling in the field of rock drilling, blasting and mechanical cutting**. Developed of one of its kind testing facilities for **Disc/Pick cutting** which was designed, fabricated and tested in IIT(ISM).

- Taking advantage of the latest and smart technology and using it for development of concepts, skills, methods in the field of mining engineering, a **virtual reality mine simulator**, only one in India at IIT(ISM) was conceived, designed and being developed. Full immersive mining methods (underground and opencast coal mining models) will be created under this.

B) Assessment of the impact of the contributions

Completion of industry projects, with challenges related to safety and productivity, can be attributed to the extensive research done. Development of a state of the art rock excavation laboratory with one of a kind testing facilities can create a cascading impact on the opportunities of research that the coming generation can undertake on the said instruments. The specific impacts of research and development may be seen through the following activities:

1. **State-of-the-art Rock Excavation Laboratory**– A **Unique National Facility**

    Drilling, Blasting, Cutting, Rock Dynamics Simulation facility

2. **Publications& Books (196)**

    IJRM&MSc. TUST, MT-IMM, GGE, NC&A, AJGS, BEG&E, CS, IJMS&T, GE-ICE, CT-TAC, JMMF, JIE(I), MEJ, IMEJ

    Papers and citations can be seen in the following link:

    https://iitism.irins.org/profile/97604

3. **Technical Reports** [195 No.s] : Key areas namely drilling for surface mines, controlled blasting for protecting structures and overbreak/backbreak, underwater drilling and rock/demolition blasting for ports, mechanical cutting systems for rock excavation and advanced rock testing facilities have enabled the mining and allied industries achieve higher productivity and safety in general. Professional development programmes in these areas have helped upskilling the industry personnel.

4. **R&D Reports** [14 No.s] : The R&D reports covering dimension stone cutting, FIST Programme for augmenting PG programme in Tunnelling and Underground Space Technology, rock characterization facilities under TEQIP I/II, TBM/Roadheader applications in mines and hydel projects, Virtual Reality Mine Simulator (in progress) have helped in creating research and modeling facilities which in turn resulted in a good number of Ph.Ds, Masters and UG Projects in the Department. Rotary cutting simulation lab with a TRL 9 project funded by DST is in progress for indigenous clean mining technology development using surface mner.

5. **Establishment of a Sandvik Chair Professor** at IIT(ISM) in the area of Rock Excavation, Mining Engg.

6. **Research findings presented** in

    30th ISEE, New Orleans, USA; 4th EFEE, Vienna, Austria; Fragblast 10 New Delhi, India; Fragblast 11 Sydney, Australia; Fragblast 12 Lulea, Sweden and sevral Indian technical fora.

7. **International Presence Through Collaborative Research (pertinent to India)**

    Duo-India Fellowship, Politecnico di Torino,Turin, Italy : TBM and Softground Tunnelling

    Erasmus Mundus Fellow, EC, Politecnico di Torino,Turin, Italy: Dimension stone cutting

    Simtars, JKMRC,University of Queensland, University of New South Wales, University of Woollongong, Australia: Mine productivity and safety through virtual reality simulation.

8. **Impact as an Academician**

    Policy planning: Best mining projects, Research Talks, Modelling and simulation skills, Industry-based research projects, Expert interactions, Excursions and field camps, International mobility for faculty and students

    Professional development programmes (PDP) – **17(last 10 years)**

    M.Tech.: 30 students placed in L&T, Gammon, Patel, Lombardi, CIL, NMDC, SAIL, Geodata, Apco-Infratech, SCCL, Shell.

    Ph.D.: 13 completed and **10 ongoing;** working in CSIR-CIMFR, NIRM, IIT-KGP, VNIT-NGP, L&T

    Awards (students):   Dr. A.K.Raina: National Mineral Award 2008-09; Dr. Kaushik Dey: Best paper awards

9. **R&D Impact**

    a. **Social Good**: **Skill development programmes designed for mining technician** for Govt. of Odisha, Signed an MoU with Govt. of Jharkhand and prepared an assessment report for ITI management in Godda, ECL

    b. **Strategic Good**:   Port deepening and widening, VPT; Overbreak control in tunnels, DRDO, Controlled basting for Aerospace Museum, ITDCem/MES, Clean mining and indigenous technology development project with L&T collaboration(in progress).

    c. **Public Good**: Controlled blasting near mines, Deployment of women [Empowerment] in underground mines, Section 12 committee, Metal Mines Regulations 2018, Mines Vocational Training Rules 2019.

10. **Industry Support and Solutions Impact**

    The research and solutions implemented in mining industry have demonstrated higher production, movement of large draft vessels, higher pull, lesser overbreak, ability to assess the cuttability with various machines etc. The science and technology developed is transferred through various PDPs across academic and mining industry. Undergrad and psotgrad teaching enriched with use/live cases. Typical distribution of research areas and industry reach presented below:
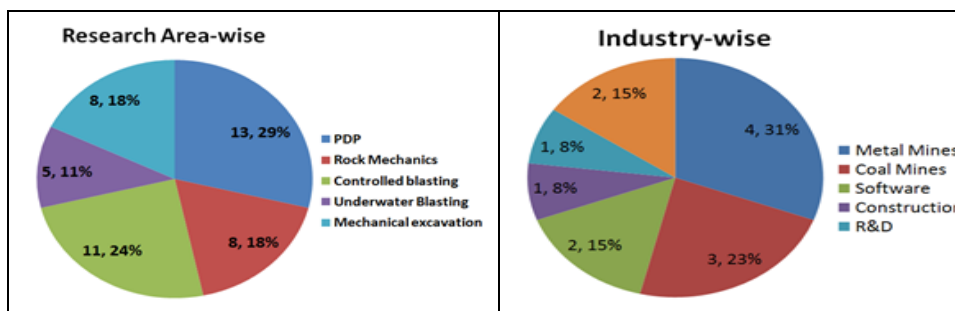
New Courses Designed

A) M.Tech. Programme in
TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY

The **M. Tech. Programme on Tunnelling and Underground Space Technology** is unique and first of its kind to be offered in this country and has significant role in providing specialized manpower, particularly, in the areas of Tunnelling, Hydel Power construction, Underground Metros, LPG storage and Nuclear waste disposal site creation.

This course is aimed at developing specialist underground engineers for planning, designing and creating tunnels and underground space to meet the growing needs of society keeping in view the safety and efficiency. The course has about 10 theory courses and 5 practicals to impart the relevant knowledge and skill sets. Relevant modeling and experimental labs and other infrastructural facilities viz. library, software etc. were established under the guidance of experienced faculty for meeting the course requirements. The course has been updated in 2018 by including latest technological developments in the field of tunneling. The course structure has open and departmental electives to provide a broad perspective to the student.

Students of M. Tech (Tunnelling and Underground Space Technology) find their career growth in sectors like Underground Metros, Tunnelling and Irrigation Departments, Hydroelectric Projects, Urban Development authorities, Construction Companies, Oil Companies for Oil storage in rock caverns, Atomic Energy Corporation for creating Nuclear Waste Disposal sites in underground, Coal and Metal Mining Companies for creating alternative uses of space, Defence for safe hide outs etc.

The course structure that was approved in 2009-10 went through some major changes(in 2012 and 2018) to include relevant engineering inputs as the time demands. The intake of the programme is 18 while about 10 to 12 students join the programme. Most of the students get off campus placement in construction and infrastructure companies, namely, L&T, AFCONS, HCC, State and Central Irrigation Departments. Some go for Doctoral studies and join academics. Students undertake dissertation topics relevant to industry and in collaboration, wherever possible. Mentor faculty provides an opportunity to work on real-life data to make the learning whole some and relevant.

2. M.Tech. Course on NATM and TBM Tunnelling (MNC520)

3. B.Tech. Elective Course   Underground Space Technology (MEE18105)

An elective course at B.Tech.(Final year) in the name Underground Space Technology which was introduced to prepare the mining engineers to join construction and infrastructure sectors(2006 onwards).

4. B.Tech. Open Elective Course on Seabed and Asteroid Mining (MNO203)
To explore the new frontiers for sustainable mining of mineral resources a new open elective inter-disciplinary course on Seabed and Asteroid Mining has been initiated from 2021-22 Winter semester.

RESEARCH PROJECTS (14)

Sl. No.	Project Title	Amount in ₹ (Lakh)	Role (PI/ Co-PI)	No. of Co-PIs	Funding Agency	Duration	Status (Completed / Ongoing)
1	Scientific study to develop a controlled excavation methodology for dismantling concrete berths at OR-I and OR-II Site, Vishakhapatnam Port Trust, ITD CEM/2020-2021/779/ME	31.86	PI	1	ITDCIL	1.5 years 01.03.2021 to 31.08.2022	Ongoing
2	Investigations into the planning and design aspects governing the selective coal cutting technology using surface miner for various rock conditions for clean coal production, TMD/CERI/Clean Coal/2017/07(G), DST(CCORD)/258/2019-20/471/ME	336	PI	3	DST, CCORD	4 years 01.09.2019 to 31.08.2023	Ongoing
3	Evaluation study of the central sector schemes for their continuation beyond 2019-20, Project No.:MoC(3)/2019-2020/693ME	33.3	Co-PI	-	MoC	6 months 01.11.2020 to 01.04.2020	Completed
4	Development of Virtual Reality Mine Simulator (VRMS) for improving Safety and Productivity in Indian Coal Mines Project No.: CIL(9)/2017-2018/540/ME	1410 1320/90	PI	3	CIL R&D	4.5 years 01.09.2017 to 31.05.2022	Ongoing
5	Development of a selection methodology for roadheader and tunnel boring machine in different geological conditions for rapid tunneling (2016), CPRI/2016-17/492/ME.	289.2 (117)	PI	1	NPP-CCAR-CPRI	4 years 01.10.2016 to 30.09.2020	Completed
6	Centre of Excellence in Mining Technology(Indo-Australian Collaboration)	675	PI	4	MHRD	22.01.2016	Granted
7	Erasmus Mundus India4EUII Project Report, Erasmus Mundus Exchange Project No.: IPEM(1)/2013-14/367/INST mme (EMA Action-2,23 mobilities with 194 man-months	211	PI	-	EC	2013-2016	Completed
8	Development of rock characterization facilities for tunnelling and underground space technology PG programme	20	PI	1	TEQIP I/II, MHRD	2012-2015	Completed
9	FIST Program, For augmenting the PG programmes namely tunnelling and underground space technology and Geomatics, 97- 266- ETII-015, ISM Proj NO.: DST(65)/2012-13/310/ME	257	PI	1	DST-FIST	5 years 2013-2017	Completed
10	Centre of excellence in safety, occupational health and disaster management	7767	PI	4	MHRD	2011-13	Granted
11	Rock characterization and simulation of dimension stone cutting by diamond wire saw with special reference to marble, Indo-Italy Joint Research Proposal funded by DST, GOI, India and MAE, Italy, DET-1(73)/POC(2008-2010)/09, Project No: DST(44)/2009-2010/248/ME	5			DST-IOC	27.10.2009 to 31.07.2012	Completed
12	Development of a new rock characterization methodology for optimizing support requirement in tunnels/mines, MHRD(40)/01-02/144/ME	8	PI	-	MHRD-R&D	12.04.2002 to 31.05.2006	Completed
13	Development of predictive models for blast-induced rock damage (BIRD), in tunnels, MHRD(27)/99-00/111/ME	12	PI	-	MHRD-TATE	01.04.1999 to 31.03.2003	Completed
14	Development of a rock classification system for computer aided tunnel blasting design, Ministry of Water Resources, INCRMTT, New Delhi	25	Co-PI	-	INCRMTT	31.03.1998	Completed

RESEARCH INTERESTS - LAB DEVELOPMENT-OUTCOMES

Rock Characterization

Studies pertaining to rock/rockmass characterisation for selecting different rock excavation methods and equipment covering drills, shearers, roadheaders, impact hammers, continuous miners, tunnel boring machines, surface miners, ripper-dozers, bucket wheel excavators, diamond wire cutting saw.

Drilling and Blasting

Design of optimum methods of rock excavation by blasting for construction of caverns, tunnels, shafts, rises, open excavations, water plugs and special shapes like niches, surface and underground mines.

Controlled blasting to reduce environmental threats such as fly rock, and ground vibration and also recent developments like air decking. Roof/wall damage control, ore dilution control etc.

Rock-explosive interaction studies

Underwater drilling and blasting

Design of underwater drilling and blasting systems for hard rock dredging in sea ports and water ways coupled with controlled blasting methodologies for protecting marine structures.

Mechanized Rock Excavation

Optimisation of roadway drivage rates in Coal Mines deploying roadheaders by systems simulation, modelling.(Awarded Ph.D. from ISM in 1997).

Tunnelling and Underground Space Technology

Planning and design of underground space, Creation of underground Space, Control of overbreak, Pull optimisation, Prediction of rock loads and support requirement for underground openings. Instrumentation for monitoring convergence and rock load for tunnels, caverns and mine roadways using multi-point borehole extensometers, tape extensometers, stress meters and load cells.

Specific Solutions pertaining to:

1. Explosive selection based on rock characterization, optimum blast design, cost optimization, fly rock control, blast efficiency improvement, ground and air vibration monitoring, controlled/cautious blasting, air deck blasting and fragmentation analysis.
2. Design of optimum methods of rock excavation by blasting for construction of caverns, tunnels, shafts, rises, open excavations, water plugs and special shapes like niches etc. Improving drivage rate in tunnels and mine development roadways using site-specific blast design patterns.
3. Blast-induced rock damage assessment for driving under fragile roof conditions and methods to minimize damage (Controlled blasting techniques).
4. Underwater drilling and blasting for port deepening.
5. Mechanized roadway development system design:
   Machine selection (Roadheader, continuous miner, shearer and tunnel boring machine) based on rock characterization and cuttability studies, reliability analysis and stochastic modelling. Roadheading systems simulation and performance assessment subject to machine and roof failures.
6. Tunnel instrumentation and support design (Analytical, Empirical and Observational methods): Prediction of rock loads and support requirements for underground openings. Instrumentation for monitoring rock loads and convergence using load cells and multi-point borehole and tape extensometers.
7. Dimension stone cutting by diamond wire saw technique
8. Cavity scanning through boreholes
9. Borehole scanning for rock characterization

RESEARCH OUTCOMES

Coal Mining :
- Design of Blasting-off-solid in different geo-mining set up with suitable blast patterns for improving production and coal face productivity with SDL/LHD mechanization(Tandsi, Pathakhera, Bhandewada and Saoner Mines, WCL)
- Development of a methodology for support load estimation based on blast-induced damage heights(SCCL and BCCL Mines) –R&D Project funded by MHRD-144
- Anchorage testing of the rock bolts with paper and pvc cement capsules (Inder/Kamptee Colliery, WCL).
- Design methodology for coal gallery blasting and induced blasting of roof in blasting gallery method of coal mining(Guided Ph.D.)
- Pot-hole subsidence prediction and control(Guided Ph.D)

Drilling & Blasting :
- Development of suitable gadgets for roof vibration monitoring.
- Roof vibration monitoring for determining the reasons for low pull and high vibrations and effect of delay time on pull enhancement.
- Blast-induced damage using vibration measurements and seismic characterization to re-design the maximum charge explodable- R&D Project funded by MHRD-111(Guided Ph.D)
- Fly rock distance prediction in different geomining conditions(Guided Ph.D.)

Mechanized Rock Excavation:
- Design of motor power rating of **shearers** based on rock cutting theories and modification of the power rating from the workability classification of coal.(M.Tech.-self)
- Performance analysis of **road headers** in Indian longwall mines under equipment and roof failure situation using Markov Modelling.(Ph.D.-self)
- Performance assessment of surface miners from intact rock and rockmass properties(Guided Ph.D.)

Metal Mining :
- Investigation on drivage rate optimization in manganese, zinc, chromite and uranium underground mines
- Predictive models for blast-induced damage assessment for uranium and chromite mines for reduced ore dilution(R&D Project)

Tunneling:
- Faster drivage of tunnels and inclines through drilling and blasting (Koyna Hydel Tunnels, Tandsi, WCL)
- Controlled blasting for reduced damage in lake-tap tunnels.(Koyna Hydel Project)
- Rock characterization for roadheader and tunnel boring machine selection(NHPC and NTPC Projects)

Caverns:
- Instrumentation and special excavation techniques have been implemented.(Koyna Hydel Project)

Sea Ports:
- Underwater drilling and blasting methodology (upto 20 m depth)-Visakhapatnam Port Trust, Dharti Dredging and Infrastructure Limited, International Seaport Dredging Limited, Vizag Seaport Limited.

Mining Environment:
- Planning strategies for mine closure of surface iron ore mines in fragile locations (Guided Ph.D.)

SPECIFIC CONTRIBUTIONS

AREA: ROCK EXCAVATION ENGINEERING AND TUNNELLING

Concept Development
- Dynamic load assessment in blasting for design of safe and foolproof muffling methods
- Empirical equations to predict roadheader performance in coal mine roadway development based on rock excavatability, roof standability and machine maintainability.
- Computer aided simulation package to model the production systems performance particularly for the development headings in coal employing roadheaders subject to machine and roof failures.
- Overbreak control models based on acceleration and PPV based techniques
- Seismic imaging for blast-induced rock damage assessment
- Fly rock distance prediction in surface mines
- Planning strategies for mine closure in surface iron ore mines
- Fragmentation assessment through blast-induced borehole pressure measurement

Technology Development
- Air-deck blasting technique for production blasting – Dongri-Buzurg Opencast mine, MOIL
- Modified wedge cut for improved pull in underground coal mines – Mine 1, Saoner Project, WCL
- Muffle blasting technique-Upper Kolab Hydel Project, Orissa
- Selective granite block mining – Project Sea-Bird, Indian Navy
- Narrow niche excavation technique – Koyna Hydel Project
- Instrumentation for stability assessment – Koyna and Sri Sailam Hydel Projects
- Rapid and safe drivage technique – Koyna Hydel Project
- Rock mass characterization for Shearer, Roadheader, TBM, Continuous Miner, Surface Miner, Ripper and Drill selection(CIL, L&T, NHPC Ltd., NTPC Ltd.)
- Underwater drilling and blasting methodology(VPT, DDIL, VSPL, ISDL)
- Cuttability Index of Surface Miner(CISM) modified as Rock Cuttability Index
- Blasting gallery system design
- Pot-hole subsidence prediction in coal mines**(Ph.D.)**
- Design and development of Blast Acceleration measurement system for BIRD assessment(MHRD Project, 111)**(Ph.D.)**
- Design and development of seismic imaging technique for blast damage assessment(MHRD Project, 144)
- Fragmentation assessment through blast-induced borehole pressure measurement**(Ph.D.)**

Equipment Development
- Developed a multi-shot exploder and a sequential blasting machine (Tandsi Project)
- Modification, calibration and testing of multi-point bore hole extensometers and load cells to suit the field requirements (Koyna Hydel Project)
- Design of a muffle bucket cum shield for cautious blasting near important structures(Upper Kolab Project)
- Design, fabrication and use of blasting mats (Gujarat Ambuja Cement Project)
- Air deck blasting with bamboo spacers for improved fragmentation (Kaypee Project)
- Design and development of Drilling Rate Index setup (NHPC and NTPC Projects)
- Cerchar Abrasivity Index Apparatus

Rock Excavation Laboratory Experiment Development
- Cerchar Abrasivity Index Apparatus
- Brittleness Index Apparatus
- Siever's J Value Apparatus(modified CHI)
- Drilling Rate Index Apparatus
- Cavity Scanner(FIST Grant)
- Slim Borehole Scanner(FIST Grant)
- Blast Acceleration Measurement Setup(MHRD TATE project)
- Shallow Seismic Imaging Apparatus(MHRD R&D Project)
- Machine Vibration Measuring Apparatus
- Cutting Tool Temperature, Force and displacement Analysis Setup
- Petrological Analysis Setup for Rocks
- Cutting Tool Wear Analysis Setup
- Concrete quality testing with Schmidt Hammer
- Drillability assessment using Coarseness Index
- Fracture Toughness Setup
- Cutting Force, Temperature and vibration measurement setup while drilling of rocks(TEQIPII)
- Cavity Scanning setup through borehole (under FIST): INR 65 lakhs
- Borehole Scanning for rock characterization studies (under FIST): INR 45 lakhs
- Triaxial vibration measurement setup for near-field vibration analysis (under FIST)
- High pressure microphone for near-field air overpressure measurement (under FIST)