

Course Code	CET511			
Course Category	Core			
Course Title	Advanced Engineering Geology			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

Course on Engineering Geology at Under Graduate Level

Course Objectives:

Knowledge:

1. Educate students in principles of geology for tunnel and underground openings.
2. Provide students with background and tools to identify the basic behavior of rock in underground openings.

Skills:

1. Problem identification.
2. Interpretation skills and problem solving.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. Apply engineering geological concepts and approaches on rock engineering projects. (CL-III).
2. Analyze the engineering behavior of rocks (CL-IV).
3. Evaluation of engineering geological data in construction process of underground openings in rock. (CL-V).
4. Interpret the geologic data to establish the geological framework needed for design and construction of underground openings. (CL-V).

Course Contents:

Engineering geology in theory and practice. Influence of various minerals on the engineering behavior of rocks, Engineering properties of rocks.

Engineering Geological Investigation for Tunnels or underground openings; stability of portal sections; evaluation of tunnel alignment.

Choice of method of tunneling depending on the geological framework.

Mass movements, slope stability problems, their predictions

Earthquakes and seismicity, seismic zones of India, influence of seismicity on underground openings.
Problems in underground openings of coastal area.

Learning Resources:

1. Engineering Geology and Geotechniques *By. F. G. Bell.*
2. Engineering Geology *By De Fratus.*
3. Engineering Geology *By Tony Walthem.*

Supplementary Reading:

Web links:

1. [http:// WWW.Visionlearning.com/ Library /module_ viewer.php?mid=69](http://WWW.Visionlearning.com/Library/module_viewer.php?mid=69)
2. [http:// www.geology.iupui.edu.](http:// www.geology.iupui.edu)

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		<i>Theory</i>	<i>Lab</i>	<i>Assess</i>
1	Engineering geology in theory and practice. Influence of various minerals on the engineering behavior of rocks, Engineering properties of rocks.	10	--	--
2	Engineering Geological Investigation for Tunnels or underground openings; stability of portal sections; evaluation of tunnel alignment.	10	--	--
3	Choice of method of tunneling depending on the geological framework.	6	--	--
4	Mass movements, slope stability problems, their predictions Earthquakes and seismicity, seismic zones of India, influence of seismicity on underground openings. Problems in underground openings of coastal area.	6	--	--

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Course Code	CET 512			
Course Category	Core			
Course Title	Tunneling and Underground Space Applications			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

1. Engineering Geology.
2. Structural Engineering

Course Objectives:

Knowledge:

1. To understand the need of utilization of Underground Space for various applications.
2. To develop the plan for infrastructure for transport.

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. Prepare plans of different underground space application (CL-VI).
2. Compare the costs involved in various methods for utilization of Underground Space (CL-IV).

Course Contents:

Historical: Natural caves, archeological caves and their construction, tunnels for road, rail and hydropower.
 Need for Underground Space: Congestion driven needs for development of infrastructure for transport, water, power supply, vehicle movement in cities, storage of materials.
 Engineering Utilities: Hydropower tunnels and caverns, underground storage for LPG, LNG, Crude and its products – basic principles.
 Nuclear Waste Disposal: Conditions for waste disposal, effect of radioactivity and heat on surrounding rock, conceptual design of a nuclear waste disposal facility
 Strategic Utilities: Defense facilities, civil shelters, navy bases, air force hangers, safety and risk assessment

systems.

Other Storage: Grain storage, their advantages, disadvantages, underground cold storage and cellar for foods and beverages

Modern Developments: Underground ring roads in mega cities, submerged and floating tunnels, underground libraries, museums, dwelling units, resorts.

Traffic surveillance and control system (TSCS) in tunnels: Traffic control signs, signals, lights, cameras.

Tutorials: Preparation of different underground space application plans.

Learning Resources:

1. Engineering Geology & Tunnels Engineering, Jaafar Mohammed
2. Tunnel Engineering Handbook, John O. Bickel and T. R. Kuesel, Krieger Publishing Company
3. Art of Tunnelling, K. Szechy

Supplementary Reading:

Web links:

1. <https://www.tunneltalk.com>
2. <https://civilengineerspk.com/tunnel-engineering/>
3. <https://www.ice.org.uk/events/exhibitions/ice-tunnel-engineering>

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Historical: Natural caves, archeological caves and their construction, tunnels for road, rail and hydropower. Need for Underground Space: Congestion driven needs for development of infrastructure for transport, water, power supply, vehicle movement in cities, storage of materials.	6	--	--
2	Engineering Utilities: Hydropower tunnels and caverns, underground storage for LPG, LNG, Crude and its products – basic principles. Nuclear Waste Disposal: Conditions for waste disposal, effect of radioactivity and heat on surrounding rock, conceptual design of a nuclear waste disposal facility	8	--	--
3	Strategic Utilities: Defense facilities, civil shelters, navy bases, air force hangers, safety and risk assessment systems. Other Storage: Grain storage, their advantages, disadvantages, underground cold storage and cellar for foods and beverages	6	--	--
4	Modern Developments: Underground ring roads in mega cities, submerged and floating tunnels, underground libraries, museums, dwelling units, resorts. Traffic surveillance and control system (TSCS) in tunnels: Traffic control signs, signals, lights, cameras. Tutorials: Preparation of different underground space application plans.	10	--	--

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Course Code	CET 513			
Course Category	Core			
Course Title	Tunnel Engineering			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

1. Engineering geology
2. Rock Mechanics

Course Objectives:

Knowledge:

1. Design tunnels, rock support and grouting and evaluate the most important issues in the procedure
2. Evaluate tunnel excavation method from technical and production aspects
 Analyze cost and time for ordinary tunnels based on risks and construction management principles

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. Design tunnels, rock support and grouting and evaluate the most important issues in the procedure. (CL-VI).
2. Evaluate tunnel excavation method from technical and production aspects. (CL-V).
3. Analyze cost and time for ordinary tunnels based on risks and construction management principles. (CL-IV).

Course Contents:

Introduction: Scope and application, historical developments, art of tunneling, tunnel engineering, future tunneling considerations.

Types of Underground Excavations: Tunnel, adit, decline, shaft; parameters influencing location, shape and size; geological aspects; planning and site investigations.

Tunneling Methods: Types and purpose of tunnels; factors affecting choice of excavation technique; Methods - soft ground tunneling, hard rock tunneling, shallow tunneling, deep tunneling; Shallow tunnels – cut and cover, cover and cut, pipe jacking, jacked box excavation techniques, methods of muck disposal, supporting, problems encountered and remedial measures.

Tunneling by Drilling and Blasting: Unit operations in conventional tunneling; Drilling - drilling principles, drilling equipment, drilling tools, drill selection, specific drilling, rock drill ability factors; Blasting - explosives, initiators, blasting mechanics, blast holes nomenclature; types of cuts- fan, wedge and others; blast design, tunnel blast performance - powder factor, parameters influencing, models for prediction; mucking and transportation equipment selection.

Tunneling by Road headers and Impact Hammers: Cutting principles, method of excavation, selection, performance, limitations and problems.

Tunneling by Tunnel Boring Machines: Boring principles, method of excavation, selection, performance, limitations and problems; TBM applications.

Supports in Tunnels: Principal types of supports and applicability.

Ground Treatment in Tunneling: Adverse ground conditions and its effect on tunneling; introduction to ground control.

Tunnel Services: Ventilation, drainage and pumping.

Methods of Sinking Shafts: Vertical and inclined, decline; shaft/raise boring machines and their application.

Tunneling Hazards: Explosion, flooding, chimney formation, squeezing ground.

Learning Resources:

1. Underground excavation of rock, Hoek and Brown
2. Rock Engineering, Palmström and Stille

Supplementary Reading:

Web links:

1. <https://www.isrm.net>
2. www.nirm.in
3. <http://umich.edu/~gs265/tunnel.htm>

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Introduction: Scope and application, historical developments, art of tunneling, tunnel engineering, future tunneling considerations. Types of Underground Excavations: Tunnel, adit, decline, shaft; parameters influencing location, shape and size; geological aspects; planning and site investigations.	6	--	--
2	Tunneling Methods: Types and purpose of tunnels; factors affecting choice of excavation technique; Methods - soft ground tunneling, hard rock tunneling, shallow tunneling, deep tunneling; Shallow tunnels – cut and cover, cover and cut, pipe jacking, jacked box excavation techniques, methods of muck disposal, supporting, problems encountered and remedial measures.	7	--	--
3	Tunneling by Drilling and Blasting: Unit operations in conventional tunneling; Drilling - drilling principles, drilling equipment, drilling tools, drill selection, specific drilling, rock drill ability factors; Blasting - explosives, initiators, blasting mechanics, blast holes nomenclature; types of cuts- fan, wedge and others; blast design, tunnel blast performance - powder factor, parameters influencing, models for prediction; mucking and transportation equipment selection	7	--	--
4	Tunneling by Road headers and Impact Hammers: Cutting principles, method of excavation, selection, performance, limitations and problems. Tunneling by Tunnel Boring Machines: Boring principles, method of excavation, selection, performance, limitations and problems; TBM applications. boring machines and their application. Tunneling Hazards: Explosion, flooding, chimney formation, squeezing ground.	5	--	--
5	Supports in Tunnels: Principal types of supports and applicability. Ground Treatment in Tunneling: Adverse ground conditions and its effect on tunneling; introduction to ground control. Tunnel Services: Ventilation, drainage and pumping. Methods of Sinking Shafts: Vertical and inclined, decline; shaft/raise	5	--	--

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Course Code	CET 514			
Course Category	Core			
Course Title	Lab. Practice-I			
Teaching Scheme and Credits	L	T	P	Credits
	--	--	6 Hrs/week	3

Pre-requisites:

1. Engineering Geology.
2. Rock Mechanics.

Course Objectives:

Knowledge:

1. To understand the role of geology in the design and construction process of underground openings in rock.
2. To apply geologic concepts and approaches on rock engineering projects.
3. To identify and classify rock using basic geologic classification systems.
4. To use the geologic literature to establish the geotechnical framework needed to properly design and construct heavy civil works rock projects.
5. To identify and characterize intact rock/rock mass properties.

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. To apply geologic concepts and approaches on rock engineering projects. (CL-III).
2. To identify and classify rock using basic geologic classification systems. (CL-IV).
3. To use the geologic literature to establish the geotechnical framework needed to properly design and construct heavy civil works rock projects. (CL-IV).
4. To identify and characterize intact rock/rock mass properties. (CL-IV).

Course Contents:

Practicals/Exercises on Engineering Geology, maps and sections of dam sites, Reservoir sites, Tunnels, Hill slopes, Open pit slopes. Determination of physical properties of rocks and soils.

1. Geological cross sections and study of geological maps.
- 2.

Learning Resources:

1. Engineering & General Geology, Parbin Singh, S.K. Kataria & Sons, New Delhi
2. A Text Book of Remote Sensing and Geographical Information Systems, M.Anji Reddy, B S Publication.
3. K.M., Principles of Engineering Geology, Bangar, Standard Publishers Distributors
4. Structural Geology, Billings, Marland P., Prentice-Hall India, New Delhi.

Supplementary Reading:**Web links:**

1. <https://www.isrm.net>
2. www.nirm.in
3. <http://umich.edu/~gs265/tunnel.htm>

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Lab Continuous Assessment (LCA):

Tool 1	Tool 2	Tool 3	Tool 4	Tool 5	Total out of 50 marks
Geological Site Investigation and Assessment	Analysis and Computations	Exercise on use of Software	Contents of File	Attendance/ Discipline/ Initiative/ Behavior	
10 (20%)	10 (20%)	10 (20%)	10 (20%)	10 (20%)	

Term End Examination: Oral examination: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		<i>Theory</i>	<i>Lab</i>	<i>Assess</i>
1	Study of Physical properties of minerals	--	10	--
2	Identification of rocks forming silicate and ore minerals	--	8	--
3	Recognition of rocks	--	10	--
4	Use of clinometers compass and Burton compass for measurement dip and strike of formations.	--	8	--
5	Geological cross sections and study of geological maps.	--	10	--
6	Study of models of geological structures and out crops patterns of different types of rocks and land forms.	--	14	--

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Course Code	CET 521			
Course Category	Core			
Course Title	Rock Mass Characterization			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2
Pre-requisites:				
<ol style="list-style-type: none"> 1. Engineering Geology. 2. Tunnel Engineering. 				
Course Objectives:				
Knowledge:				
<ol style="list-style-type: none"> 1. Analyze engineering behavior of rocks and influence on underground openings. 2. Design an experimental model to correlate all the rock testing together. 3. Evaluate stress distribution around underground openings. 				
Skills:				
<ol style="list-style-type: none"> 1. Problem identification and solving. 2. Interpretation. 				
Attitude:				
Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:-				
<ol style="list-style-type: none"> 1. Analyze the geophysical and rock mechanics data. (CL-IV). 2. Assess the engineering behavior of rock and evaluate rock quality (CL-V). 3. Evaluate stress distribution around underground openings (CL-V). 				
Course Contents				
Application of rock mechanics in civil/mining industry				
Concept of Stress and Strain in Rock:				
Failure Criteria for Rock and Rock Mass: Classical theories of rock failure: Coulomb's criterion, Mohr's criterion, Griffith's theory, Cook-Wiebol's criteria; Empirical failure criteria.				
Strength and Deformability of Rock Mass: In situ shear tests; evaluation of shear strength; in situ bearing strength test; in situ deformability tests- plate loading test, plate jacking test and borehole jack tests.				
Engineering Classification of Rocks and Rock Masses: Classification systems in rock engineering;				

classification of intact rocks; classification of rockmass system- Terzaghi's rock load, RMR, Q-system, Laubscher's - MRMR, Hoek's - GSI, Palmstrom's RMi, CMRI-ISM rock mass classification and recent developments; correlations between different classification systems; applications of rock mass classification in rock engineering.

Groundwater flow: Permeability and pressure: Groundwater flow within soil and rock masses; permeability conditions; influence of groundwater soil and rock mass behavior; measurement of groundwater pressure and permeability.

Response of Rock mass to Excavations Underground: Induced stresses and displacements around single and multiple excavations in rock mass; energy changes due to excavations in underground.

Monitoring of Excavation Stability: Purpose and nature of monitoring excavation stability, instrumentation and monitoring systems of stability of rock excavation-load; stress and deformation measuring devices; interpretation of monitoring data; practical aspects of monitoring.

Rock bursts: Type, effect and causes of rock bursts; mechanics of rock burst; prediction of rock burst; control of rock burst incidence and damage.

Learning Resources:

1. Engineering & General Geology, Parbin Singh, S.K. Kataria & Sons, New Delhi
2. A Text Book of Remote Sensing and Geographical Information Systems, M.Anji Reddy, B S Publication.
3. K.M., Principles of Engineering Geology, Bangar, Standard Publishers Distributors
4. Structural Geology, Billings, Marland P., Prentice-Hall India, New Delhi.

Supplementary Reading:

Web links:

1. <https://www.isrm.net>
2. www.nirm.in
3. <http://umich.edu/~gs265/tunnel.htm>

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3		
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks	
20 (40%)	20 (40%)	10 (20%)		

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	<p>Introduction: Application of rock mechanics in civil/mining industry</p> <p>Concept of Stress and Strain in Rock: Analysis of stress, analysis of strain, constitutive relations, strain energy, stress-strain behavior of isotropic and anisotropic rock, parameters influencing strength/stress-strain behavior.</p> <p>Static and dynamic elastic constants of rock, abrasivity of rock and its determination.</p> <p>Time dependent properties of Rock: Creep strain, time-dependent deformation; time-dependent strength reduction; rheological models.</p> <p>Engineering Classification of Rocks and Rock Masses: Classification systems in rock engineering; classification of intact rocks; classification of rockmasses-terzaghi's rock load, RQD, rock structure rating, Bieniawski's RMR, Barton's Q-system, Laubscher's-MRMR, Hoek's-GSI, Palmstrom's Rmi, CMRI-ISM rock mass classification and recent developments; correlations between different classification systems; applications of rock mass classification in rock engineering.</p> <p>Failure Criteria for Rock and Rock Mass: Classical theories of rock failure: Coulomb's criterion, Mohr's criterion, Griffith's theory, Cook-Wiebol's criteria; Empirical failure criteria.</p>	10	--	--
2	<p>Strength and Deformability of Rock Mass: In situ shear tests; evaluation of shear strength; in situ bearing strength test; in situ deformability tests-plate loading test, plate jacking test and borehole jack tests.</p> <p>Groundwater flow: Permeability and pressure: Groundwater flow within soil and rock masses; permeability conditions; influence of groundwater soil and rock mass behavior; measurement of groundwater pressure and permeability.</p> <p>Response of Rock mass to Excavations Underground: Induced stresses and displacements around single and multiple excavations in rock mass; energy changes due to excavations in underground.</p>	7	--	--
3	<p>Monitoring of Excavation Stability: Purpose and nature of monitoring excavation stability, instrumentation and monitoring systems of stability of rock excavation-load; stress and deformation measuring devices; interpretation of monitoring data; practical aspects of monitoring.</p> <p>Rock Slope Engineering: Slope failure causes and process; general modes of slope failure; parameters related to slope stability; basic approaches to slope stability analysis-circular, non-circular, planar, wedge and topping failures; monitoring of slope stability and stabilization techniques.</p>	8	--	--
4	<p>Rock bursts: Type, effect and causes of rock bursts; mechanics of rock burst; prediction of rock burst; control of rock burst incidence and damage.</p> <p>Subsidence: Types, causes and impacts of subsidence; factors influencing subsidence; subsidence prediction, control, prevention and monitoring.</p>	5	--	--

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Course Code	CET 522			
Course Category	Core			
Course Title	Planning and geometric design for tunnels and underground space.			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2
Pre-requisites:				
<ol style="list-style-type: none"> 1. Engineering Geology. 2. Rock and Soil Mechanics. 3. Tunnels and Underground Space Applications. 				
Course Objectives:				
Knowledge:				
<ol style="list-style-type: none"> 1. Planning and design process for excavation of tunnel. 2. Geo-engineering Investigations for Rock/rock mass Characterization. 3. Determination of appropriate location, size, shape and alignment. 4. Planning and Design of tunnels in soft ground. 				
Skills:				
<ol style="list-style-type: none"> 1. Problem identification and solving. 2. Computing skills, software skills. 				
Attitude:				
Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:-				
<ol style="list-style-type: none"> 1. Plan and design process for excavation of tunnel. (CL-VI). 2. Carry out geo-engineering Investigations for Rock/rock mass Characterization. (CL-III). 3. Decide appropriate location, size, shape and alignment. (CL-VI). 4. Plan and design tunnels in soft ground. (CL-VI). 				
Course Contents:				
Introduction: Planning and design process for excavation of roadways, tunnels and caverns				

Underground Space Planning and Design: Benefits and draw backs, classification and configurations, psychological and physiological effects, Legal and administrative issues, exterior and entrance design, layout and spatial contributions.

Geo-engineering Investigations for Rock/rock mass Characterization: Topographical and geological survey, augering, drilling, soil and rock sampling and testing, preparing sub-surface geological cross section, geo radar use and data analysis for shallow tunnels, geophysical investigations to prove deeper sub-surface features, Physico-mechanical properties and collection of rock mechanical data, stability analysis and identification of failure.

Planning and Design: Determination of appropriate location, size, shape and alignment, Assessment of behavior of tunneling media - deformation modulus and support pressure measurement, instrumentation and monitoring of rockmass performance, application of numerical modeling in space design, earthquake effects on tunnels, design of underground space in rocks with the help of field data.

Planning and Design of tunnels in soft ground: design considerations, lining type, short term and long-term behavior, subsidence, instrumentation and monitoring, case study.

Planning and Design of tunnels and caverns in hard rock: design considerations, design approaches, estimation of support pressures, ground behavior, instrumentation and monitoring, case study.

Learning Resources:

1. Tunnel Engineering Handbook, by J.O. Bickel and T.R. Kuesel .
2. Rock Mechanics Design in Mining and Tunneling by Z.T. Bieniawski.

Supplementary Reading:

Web links:

1. <http://www.asce.org/templates/conferences-events-event-detail.aspx?id=6144>
2. <http://nptel.ac.in/courses/105103093/24>

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Introduction: Planning and design process for excavation of roadways, tunnels and caverns. Underground Space Planning and Design: Benefits and draw backs, classification and configurations, psychological and physiological effects, Legal and administrative issues, exterior and entrance design, layout and spatial contributions.	5	--	--
2	Geo-engineering Investigations for Rock/rock mass Characterization: Topographical and geological survey, augering, drilling, soil and rock sampling and testing, preparing sub-surface geological cross section, georadar use and data analysis for shallow tunnels, geophysical investigations to probe deeper sub-surface features, Physico-mechanical properties and collection of rock mechanical data, stability analysis and identification of failure.	7	--	--
3	Planning and Design: Determination of appropriate location, size, shape and alignment, Assessment of behavior of tunneling media - deformation modulus and support pressure measurement, instrumentation and monitoring of rockmass performance, application of numerical modeling in space design, earthquake effects on tunnels, design of underground space in rocks with the help of field data.	8	--	--
4	Planning and Design of tunnels in soft ground: design considerations, lining type, short term and long-term behavior, subsidence, instrumentation and monitoring, case study.	5	--	--
5	Planning and Design of tunnels and caverns in hard rock: design considerations, design approaches, estimation of support pressures, ground behavior, instrumentation and monitoring, case study.	5	--	--

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Course Code	CET 523			
Course Category	Elective -I			
Course Title	Project Finance and Accounting Systems			
Teaching Scheme and Credits	L	T	P	Credits
	3hrs/week	-	--	2

Pre-requisites:

- 1 Project Management and Engineering Economics at U.G level

Course Objectives:

1. To differentiate between debt capital and equity capital.
2. To analyze the components of the working capital needed on construction projects.
3. To study capital budgeting and its accounting system.
4. To understand portfolio characteristics and evaluate them.

Course Outcomes:

After completion of the course, students will be able to:

1. Compare between various means of construction project finance and select an appropriate funding pattern. (CL-IV).
2. Estimate and organize for the working capital needs of contractors based on project requirements and contract conditions. (CL-V).
3. Account the construction expenses and monitor the financial health of construction firms. (CL-V).
4. Decide the investment strategy based on risk-return characteristics of Portfolio. (CL-VI).

Course Contents:

Project Finance: Infrastructure projects, construction projects planned and executed for national development—Funding requirements. Types of capital debt, equity. Debt: Equity ratio. Means of finance such as equity, preference shares, debentures, mutual funds, bonds comparative analysis. Financial institutions. Stakeholders involved in funding projects. Rights, duties of stakeholders.

Working Capital: Cash flow cycle. Estimation of working capital needs. Cash flow diagrams. Impact of tender conditions, inflation, risks on the requirement of working capital. Management of the working capital.

Capital Budgeting : Need. Objectives of financial management. Role of Lender's engineer and finance manager. Traditional methods and modern/ discounted cash flow methods of analysis.

Financial performance Assessment of Companies : Importance. Strategic objectives Financial Ratios—classification. Use of financial indices/ratios in performance assessment. Accounting Systems. Use of Balance sheet, cash flow statements, funds flow statements and income-expenditure/profit-loss statements in financial health monitoring evaluation and improvement.

Construction Accounts: Basic principles of accounting. Preparation of contract accounts for each project. Estimation of company profits/loss based on contract account. Accounting for head office establishment costs and site/job overheads. Escrow account and its use in public/private partnership or in Special Purpose Vehicles (SPV).

Portfolio Analysis: Concept of Portfolio. Risk—Return characteristics of assets. Weighted analysis. Correlation analysis based on demand/fall of asset values. Portfolio analysis.

Learning Resources:

Reference Books:

1. Brealey R.A ,Principles of Corporate Finance , Tata McGraw Hill, New Delhi, 2003.
2. Indian Institute of Banking and Finance ,Financial Management, Macmillan Publications, 2012.
3. Prasanna Chandra Projects planning, Analysis Selection, Implementation and Review, Tata McGraw Hill, New Delhi, 2005.
4. M. Y. Khan and Prabhakiran Jain, Financial Management McGraw Hill Education, 7th Edition ,2017.

Supplementary Reading:

Web Resources/Links

1. 164.100.133.129:81/eCONTENT/Uploads/Financial_Management.pdf
2. www.mheducation.co.in/9789339213053-india-financial-management.
3. www.jobsfundaz.com/2016/07/free-book-financial-management-khan-jain-pdf.html
4. gurukpo.com/financial-management-3/

MOOCs: nptel.ac.in/courses/105103023/39

Pedagogy:

1. Presentations
2. Case studies
3. Videos

Assessment Scheme:

Class Continuous Assessment (CCA)

Tool 1	Tool 2	Tool 3	Total out of 50 marks
Assignments	One Mid Term Test	Attendance/ Behavior/ Discipline/ Learning beyond the syllabus Initiative/	
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Contents	Workload in Hrs		
		Theory	Lab	Assess
1	Project Finance: Infrastructure projects, construction projects planned and executed for national development—Funding requirements. Types of capital debt, equity. Debt: Equity ratio. Means of finance such as equity, preference shares, debentures, mutual funds, bonds comparative analysis. Financial institutions. Stakeholders involved in funding projects. Rights, duties of stakeholders.	6		
2	Working Capital : Cash flow cycle. Estimation of working capital needs. Cash flow diagrams. Impact of tender conditions, inflation, risks on the requirement of working capital. Management of the working capital.	6		
3	Capital Budgeting : Need. Objectives of financial management. Role of Lender's engineer and finance manager. Traditional methods and modern/ discounted cash flow methods of analysis.	6		
4	Financial performance Assessment of Companies : Importance. Strategic objectives Financial Ratios—classification. Use of financial indices/ratios in performance assessment. Accounting Systems. Use of Balance sheet, cash flow statements, funds flow statements and income-expenditure/profit-loss statements in financial health monitoring evaluation and improvement.	6		
5	Construction Accounts: Basic principles of accounting. Preparation of contract accounts for each project. Estimation of company profits/loss based on contract account. Accounting for head office establishment costs and site/job overheads. Escrow account and its use in public/private partnership or in Special Purpose Vehicles (SPV).	6		
6	Portfolio Analysis: Concept of Portfolio. Risk—Return characteristics of assets. Weighted analysis. Correlation analysis based on demand/fall of asset values. Portfolio analysis.	6		

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Course Code	CET 524			
Course Category	Core			
Course Title	Lab. Practice-II			
Teaching Scheme and Credits	L	T	P	Credits
		--	6 Hrs/week	
Pre-requisites: Theory of Rock and soil mechanics.				
Course Objectives: Knowledge: <ol style="list-style-type: none"> 1. To determine triaxial strength and punch shear strength of rock. 2. Modulus of elasticity and Poisson's ratio of rock; Slake durability index of rock. 3. Determination of in situ stresses in rock. 				
Skills: <ol style="list-style-type: none"> 1. Problem identification and solving. 2. Computing skills, software skills. 				
Attitude: Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:- <ol style="list-style-type: none"> 1. To determine triaxial strength and punch shear strength of rock. (CL-V). 2. To determine and correlate Modulus of elasticity and Poisson's ratio of rock; Slake durability index of rock. (CL-V). 3. To determine in situ stresses in rock. (CL-V). 				
Course Contents: Practicals on -- Methods for determination of compressive strength, tensile strength, shear strength and triaxial strength of rock; porosity of rock; punch penetration test of rock; Abrasivity of rock; Strength indices of rock; Modulus of elasticity and Poisson's ratio of rock; Slake durability index of rock; Shear strength, consistency, consolidation and compaction of soil; Dynamic Modulus of elasticity and Poisson's ratio of rock; Determination of in situ stresses in rock; Load cell, extensometer, vibrating wire stress meter and convergence meter.				

1. Methods for determination of compressive strength, tensile strength, shear strength and triaxial strength of rock; porosity of rock.
2. Punch penetration test of rock; Abrasivity of rock; Strength indices of rock.
3. Modulus of elasticity and Poisson's ratio of rock; Slake durability index of rock.
4. Shear strength, consistency, consolidation and compaction of soil; Dynamic Modulus of elasticity and Poisson's ratio of rock.
5. Determination of in situ stresses in rock; Load cell, extensometer, vibrating wire stress meter and convergence meter.

Learning Resources:

1. Rock Mechanics - an introduction for the practical engineer, E. Hoek
2. Engineering Rock Mechanics-An Introduction to the Principles, John Hudson and John Harrison

Supplementary Reading:

Web links:

1. <https://www.isrm.net/>
2. www.nirm.in/
3. www.geoengineer.org/education/web-based-class-projects/rock-mechanics

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (LCA):

Assessment Scheme:

Lab Continuous Assessment (LCA):

Tool 1	Tool 2	Tool 3	Tool 4	Tool 5	Total out of 50 marks
Geotechnical Site Investigation and Assessment	Analysis and Computations	Exercise on use of Software	Contents of File	Attendance/ Discipline/ Initiative/ Behavior	
10 (20%)	10 (20%)	10 (20%)	10 (20%)	10 (20%)	

Term End Examination: Oral examination: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		<i>Theory</i>	<i>Lab</i>	<i>Assess</i>
1	Methods for determination of compressive strength, tensile strength, shear strength and triaxial strength of rock; porosity of rock.	--	10	--
2	Punch penetration test of rock; Abrasivity of rock; Strength indices of rock.	--	12	--
3	Modulus of elasticity and Poisson's ratio of rock; Slake durability index of rock.	--	10	--
4	Shear strength, consistency, consolidation and compaction of soil; Dynamic Modulus of elasticity and Poisson's ratio of rock.	--	12	--
5	Determination of in situ stresses in rock; Load cell, extensometer, vibrating wire stress meter and convergence meter.	--	10	--

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Course Code	CET 531			
Course Category	Core			
Course Title	Analysis and Design of Tunnel Supporting Systems			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

1. Tunnel Engineering.
2. Tunnels and underground space applications.

Course Objectives:

Knowledge:

1. To study the various types of support systems and their merits and demerits
2. To estimate support requirement on the basis of rock mass classifications.
3. To select appropriate support system for given site.

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. To estimate performance of various types of support systems. (CL-V).
2. To select appropriate support system for given site. (CL-VI).
3. To design support system on the basis of rock mass classifications and site conditions. (CL-VI).

Course Contents:

Introduction:

Design and operational criteria and principal support types used in civil/mining engineering applications.
Underground excavation support design: Rock support interaction analysis, use of rock mass classifications for estimating support requirement, classification of supports, passive and active supports,

temporary and permanent supports.

Wooden supports: Types, application, typical capacities, forepoling

Steel supports: Lining types, cast iron-steel linings, RSJ supports, rigid and yielding type arches, design and selection of arches, support of wedges or blocks which are free to fall, support of wedges or blocks which are free to slide, comparison of underground excavations support predictions.

Rock bolts and wire mesh:

Introduction, mechanism of support, organization of rock bolting programme, review of typical rock bolt systems, rock bolt installations, wire mesh, Pre-tensioning, testing, pre-reinforcement of rock mass. Concrete and Shotcrete.

Lining: Engineering properties of concrete, concrete segmental supports, cast in situ or monolithic concrete lining, water proofing of concrete lining; engineering properties of shotcrete, design of steel fiber reinforced shotcrete.

Grouting and Freezing:

Methods Compensation grouting, Jet grouting, Advance grouting, Ground freezing

Support of tunnels and underground space:

New Austrian Tunneling Method, Norwegian Tunneling Method. Support design exercises: Case studies covering some tunnels and caverns

Learning Resources:

1. Practical Tunnel Construction, Hemphill, G. B. 2012. John Wiley & Son
2. Tunnel Design Overview. Prasad, B. 2015.

Supplementary Reading:

Web links:

1. <https://www.linkedin.com/pulse/tunnel-design-overview-bandula-prasad>
2. <https://www.bentley.com/en/solutions/tunnel-design-and-analysis>

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Introduction: Design and operational criteria and principal support types used in civil/mining engineering applications. Underground excavation support design: Rock support interaction analysis, use of rock mass classifications for estimating support requirement, classification of supports, passive and active supports, temporary and permanent supports.	4	--	--
2	Wooden supports: Types, application, typical capacities, forepoling Steel supports : Lining types, cast iron-steel linings, RSJ supports, rigid and yielding type arches, design and selection of arches, support of wedges or blocks which are free to fall, support of wedges or blocks which are free to slide, comparison of underground excavations support predictions.	5	--	--
3	Rock bolts and wire mesh: Introduction, mechanism of support, organization of rock bolting programme, review of typical rock bolt systems, rock bolt installations, wire mesh, Pre-tensioning, testing, pre-reinforcement of rock mass.	4	--	--
4	Concrete and Shotcrete Lining: Engineering properties of concrete, concrete segmental supports, cast in situ or monolithic concrete lining, water proofing of concrete lining; engineering properties of shotcrete, design of steel fiber reinforced shotcrete.	6	--	--
5	Grouting and Freezing Methods: Compensation grouting, Jet grouting, Advance grouting, Ground freezing	4	--	--
6	Support of tunnels and underground space: New Austrian Tunneling Method, Norwegian Tunneling Method. Support design exercises: Case studies covering some tunnels and caverns	7	--	--

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Course Code	CET 532			
Course Category	Core			
Course Title	Advanced excavation techniques for tunnels and underground space			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisite:

1. Engineering Geology.
2. Tunnels and Underground Space Applications.
3. Tunnel Engineering.
4. Rock and soil mechanics.

Course Objectives:

Knowledge:

1. To study different methods of advanced drilling techniques.
2. To study TBM and Shield Tunneling
3. To understand excavation of large and deep tunnels
4. To understand excavation of large and deep caverns

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. To compare different methods of advanced drilling techniques and select the appropriate one. (CL-IV).
2. To understand various aspects of TBM and Shield Tunneling. (CL-II).
3. To understand excavation procedure of large and deep tunnels. (CL-II).
4. To understand excavation procedure of large and deep caverns. (CL-II).

Course Contents:

Introduction: Underground space - types, location, size, shape, purpose; excavation process of large tunnels and caverns for hydel, LPG and storage caverns

Advanced Excavation Techniques: Advanced drilling techniques - measure while drilling, drilling machines for longer drill holes, automation in drilling machines, drilling patterns; Controlled blasting techniques - line drilling, pre-splitting, smooth blasting, cushion blasting, Factors responsible for overbreak, overbreak estimation and control, problems of drilling and blasting for large tunnels and caverns; Advances in road heading and TBM technologies, cuttability/boreability assessment, performance prediction in tunneling with machine selection methodology.

Shield Tunneling: Introduction; advantages of shield tunneling; classification; different types of shield tunneling techniques – open shield, close shield, half shield; conventional shields, special features in shield tunneling; factors affecting selection of a shield; slurry shield, earth pressure balance shield, slime shields, other shield development methods, problems encountered with possible remedies.

Twin tunnels: excavation process, case study of a twin tunnel project

Excavation of large and deep tunnels: Introduction; purpose and use of large and deep tunnels; excavation issues governing large and deep tunnels; excavation methods of large and deep tunnels - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, road and rail tunnels.

Excavation of large and deep caverns: Introduction; purpose and use of large and deep caverns; excavation issues governing large and deep caverns; excavation methods of large and deep caverns - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, LPG and storage caverns.

Submerged and Floating Tunnels; Micro-tunneling; Trenchless excavation

Novel Excavation Techniques: Penetrating Cone Fracture, Bottom-hole pressurisation, Expanding cements, Diamond wire saw.

Learning Resources:

1. Underground tunnel excavation/passages methods and excavation techniques , Aydın BİLGİN

Supplementary Reading:

Web links:

- http://se.sze.hu/images/ngm_se108_1/Tunnels_2015-03-20_Toht_1-Excavation.pdf
<https://www.usbr.gov/ssle/safety/RSHS/sec23.pdf>
<https://www.osha.gov/Publications/osha3115.html>

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Introduction: Underground space - types, location, size, shape, purpose; excavation process of large tunnels and caverns for hydel, LPG and storage caverns, Advanced Excavation Techniques: Advanced drilling techniques - measure while drilling, drilling machines for longer drill holes, automation in drilling machines, drilling patterns.	4	--	--
2	Controlled blasting techniques - line drilling, pre-splitting, smooth blasting, cushion blasting, Factors responsible for overbreak, overbreak estimation and control, problems of drilling and blasting for large tunnels and caverns; Advances in road heading and TBM technologies, cuttability/boreability assessment, performance prediction in tunneling with machine selection methodology.	6	--	--
3	Shield Tunneling: Introduction; advantages of shield tunneling; classification; different types of shield tunneling techniques – open shield, close shield, half shield; conventional shields, special features in shield tunneling; factors affecting selection of a shield; slurry shield, earth pressure balance shield, slime shields, other shield development methods, problems encountered with possible remedies.	6	--	--
4	Twin tunnels: excavation process, case study of a twin tunnel project Excavation of large and deep tunnels: Introduction; purpose and use of large and deep tunnels; excavation issues governing large and deep tunnels; excavation methods of large and deep tunnels - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, road and rail tunnels.	5	--	--
5	Excavation of large and deep caverns: Introduction; purpose and use of large and deep caverns; excavation issues governing large and deep caverns; excavation methods of large and deep caverns - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, LPG and storage caverns.	5	--	--
6	Submerged and Floating Tunnels; Micro-tunneling; Trenchless excavation Novel Excavation Techniques: Penetrating Cone Fracture, Bottom-hole pressurisation, Expanding cements, Diamond wire saw.	4	--	--

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Course Code	CET 533			
Course Category	Elective II			
Course Title	Numerical Modeling in Ground Control			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2
Pre-requisites:				
<ol style="list-style-type: none"> 1. Theory of elasticity and failure criteria, 2. Estimation of rock mass property for numerical modeling of excavations. 				
Course Objectives:				
Knowledge:				
<ol style="list-style-type: none"> 1. To apply various Finite element Methods for ground modeling 2. To apply numerical modeling in solving the ground control problem in underground structures. 				
Skills:				
<ol style="list-style-type: none"> 1. Problem identification and solving. 2. Computing skills, software skills. 				
Attitude:				
Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:-				
<ol style="list-style-type: none"> 1. To apply various Finite element Methods for ground modeling. (CL-III) 2. To apply numerical modeling in solving the ground control problem in underground structures. (CL-IV) 				
Course Contents:				
Introduction: Numerical modeling techniques for rock mechanics and ground control, excavation in rock and related rock mechanics problems, need of numerical modeling in solving the ground control problem in underground structures.				
Finite element Method: Potential energy and Rayleigh-Ritz method, finite element form of Rayleigh-Ritz method, isoperimetric formulation of FE, introduction to non-linear solution method.				
Finite Difference method: Derivation of finite difference equations, introduction to FDM implementation in FLAC.				
Constitutive modeling and their uses: Mohr's Coulomb plasticity model for simulation of rock failure, interfaces to simulate the bedding planes, simulation of support in rock: bolts, props and lining. Boundary				

Element method.

Advanced Numerical Methods:

Solution of tri diagonal system; Evaluation of double and triple integrals by numerical method and its application, solution of non-linear simultaneous equations, numerical solution of integral equations; Advanced method of interpolation, Spline interpolation; Numerical solution of simultaneous first order ordinary differential equations (ODE); Initial and Boundary value problems; Numerical solution of partial differential equations; Laplace and Poisson equation; Heat conduction and wave equations.

Applied Statistics:

Review of binomial, Poisson, normal and log normal distributions. Interval estimates, tests of significance for mean, variance (one & two population case – Z, t, χ^2 and F tests), tests for correlation and regression coefficients. Non-parametric tests: Sign test, Mann-Whitney Wilcoxon U-test, run test and test of randomness. One way and two way analysis of variance. Time series analysis, reliability and life testing experiments in engineering problems.

Learning Resources:

1. Numerical Modeling for Designing Tunnel Support, Keping Zhou Changsha and Ming Xia
2. Numerical Modeling for Shallow Tunnels in Weak Rock, Evert Hoek

Supplementary Reading:

Web links:

1. https://www.researchgate.net/publication/312607757_NUMERICAL_MODELING_FOR_CIRCL_E_TUNNEL_UNDER_STATIC_AND_DYNAMIC_LOADS_FOR_DIFFERENT_DEPTH
2. <https://www.eoas.ubc.ca/courses/eosc547/lecture-material/Topic5-WeakRockTunnelling.pdf>

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Introduction: Numerical modeling techniques for rock mechanics and ground control, excavation in rock and related rock mechanics problems, need of numerical modeling in solving the ground control problem in underground structures.	4	--	--
2	Theory of elasticity and failure criteria, estimation of rock mass property for numerical modeling of excavations. Finite element Method: Potential energy and Rayleigh-Ritz method, finite element form of Rayleigh-Ritz method, isoperimetric formulation of FE, introduction to non-linear solution method.	8	--	--
3	Finite Difference method: Derivation of finite difference equations, introduction to FDM implementation in FLAC. Constitutive modeling and their uses: Mohr's Coulomb plasticity model for simulation of rock failure, interfaces to simulate the bedding planes, simulation of support in rock: bolts, props and lining. Boundary Element method.	6	--	--
4	Advanced Numerical Methods: Solution of tri diagonal system; Evaluation of double and triple integrals by numerical method and its application, solution of non-linear simultaneous equations, numerical solution of integral equations; Advanced method of interpolation, Spline interpolation; Numerical solution of simultaneous first order ordinary differential equations (ODE); Initial and Boundary value problems	7	--	--
5	Applied Statistics: Review of binomial, Poisson, normal and log normal distributions. Interval estimates, tests of significance for mean, variance (one & two population case – Z, t, χ^2 and F tests), tests for correlation and regression coefficients. Non-parametric tests: Sign test, Mann-Whitney Wilcoxon U-test, run test and test of randomness. One way and two way analysis of variance. Time series analysis, reliability and life testing experiments in engineering problems.	5	--	--

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Course Code	CET 534			
Course Category	Elective -III			
Course Title	Contracts, Legal aspects in tunnels and underground construction			
Teaching Scheme and Credits	L	T	P	Credits
	3hrs/week	01	--	3

Pre-requisites:

1. Estimation, Tendering and Contracts at under graduate level

Course Objectives:

Knowledge: 1) To study and understand provisions in different types of contracts.

2) To interpret from the various contract conditions.

3) To analyze legal aspects involved in contracts.

Skills: 1) Application of legal aspects in contract implementation.

Attitude: 2) Importance of role performance for success of contracted project.

Course Outcomes:

At the end of the course, students will be able to :-

1. Differentiate between various contract types and select the appropriate type needed for a particular project. (CL-V)
2. Scrutinize contractor's bids and select a reliable, competent contractor. (CL-V)
3. Analyze the provisions made in the Contract Act and Arbitration act; interpret their repercussions on the contract performance. (CL-IV)
4. Apply the FIDIC document provisions in contracting practice. (CL-III)

Course Contents

Contracts

Definitions as per Indian Contract Act (1872), Contract packages on projects, Types of Contracts, General and particular conditions. MOSPI, FIDIC

FIDIC

Types of FIDIC books. Applications details of FIDIC clauses of the NEW RED BOOK

Contractor selection

Prequalification, Request for Proposal (RFP), Request for Qualification (RFQ) Qualitative, Quantitative methods of contractor prequalification.

Contract Performance

Project Monitoring based on Contract Conditions. Billing, Claims, Negotiations, Settlement, disputes resolution methods. Project Partnering as an effective method.

Indian Contract Act (1872)

Major provisions with respect to contract formation, contract performance, contract closure and contract breach.

Indian Arbitration and Conciliation Act

Comparison between 1940, 1996 and 2015 version. Main provisions of 1996 and 2015 versions. Role of judiciary. Role of Arbitrators. Declaration of Awards and their enforcement case studies. Role of Institutionalized Arbitration.

Learning Resources:

Reference Books:

- 1) Civil Engineering Contracts and Estimates - B. S. Patil – Universities Press- 2006 Edition, reprinted in 2009.
- 2) The Indian Contract Act (9 of 1872), 1872- Bare Act- 2006 edition, Professional Book Publishers.
- 3) The Arbitration and Conciliation Act,(1996), 1996 (26 of 1996)- 2006 Edition, Professional Book Publisher.
- 4) FIDIC Document.
- 5) Dispute Resolution Board foundation manual-www.drbf.org.

Supplementary Reading:

- Web links:** 1) www.mca.gov.in/Ministry/notification/pdf/AS_7
 2) <https://books.google.co.in/books?isbn=0421674105>

Pedagogy:

1. Power point presentation.
2. Case studies

Assessment Scheme:

Class Continuous Assessment (CCA)

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/ Discipline/ Initiative/ Behavior/ Learning beyond the syllabus	Total out of 50 marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Contents	Workload in Hrs		
		<i>Theory</i>	<i>Lab</i>	<i>Assess</i>
1	Contracts Definitions as per Indian Contract Act (1872), Contract packages on projects, Types of Contracts, General and particular conditions. MOSPI, FIDIC	6	-	-
2	FIDIC Types of FIDIC books. Applications details of FIDIC clauses of the NEW RED BOOK	6	-	-
3	Contractor selection Prequalification, Request for Proposal (RFP), Request for Qualification (RFQ) Qualitative, Quantitative methods of contractor prequalification.	6	-	-
4	Contract Performance Project Monitoring based on Contract Conditions. Billing, Claims, Negotiations, Settlement, disputes resolution methods. Project Partnering as an effective method.	6	-	-
5	Indian Contract Act (1872) Major provisions with respect to contract formation, contract performance, contract closure and contract breach.	6	-	-
6	Indian Arbitration and Conciliation Act Comparison between 1940, 1996 and 2015 version. Main provisions of 1996 and 2015 versions. Role of judiciary. Role of Arbitrators. Declaration of Awards and their enforcement case studies. Role of Institutionalized Arbitration.	6	-	-

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School of Civil Engineering,
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Approved By

Prof. Dr. Mrs. M. S. Kulkarni)
Professor & Program Head
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Course Code	CET 535			
Course Category	Interdisciplinary			
Course Title	Seminar-I			
Teaching Scheme and Credits	L	T	P	Credits
	--	--	4 hrs/week	2

Students should identify any problem in tunnel engineering which requires a techno-commercial solution based on application of fundamental concepts involved in multiple disciplines of engineering. Students should devise an action plan for solving it, implement it and come out with a creative, innovative solution.

The interdisciplinary mini project should be done in a group of minimum 2 to maximum 4 students, but an individual report should be submitted.

A mini project report documenting the above in standard format is to be submitted. A Physical/Mathematical/Virtual/Model is to be prepared. Power point presentation of 15 minutes is to be prepared and delivered by each individual

Assessment Scheme:

Lab. Continuous Assessment (LCA)

Tool 1	Tool 2	Tool 3	Tool 4	Tool 5	
Problem Identification & Methodology of Solution	Creative & Innovative Approach	Submission of Seminar Report and Power point presentation	Model Submission	Attendance/ Discipline/ Initiative/ Behavior	Total out of 50 marks
10 (20%)	10 (20%)	10 (20%)	10 (20%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: Oral examination on the above report : (50 Marks)

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Course Code	CET 611			
Course Category	Core			
Course Title	Tunnel Safety and hazard analysis			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

Tunnel planning, designing and construction

Course Objectives:

Knowledge:

1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts.
2. To understand the subjective and objective approaches of risk management.
3. To study different methods of risk analysis.

Skills:

1. Risk identification and assessment
2. Risk management.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III).
2. Evaluate critically project failure factors and minimize their vulnerability (CL V).
3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV)
4. Apply risk analysis methods to real life tunnel projects. (CL IV)

Course Contents:

CONCEPTS AND TECHNIQUES

History of Safety movement –Evolution of modern safety concept- general concepts of management – planning for safety for optimization of productivity -productivity, quality and safety-line and staff functions for safety-budgeting for safety-safety policy. Incident Recall Technique (IRT), disaster control, job safety analysis, safety survey, safety inspection, safety sampling, evaluation of performance of supervisors on safety.

SAFETY AUDIT - INTRODUCTION

Components of safety audit, types of audit, audit methodology, non conformity reporting (NCR), audit checklist and report – review of inspection, remarks by government agencies, consultants, experts – perusal of accident and safety records, formats – implementation of audit indication - liaison with departments to ensure co-ordination – check list – identification of unsafe acts of workers and unsafe conditions in the shop floor.

TUNNEL SAFETY

To promote safety for those who work in underground construction, the Occupational Safety and Health Administration requires that employees receive extensive training in: Air monitoring and ventilation, Illumination, Communications, Flood control, Personal protective equipment, Emergency procedures, including evacuation plans, Check-in/check-out procedures, Explosives, Fire prevention and protection, Mechanical equipment

TUNNEL CONSTRUCTION HAZARDS

Hard physical labor bodily injuries, Roof falls or cave-ins, head injuries, crush injuries, suffocation or death, Exposure to crystalline silica dust and cement dust, respiratory, lung or skin problems.

Exposure to chemical vapors, lung problems, including chemical pneumonitis, respiratory failure and death if left unchecked, Exposure to radon can cause lung cancer. Oxygen-deficient atmospheres can contribute to breathing problems, such as asthma.

Learning Resources:

https://about.ita-aies.org/publications/wg-publications/download/81_7413b365cf767e6d8bdff18e0f9da36f

http://www.tunnel-online.info/en/artikel/tunnel_risk-management_331045.html

<http://www.cwejournal.org/vol10noSpecial/identify-and-analyze-the-risks-involved-in-tunnel-projects/>

Supplementary Reading:

Web links:

<https://www.icevirtuallibrary.com/doi/abs/10.1680/cotcadm12006.45224.0013>

https://www.itacet.org/sites/default/files/Health_Safety_Tunnel_Construction.pdf

<http://tunneltalk.com/images/laneCoveCollapse/Ref6-Australia-Code-of-Practice-for-Tunnels-Under-Construction.pdf>

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	<p>CONCEPTS AND TECHNIQUES</p> <p>History of Safety movement –Evolution of modern safety concept-general concepts of management – planning for safety for optimization of productivity -productivity, quality and safety-line and staff functions for safety-budgeting for safety-safety policy. Incident Recall Technique (IRT), disaster control, job safety analysis, safety survey, safety inspection, safety sampling, evaluation of performance of supervisors on safety.</p>	7		
2	<p>SAFETY AUDIT - INTRODUCTION</p> <p>Components of safety audit, types of audit, audit methodology, non conformity reporting (NCR), audit checklist and report – review of inspection, remarks by government agencies, consultants, experts – perusal of accident and safety records, formats – implementation of audit indication - liaison with departments to ensure co-ordination – check list – identification of unsafe acts of workers and unsafe conditions in the shop floor.</p>	7		
3	TUNNEL SAFETY	7		

	<p>To promote safety for those who work in underground construction, the Occupational Safety and Health Administration requires that employees receive extensive training in: Air monitoring and ventilation, Illumination, Communications, Flood control, Personal protective equipment, Emergency procedures, including evacuation plans, Check-in/check-out procedures, Explosives, Fire prevention and protection, Mechanical equipment.</p>			
4	<p>TUNNEL CONSTRUCTION HAZARDS</p> <p>Hard physical labor bodily injuries.,Roof falls or cave-ins, head injuries, crush injuries, suffocation or death. ,Exposure to crystalline silica dust and cement dust, respiratory, lung or skin problems.</p> <p>Exposure to chemical vapors, lung problems, including chemical pneumonitis, respiratory failure and death if left unchecked. ,Exposure to radon can cause lung cancer. Oxygen-deficient atmospheres can contribute to breathing problems, such as asthma.</p>	7		

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Course Code	CET 612			
Course Category	Elective IV			
Course Title	Ventilation for tunnels and underground space			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

1. Tunnel planning, designing and construction.

Course Objectives:

Knowledge:

1. Sampling and analysis of air –Gas chromatography
2. Sources of heat in underground space
3. Methods of Ventilation and Equipment

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. Assess and monitor sampling and analysis of air in tunnel (CL III).
2. Compare Methods of Ventilation and Equipments (CL V).
3. Plan & Design of ventilation system for tunnels. (CL IV)

Course Contents:

Underground environment: Composition of atmospheric air, O₂ deficiency – causes, effects & detection, Underground environment: Composition, Underground gases- CO₂, CO, H₂S, NO_x, CH₄, Radon gas – properties, physiological effects on man, occurrence & detection, Assessment, monitoring and remedial measures- Sampling and analysis of air –Gas chromatography, IR gas analyzer.

Heat and Humidity: Sources of heat in underground space, Metabolism and heat balance in human body, physiological effects of heat and humidity, Psychrometry, Cooling power of air, Air conditioning – basic principles.

Dust : Sources, measurement equipment & techniques, control measures

Air flow through underground openings: Introduction, general energy balance equation, flow of viscous

(Dr. L. K. Kshirsagar)

(Dean / Director / Principal)

fluids, laminar and turbulent flow, resistance of smooth walled pipes, flow through ducts, shock resistance, pressure losses, determination of resistance in air ways (pressure drop and quantity of flow through field measurement)

Methods of Ventilation and Equipment: Natural ventilation – Causes, Natural Ventilation Pressure (NVP)- Calculation of NVP from air density, Motive column, other methods of determining NVP, Numerical problems, Mechanical ventilation- Types of fans, Centrifugal fan – theoretical head developed, theoretical characteristic curves, fan losses, actual characteristics curves of CF fan, fan efficiency, Axial-flow fan – drag and lift, characteristic curves, variable pitch fan., Fan laws, Selection of fan, installation of fan – forcing & exhaust, Fan drift, diffuser and evasee, series and parallel operation of fans, fan control, Booster fan – function of booster fan, installation, pressure gradient diagram and positioning, Auxiliary ventilation, Forcing and exhaust ventilation systems, Numerical problems.

Standards of ventilation tunnels made for different purposes

Planning & Design of ventilation system for tunnels

Lighting systems and fixtures in tunnels: specifications, maintenance, emergency lighting.

Learning Resources:

1. Road Tunnel Ventilation Compendium and practical guideline by Petr Pospisil.
2. Tunnel Ventilation , Practical Tunnel construction by Gary B. Hemphill

Supplementary Reading:

Web links:

<https://www.wikipedia.org/wiki/project>

<https://www.projectmanager.com/blog>

<https://www.mooc-list.com/tags/risk>

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks

20 (40%)	20 (40%)	10 (20%)		
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Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Underground environment: Composition of atmospheric air, O ₂ deficiency – causes, effects & detection, Underground environment: Composition, Underground gases- CO ₂ , CO, H ₂ S, NO _x , CH ₄ , Radon gas – properties, physiological effects on man, occurrence & detection, Assessment, monitoring and remedial measures- Sampling and analysis of air –Gas chromatography, IR gas analyzer. Heat and Humidity: Sources of heat in underground space, Metabolism and heat balance in human body, physiological effects of heat and humidity, Psychrometry, Cooling power of air, Air conditioning – basic principles.	6		
2	Dust : Sources, measurement equipment & techniques, control measures Air flow through underground openings: Introduction, general energy balance equation , flow of viscous fluids, laminar and turbulent flow, resistance of smooth walled pipes, flow through ducts, shock resistance, pressure losses, determination of resistance in air ways (pressure drop and quantity of flow through field measurement)	6		
3	Methods of Ventilation and Equipment: Natural ventilation – Causes, Natural Ventilation Pressure (NVP)-Calculation of NVP from air density, Motive column, other methods of determining NVP, Numerical problems, Mechanical ventilation- Types of fans, Centrifugal fan – theoretical head developed, theoretical characteristic curves, fan losses, actual characteristics curves of CF fan, fan efficiency, Standards of ventilation tunnels made for different purposes	6		
4	Planning & Design of ventilation system for tunnels Lighting systems and fixtures in tunnels: specifications, maintenance, emergency lighting.	6		
5	Axial-flow fan – drag and lift, characteristic curves, variable pitch fan., Fan laws, Selection of fan, installation of fan – forcing & exhaust, Fan drift, diffuser and evasee, series and parallel operation of fans, fan control, Booster fan – function of booster fan, installation, pressure gradient diagram and positioning, Auxiliary ventilation, Forcing and exhaust ventilation systems, Numerical problems.	6		

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Course Code	CET 613			
Course Category	Core			
Course Title	Lab Practice III NUMERICAL MODELLING IN GROUND CONTROL PRACTICAL			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2
Pre-requisites: 1. Analysis of Tunnels.				
Course Objectives: Knowledge: 1. Evaluation of failure factors of the tunnel critically. 2. Modeling of Drill and blast tunnel 3. Modelling of a TBM tunnel, precast line segments.				
Skills: 1. Problem identification and solving. 2. Computing skills, software skills. Attitude: 1. Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:- 1. Model Drill and blast tunnel (CL V). 2. Model of NATM tunnel (CL IV)				
Course Contents: Solving problems on excavation in rock and support. Patch test and stress around simple openings and comparing the numerical solution with closed form solution. Modeling of Drill and blast tunnel				

Modeling of NATM tunnel
 Modeling of caving behaviour in strata.
 Modelling of slope.
 Modelling of supports in NATM Tunnel
 Modelling of a TBM tunnel, precast line segments

Learning Resources:

1. Numerical Simulation in Tunnelling, Editors: Beer, Gernot , Springer Publication
2. Innovative Numerical Modelling in Geomechanics , CRC Press

Supplementary Reading:

Web links:

https://Awr4xJSzA8dbfuEA_ghXNyoA;_ylu=X3oDMTByYnR1Zmd1BGNvbG8DZ3ExBHBvcw

https://r.search.yahoo.com/_ylt=Awr4xJSzA8dbfuEAAQIXNyoA;_ylu=X3oDMTByc3RzMXFjBGNvbG8

ANALYSIS-OF-SHALLOW-TUNNELS-IN-SOFT-GROUND

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		<i>Theory</i>	<i>Lab</i>	<i>Assess</i>
1	Solving problems on excavation in rock and support.	5		
2	Patch test and stress around simple openings and comparing the numerical solution with closed form solution.	5		
3	Modeling of Drill and blast tunnel, Modeling of NATM tunnel	5		
4	Modelling of supports in NATM Tunnel	5		
5	Modeling of caving behaviour in strata, Modelling of slope.	5		
6	Modelling of a hydroelectric cavern and gas oil storage cavern.	5		

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Course Code	CET 614			
Course Category	Core			
Course Title	Project Stage-I			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

3.

Course Objectives:

Knowledge:

1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts.
2. To understand the subjective and objective approaches of risk management.
3. To study different methods of risk analysis.

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III).
2. Evaluate critically project failure factors and minimize their vulnerability (CL V).
3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV)
4. Apply risk analysis methods to real life tunnel projects. (CL IV)

Course Contents:

1. Project Stage I.

Learning Resources:

1. Kumar Neeraj Jha0Construction Project Management.
2. R. Balaraman, D. P. chatterjee—Risk Managemnt, Indian Institute of Banking and finance, Macmilan, Education.
3. Chitkara, Construction Project Management, Tata McGraw Hill Publication.

Supplementary Reading:

Web links:

<https://www.wikipedia.org/wiki/project>

<https://www.projectmanager.com/blog>

<https://www.mooc-list.com/tags/risk>

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

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Course Code	CET 621			
Course Category	Core			
Course Title	Construction of Tunnel (TBM and NATM)			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2

Pre-requisites:

Course Objectives:

Knowledge:

1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts.
2. To understand the subjective and objective approaches of risk management.
3. To study different methods of risk analysis.

Skills:

1. Problem identification and solving.
2. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III).
2. Evaluate critically project failure factors and minimize their vulnerability (CL V).
3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV)
4. Apply risk analysis methods to real life tunnel projects. (CL IV)

Course Contents:

Introduction: Underground space - types, location, size, shape, purpose; excavation process of large tunnels.
Advanced Excavation Techniques: Advanced drilling techniques - measure while drilling, drilling machines for longer drill holes, automation in drilling machines, drilling patterns; Controlled blasting techniques - line drilling, pre-splitting, smooth blasting, cushion blasting, Factors responsible for overbreak, overbreak estimation and control, problems of drilling and blasting for large tunnels and caverns; Advances in roadheading and TBM technologies, cuttability/boreability assessment, performance prediction in

tunnelling with machine selection methodology.

Shield Tunneling: Introduction; advantages of shield tunnelling; classification; different types of shield tunneling techniques – open shield, close shield, half shield; conventional shields, special features in shield tunnelling; factors affecting selection of a shield; slurry shield, earth pressure balance shield, slime shields, other shield development methods, problems encountered with possible remedies.

Twin tunnels: excavation process, case study of a twin tunnel project

Excavation of large and deep tunnels: Introduction; purpose and use of large and deep tunnels; excavation issues governing large and deep tunnels; excavation methods of large and deep tunnels - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, road and rail tunnels.

Excavation of large and deep caverns: Introduction; purpose and use of large and deep caverns; excavation issues governing large and deep caverns; excavation methods of large and deep caverns - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, LPG and storage caverns.

Submerged and Floating Tunnels; Micro-tunnelling; Trenchless excavation

Novel Excavation Techniques: Penetrating Cone Fracture, Bottom-hole pressurisation, Expanding cements, Diamond wire saw

Learning Resources:

1. Practical Tunnel Construction, Gary B. Hemphill, Wiley Publication
2. Tunnel Engineering Handbook, Authors: Kuesel, Thomas R., King, Elwyn H., Bickel, John

Supplementary Reading:

Web links:

<https://www.wikipedia.org/wiki/project>
<https://www.projectmanager.com/blog>
<https://www.mooc-list.com/tags/risk>

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks

20 (40%)	20 (40%)	10 (20%)		
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Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	Introduction: Underground space - types, location, size, shape, purpose; excavation process of large tunnels and caverns for hydel, LPG and storage caverns Advanced Excavation Techniques: Advanced drilling techniques - measure while drilling, drilling machines for longer drill holes, automation in drilling machines, drilling patterns; Controlled blasting techniques - line drilling, pre-splitting, smooth blasting, cushion blasting, Factors responsible for overbreak, overbreak estimation and control, problems of drilling and blasting for large tunnels and caverns; Advances in roadheading and TBM technologies, cuttability/boreability assessment, performance prediction in tunnelling with machine selection methodology.	5		
2	Shield Tunneling: Introduction; advantages of shield tunnelling; classification; different types of shield tunneling techniques – open shield, close shield, half shield; conventional shields, special features in shield tunnelling; factors affecting selection of a shield; slurry shield, earth pressure balance shield, slime shields, other shield development methods, problems encountered with possible remedies.	5		
3	Twin tunnels: excavation process, case study of a twin tunnel project Excavation of large and deep tunnels: Introduction; purpose and use of large and deep tunnels; excavation issues governing large and deep tunnels; excavation methods of large and deep tunnels - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, road and rail tunnels.	5		
4	Excavation of large and deep caverns: Introduction; purpose and use of large and deep caverns; excavation issues governing large and deep caverns; excavation methods of large and deep caverns - unit operations, different equipment, types of rock pressure and methods to deal, roof and wall supports, case studies from hydel, LPG and storage caverns.	5		
5	Submerged and Floating Tunnels; Micro-tunnelling; Trenchless excavation	5		
6	Novel Excavation Techniques: Penetrating Cone Fracture, Bottom-hole pressurisation, Expanding cements, Diamond wire saw	5		

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Course Code	CET 622			
Course Category	Elective V			
Course Title	Project Risk Management			
Teaching Scheme and Credits	L	T	P	Credits
	3 Hrs/week	--	--	2
Pre-requisites:				
<ol style="list-style-type: none"> 1. Tunnel analysis and design. 2. Tunnel ventilation. 				
Course Objectives:				
Knowledge:				
<ol style="list-style-type: none"> 1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts. 2. To understand the subjective and objective approaches of risk management. 3. To study different methods of risk analysis. 				
Skills:				
<ol style="list-style-type: none"> 1. Problem identification and solving. 2. Computing skills, software skills. 				
Attitude:				
Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:-				
<ol style="list-style-type: none"> 1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III). 2. Evaluate critically project failure factors and minimize their vulnerability (CL V). 3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV) 4. Apply risk analysis methods to real life tunnel projects. (CL IV) 				
Course Contents:				
<p>Tunneling and underground construction risks on all parties involved ,The inherent uncertainties, including ground and groundwater conditions, cost overrun and delay risks as well as environmental risks. A potential for large scale accidents during tunneling work such as tunnel collapses and other disasters, for tunnels in urban areas there is a risk of damage to a range of third party persons and heritage designated property, a risk that the problems which the tunneling project cause to the public will give rise to public protests affecting the course of the project.</p>				

The engineering decisions to be taken during the project development. The guidelines for risk management processes, systematic risk management techniques throughout the tunnel project development
Identification of potential problems, appropriate risk mitigation measures. (Dr. L. K. Kshirsagar)
(Dean / Director / Principal)

Phase 1: Early Design Stage (Feasibility and Conceptual Design) - Establish risk policy, - risk acceptance criteria, - Qualitative risk assessment of the project, - Detailed analysis of areas of special interest or concern

Phase 2: Tendering and Contract Negotiation - Requirements in tender documents, - Risk assessment in tender evaluation, - Risk clauses in contract

Phase 3: Construction Phase – Contractor’s risk management, - Owner’s risk management, - Joint risk management team between the owner and the contractor.

General hazards:

1. Contractual disputes,
2. Insolvency and institutional problems,
3. Authorities interference,
4. Third party interference,
5. Labour disputes.

Specific hazards:

6. Accidental occurrences,
7. Unforeseen adverse conditions,
8. Inadequate designs, specifications and programmes,
9. Failure of major equipment, and
10. Substandard, slow or out-of-tolerance works.

Risk classification and risk acceptance, Quantitative risk assessment

Risk management tools for judgement of risk during planning and through the different phases of a tunnelling project, identify risk, quantify risk, visualise causes and effects, and the course (chain) of events.

Fault tree analysis to analyse a single or combined causal connection (relation) that precedes a negative event.. Structuring of complex problems by using this tool, .

Event tree analysis The description of the development from an initial event, through possible sequences to a defined final state can be carried out by event tree analysis. Assessing probabilities for different outcomes give a quantitative

Learning Resources:

1. A Code Of Practice For Risk Management Of Tunnel Works - The International Tunnelling Group
2. Guidelines for tunnelling risk management: International Tunnelling Association, Working Group No. 2
3. A Risk-Assessment Methodology In Tunnelling Anita Cerić Danijela Marčić Krešo Ivandić

Supplementary Reading:

Web links:

<https://www.wikipedia.org/wiki/project>

<https://www.projectmanager.com/blog>

<https://www.mooc-list.com/tags/risk>

Pedagogy:

1. Power pint presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

Module No.	Course Contents:	Workload in Hrs		
		Theory	Lab	Assess
1	<p>Course Contents:</p> <p>Tunneling and underground construction risks on all parties involved ,The inherent uncertainties, including ground and groundwater conditions, cost overrun and delay risks as well as environmental risks. A potential for large scale accidents during tunneling work such as tunnel collapses and other disasters, for tunnels in urban areas there is a risk of damage to a range of third party persons and heritage designated property, a risk that the problems which the tunneling project cause to the public will give rise to public protests affecting the course of the project.</p>	5		
2	<p>The engineering decisions to be taken during the project development. The guidelines for risk management processes, systematic risk management techniques throughout the tunnel project development. Identification of potential problems, appropriate risk mitigation measures.</p>	5		
3	<p>Phase 1: Early Design Stage (Feasibility and Conceptual Design) - Establish risk policy, - Risk acceptance criteria, - Qualitative risk assessment of the project, - Detailed analysis of areas of special interest or concern</p> <p>Phase 2: Tendering and Contract Negotiation - Requirements in tender documents, - Risk assessment in tender evaluation, - Risk clauses in contract</p> <p>Phase 3: Construction Phase – Contractor’s risk management, - Owner’s risk management, - Joint risk management team between the owner and the contractor.</p>	5		
4	<p>General hazards: Contractual disputes, Insolvency and institutional problems, Authorities interference, Third party interference, Labour disputes.</p> <p>Specific hazards: Accidental occurrences, Unforeseen adverse conditions, 8. Inadequate designs, specifications and programmes, Failure of major equipment, and Substandard, slow or out-of-tolerance works.</p>	5		

	Risk classification and risk acceptance, Quantitative risk assessment			
5	Risk management tools for judgement of risk during planning and through the different phases of a tunnelling project, identify risk, quantify risk, visualise causes and effects, and the course (chain) of events. Fault tree analysis to analyse a single or combined causal connection (relation) that precedes a negative event.. Structuring of complex problems by using this tool.	5		
6	Event tree analysis The description of the development from an initial event, through possible sequences to a defined final state can be carried out by event tree analysis. Assessing probabilities for different outcomes give a quantitative	5		

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Course Code	CET 623			
Course Category	Interdisciplinary Skills			
Course Title	Internship			
Teaching Scheme and Credits	L	T	P	Credits
	--	--	--	6
Pre-requisites: 1. Analysis design and construction to tunnels.				
Course Objectives: Knowledge: 1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts. 2. To understand the subjective and objective approaches of risk management. 3. To study different methods of risk analysis.				
Skills: 1. Problem identification and solving. 2. Computing skills, software skills. Attitude: Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:- 1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III). 2. Evaluate critically project failure factors and minimize their vulnerability (CL V). 3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV) 4. Apply risk analysis methods to real life tunnel projects. (CL IV)				
Course Contents:				
Supplementary Reading: Web links: https://www.wikipedia.org/wiki/project https://www.projectmanager.com/blog				

<https://www.mooc-list.com>tags>risk>

Pedagogy:

1. On site working.

Assessment Scheme:

Class Continuous Assessment (CCA): NA

Laboratory Continuous Assessment (LCA): NA

Term End Oral Examination: (100 Marks)

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Course Code	CET 631			
Course Category	Elective VI			
Course Title	Online MOOC			
Teaching Scheme and Credits	L	T	P	Credits
	--	--	--	02
Pre-requisites: 1. Analysis design and construction of tunnels.				
Course Objectives: Knowledge: 1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts. 2. To understand the subjective and objective approaches of risk management. 3. To study different methods of risk analysis.				
Skills: 1. Problem identification and solving. 2. Computing skills, software skills. Attitude: Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:- 1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III). 2. Evaluate critically project failure factors and minimize their vulnerability (CL V). 3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV) 4. Apply risk analysis methods to real life tunnel projects. (CL IV)				
Course Contents: 1. On site working. 2. Report writing.				
Learning Resources: 1. Kumar Neeraj Jha0Construction Project Management.				

2. R. Balaraman, D. P. chatterjee—Risk Managemnt, Indian Institute of Banking and finance, Macmilan, Education.
3. Chitkara, Construction Project Management, Tata McGraw Hill Publication.

Supplementary Reading:

Web links:

<https://www.wikipedia.org/wiki/project>

<https://www.projectmanager.com/blog>

<https://www.mooc-list.com/tags/risk>

Pedagogy:

1. Power point presentations, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA):

Tool 1	Tool 2	Tool 3	
Assignments	One Mid Term Test	Attendance/Discipline/Initiative/Behavior /Learning beyond the syllabus	Total out of 50 Marks
20 (40%)	20 (40%)	10 (20%)	

Laboratory Continuous Assessment (LCA): NA

Term End Examination: This will cover entire syllabus: (50 Marks)

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Course Code	CET 632			
Course Category	Skills			
Course Title	Internship			
Teaching Scheme and Credits	L	T	P	Credits
	--	--	--	02

Pre-requisites:

2. Analysis design and construction of tunnels.

Course Objectives:

Knowledge:

4. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts.
5. To understand the subjective and objective approaches of risk management.
6. To study different methods of risk analysis.

Skills:

3. Problem identification and solving.
4. Computing skills, software skills.

Attitude:

Forecasting, calculated risk taking.

Course Outcomes: After completion of the course, students will be able to:-

5. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III).
6. Evaluate critically project failure factors and minimize their vulnerability (CL V).
7. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV)
8. Apply risk analysis methods to real life tunnel projects. (CL IV)

Course Contents:

3. On site working.
4. Report writing.

Learning Resources:

4. Kumar Neeraj Jha Construction Project Management.
5. R. Balaraman, D. P. chatterjee—Risk Managemnt, Indian Institute of Banking and finance, Macmilan, Education.
6. Chitkara, Construction Project Management, Tata McGraw Hill Publication.

Supplementary Reading:

Web links:

<https://www.wikipedia.org/wiki/project>

<https://www.projectmanager.com/blog>

<https://www.mooc-list.com/tags/risk>

Pedagogy:

3. Power point presentations, problem solving.
4. Netsurfing, case studies.

Assessment Scheme:

Class Continuous Assessment (CCA): NA

Laboratory Continuous Assessment (LCA): NA

Term End Oral / Examination: (50 Marks)

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Course Code	CET 633			
Course Category	Core			
Course Title	Seminar II			
Teaching Scheme and Credits	L	T	P	Credits
	--	--	04	02
Pre-requisites: 1. Internship.				
Course Objectives: Knowledge: 1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts. 2. To understand the subjective and objective approaches of risk management. 3. To study different methods of risk analysis.				
Skills: 1. Problem identification and solving. 2. Computing skills, software skills. Attitude: Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:- 1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III). 2. Evaluate critically project failure factors and minimize their vulnerability (CL V). 3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV) 4. Apply risk analysis methods to real life tunnel projects. (CL IV)				
Course Contents:				
Learning Resources: 1. Kumar Neeraj Jha0Construction Project Management. 2. R. Balaraman, D. P. chatterjee—Risk Managemnt, Indian Institute of Banking and finance,				

Macmillan, Education.

3. Chitkara, Construction Project Management, Tata McGraw Hill Publication.

Supplementary Reading:

Web links:

<https://www.wikipedia.org/wiki/project>

<https://www.projectmanager.com/blog>

<https://www.mooc-list.com/tags/risk>

(Dr. L. K. Kshirsagar)
(Dean / Director / Principal)

Pedagogy:

3. Power pint presentations, problem solving.

4. Netsurfing, case studies.

Assessment Scheme:

Laboratory Continuous Assessment (LCA): 50 Marks.

Term End Examination: This will cover entire syllabus: (50 Marks)

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Course Code	CET 634			
Course Category	Core			
Course Title	Project Stage II			
Teaching Scheme and Credits	L	T	P	Credits
	--	--	18	09
Pre-requisites:				
1. Analysis design and construction of tunnels.				
Course Objectives:				
Knowledge:				
1. To identify the various parameters which are responsible for project uncertainties and select an appropriate approach for analyzing their impacts.				
2. To understand the subjective and objective approaches of risk management.				
3. To study different methods of risk analysis.				
Skills:				
1. Problem identification and solving.				
2. Computing skills, software skills.				
3. Attitude:				
4. Forecasting, calculated risk taking.				
Course Outcomes: After completion of the course, students will be able to:-				
1. Identify project uncertainties and analyze them based on a systematic, scientific approach (CL III).				
2. Evaluate critically project failure factors and minimize their vulnerability (CL V).				
3. Compare and contrast between qualitative and quantitative risk assessment tools (CL IV)				
4. Apply risk analysis methods to real life tunnel projects. (CL IV)				
Course Contents:				
Project work				
Supplementary Reading:				
Web links:				
https://www.wikipedia.org/wiki/project				
https://www.projectmanager.com/blog				
https://www.mooc-list.com/tags/risk				

Pedagogy:

1. Self study, problem solving.
2. Netsurfing, case studies.

Assessment Scheme:

Laboratory Continuous Assessment (LCA): 100

Term End Examination: This will cover entire syllabus: (100 Marks)

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