DC1	NMNC501	Computational Geomechanics and Ground Control	3	1	0	4

Course Objective
To impart the basic concepts, principles and techniques for developing a deep understanding of theoretical and applied Geomechanics in mining and rock engineering and to provide an overview of their application in mine excavations and geo-engineering design and understand the basic functions of FE based software and its applications in Geomechanics (modelling, analysis, and interpretation of results).

Learning Outcomes
Upon successful completion of this course, students will: • be able to understand the basics concept of stress and strain in rock • have a broad understanding of failure criteria, Strength and Deformability of rock and rockmass • able to learn about the basics of theoretical and practical aspects of geo-mechanics and its importance in the design of excavations for safe & productive mining operations • have a broad understanding of fundamentals of Finite element method • have a high-level understanding of Finite Element formulations for 1D, 2D and 3D problems. • be able to impart the knowledge and skill of analyzing physical problems with FE software correctly and efficiently

Unit No.	Topics to be Covered	Lecture Hours +Tutorials	Learning Outcome
1	**Geotechnical Investigations and Classification of rock mass and soil:** Engineering properties of intact rock – physico-mechanical, Rock mass classification methods and their applications, Soil classification methods and their applications.	(9L + 1T)	Understanding of various engineering properties of rocks and soil; rock mass classification and soil classification methods and their application in the design of structures in rock and soil
2	**Introduction and Concept of stress and strain in rock**: Analysis of Stress, Analysis of Strain, Transformation of Stresses and strains, Principal stresses and stress invariants, Mohr's Circle of stress, **Stress-Strain Relationships**: Relationship between Principal Stresses and Principal Strains, Non-linear Elasticity, Plasticity, Plane Stress Conditions, Plane Strain Conditions, Axisymmetric Conditions, Equation of Equilibrium, Compatibility condition. Exercises	(8L + 4T)	This unit will help students to understand the concepts of stress at a point, strain at a point, and the stress-strain relationships for linear, elastic, homogeneous, isotropic materials. The students will solve practical problems through evaluating the relationship between stress and strain
3	**Rock and Rock Mass Failure Criteria:** Invariants of Deviatoric Stress, Mohr-Coulomb (MC) Criterion, Hoek-Brown (HB) Criterion, Drucker-Prager Criterion, Theory and mathematical formulation, Exercises.	(2L + 1T)	This unit will help students in understanding the concepts of different failure criteria of Rock and Rock Mass.
4	**Strength and Deformability of Jointed Rock Mass:** Fracture Strength of Jointed Rock Mass, Shear Strength of Rock Joint,	(3L+0T)	Students will able to understand the deformability parameters of the jointed Rock mass with effects of

	Concept of Joint Compliance and Exercises.		discontinuities on its strength. and they will gain knowledge about the shear strength parameters of the Jointed Rock Mass, and also able to understand the Joint Compliance
5	**Rock Slope Engineering:** Slope failure and causes; Basic approaches to slope stability analysis and stabilisation Monitoring of Excavation Stability: Purpose and nature of monitoring, Instrumentation and monitoring systems - Load; Stress and Deformation measuring devices; Interpretation of monitoring data; Practical aspects of monitoring and Exercises.	(5L + 2T)	The students will learn about the rock slope stability analysis and design for various mining applications. Understanding of instrumentation and monitoring systems used in surface and underground mine excavation stability.
6	**Groundwater flow:** Permeability and pressure Groundwater flow within soil and rock masses; Permeability conditions; Influence of groundwater soil and rock mass behaviour; Measurement of groundwater pressure and permeability, Exercises	(3L+0T)	Understanding of groundwater flow within soil and rock and its influence on soil and rock mass behavior; Measurement of groundwater pressure and permeability for design of mining excavations.
7	**Classification and Overview of Computational Methods:** Introduction **Finite Difference Method:** Introduction, Derivation of Finite Difference Equations and example. **Finite Element Method (FEM):** Basics of Finite Element Method (FEM) with reference to Geomechanics, Global, local, and natural coordinates and Potential energy. **The Finite Element Method in One Dimensions:** Two-Nodded Linear Element, Three-Nodded Quadratic Element, Discretization, Geometry and Nodal Connectivity, Integration of Element Matrices, Multielement Assembly, Boundary Conditions and Solution, Mathematical formulation and Exercises. **The Finite Element Method in Two Dimensions:** Three-Nodded Linear Triangle, Six-Nodded Quadratic Triangle, Four-Nodded Bilinear Quadrilateral, Eight-Nodded Quadratic Quadrilateral, Discretization, Geometry and Nodal Connectivity, Integration of Element Matrices, Multielement Assembly, Boundary Conditions and Solution, Mathematical formulation and Exercises. **The Finite Element Method in Three Dimensions:** Eight-Nodded Linear Brick Element, Discretization, Geometry and	(6L + 6T)	Students will understand the fundamental basic theory of FEA (ideas of FEM). Introduce the general procedures that are necessary to carry out an analysis. Understand the need in Design for the Finite Element Method. They also understand the global, local, and natural coordinates and Potential energy concept. Student will comprehend the formulation of one-dimensional elements (truss and beam), two-dimensional, three-dimensional elements and understand the role and significance of shape functions in finite element formulations and utility of linear, quadratic, and cubic shape functions for interpolation. They will perform and verify FEA using FEA software. This will help in designing the model and select appropriate space (plane stress or plane strain), type of element, and modelling techniques. Students can perform and verify FEA using FEA software.

	Nodal Connectivity, Integration of Element Matrices, Multi-element Assembly, Boundary Conditions and Solution, Mathematical formulation and Exercises.		
8	**Applications of the Finite Element Method in Geomechanics** **Elastic-Plastic Finite Element Analysis:** Non-Linear Solution Methods, Elastic-Plastic Analysis Method, Exercises	(6L+0T)	Students will able to understand the basic functions of FE based software and its applications in Geomechanics., and they will also understand the appropriate element and mesh for FE analysis for given problem and development of the FE-model, and also analyse the stress distribution insitu and around an opening in competent rock. This will help the students to understand the non-linear solution techniques in FEM.
	Total	56 (42L+14T)	

Text Books:

1. Finite Element method: Concepts and Applications in Geomechanics by D. Deb

Reference Books:

1. Introduction to Rock Mechanics, Goodman, RE.
2. Engineering Rock Mechanics-An Introduction and Principles: Pergamon, Hudson, J.P. and Harrison,J.P
3. Fundamental of Rock Mechanics by Jaeger, J.C. and Cook, NGW
4. Finite element procedures by (1996) K. J. Bathe
5. Concept and Application of Finite Element Analysis by RD Cook
6. Computational Geomechanics by Zienkiewicz, Chan, A. H. C. M. Pastor, B. A. Schrefler, T. Shiomi - -Wiley (1999)
7. Fundamentals of Finite Element Analysis, by David V. Hutton