GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-V

Course Title: Rock Mechanics
(Course Code: 4352203)

Diploma programme in which this course is offered	Semester in which offered
Mining Engineering	5th Semester

1. RATIONALE

The rapid growth of mining industry led to endanger the safety conditions of the rock structure and extraction losses, therefore a deep knowledge of rock mechanics is very much important for minimizing extraction loss and making the rock structure safe so that the mining can be done without any interruption.

A huge network of underground galleries and other excavation are made in naturally formed rocks at a varying depth over lying a huge stratum which has to be properly supported to make the underground working safe.

After competition of this course the students will judge the quality of rocks and its suitability for a particular support system. He can effectively supervise underground areas for any kind of structural disturbances which need support, for maintaining safe practice in mine.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- Identify the risk of rock failure conditions due to overcoming stresses.
- Adopt suitable mitigation measures to make underground working safe.

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

CO1: Identify the strength quality of rock.
CO2: Define physical and mechanical properties of rock.
CO3: Justify the rock failure conditions surrounded by various stresses.
CO4: Select suitable rock strength testing procedure.
CO5: Classify various types of rock for its strength quality.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T/2+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	-	2	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken

during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.
***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. *Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'*.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Prepare a cylindrical specimen sample for strength testing purpose by cutting, grinding and polishing.	1	4
2	Determine the quality of rock by RQD test procedure from the cores collected from the bore holes.	1	2
3	Measure durability of rock samples by durability test.	2	4
4	Determine the uniaxial compressive strength of a given specimen.	4	4
5	Determine the Impact Strength Index of given sample.	4	2
6	Determine the tensile strength of a rock by Brazilian test.	4	4
7	Determine the shear strength of a rock by Shear Box and Punch Shear test.	4	4
8	Determine point load strength index of a rock specimen by point loading testing machine.	4	4
		Total	**28**

Note

*i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to usher in uniformity of practical in all institutions across the state.

S. No.	Equipment Name with Broad Specifications	PrO.No.
1.	**Universal testing machine** *Specifications: Material - Stainless steel, measuring range/capacity – 100 kN, Voltage - 440 V, Noise free construction, ISO approved*	4,6,7
2.	**Core cutting machine** *Specifications: Machine body shall be stable in construction, having diamond impregnated cutter.*	1,2,4,6,7,8
3.	**Core grinding machine** *Specifications: Machine body shall be stable in construction; The*	1,2,4,6,7,8

S. No.	Equipment Name with Broad Specifications	PrO.No.
	outfit shall include a fine diamond impregnated grinding wheel and a sample holder.	
4.	**Core polishing machine** *Specifications: Machine body shall be stable in construction, Feed arrangement to facilitate the specimen with a uniform and smooth feeding motion for polishing.*	1,2,4,6,7,8
5.	**Slake durability apparatus with Oven** *Specifications: motorized drive unit mounted on a baseplate and connected to two or four drums and having digital display, water tank, Oven: 100^{o}C to 150^{o}C*	3
6.	**Impact strength index apparatus** *Specifications: Hollow cylindrical apparatus having minimum height of 650 mm with 2 to 2.5 kg plunger*	5
7.	**Sieve** *Specifications: minimum 0.5 mm sieve*	5
8.	**Volumeter** *Specifications: Hollow cylindrical volumeter having internal diameter of minimum 20 mm, Scale to measure height of sample in the volumeter*	5
9.	**Weighing machine** *Specifications: Digital weighing machine/scale, weighing capacity: up to 5 kg*	5
10.	**Shear box test apparatus** *Specifications: Box having two halves, Normal and horizontal/shear loading arrangement*	7
11.	**Punch Shear Test Apparatus** *Specifications: stainless steel piston shaped cylindrical jig having projected end, Hollow cylindrical block to place specimen and to fit cylindrical jig.*	7
12.	**Point loading testing machine** *Specifications: Made of stainless steel, arrangement for point load of minimum 100kN.*	8

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Uses and objective approach in problem solving.
b) Displays a professional commitment to ethical practice.
c) Work as a leader/a team member.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
Unit-I **Introduction & Rock Exploration**	1a. Explain rock mechanics and its importance in mining field. 1b. Identify the form and defects in rock. 1c. Identify the quality of rocks present in sub-surface.	1.1 Rock Mechanics - definition & its scope in mining field. 1.2 Rock- its mass & material form; defects in rock mass with its effects. 1.3 Rock Exploration- its objectives to get sub surface information 1.3.1 Rock exploration by direct penetration- core boring, core recovery, Rock quality designation (RQD)- its determination, fracture frequency, core logging, & large diameter calyx hole.
Unit-II **Rock Properties**	2a. Define various physical & mechanical properties of rocks.	2.1 Physical properties of rock: Porosity, Density, Moisture content, Coefficient of permeability, Electrical properties, Thermal properties, Swelling, Anisotropy, Durability, & Degree of saturation. 2.2 Mechanical properties of rock: Strength - Compressive strength, Tensile strength, & Shear strength; Deformability; Elasticity; Plasticity; Poisson's ratio & Hardness with its Mohr's scale.
Unit-III **Rock Pressure & Its failure**	3a. Define the types of stress acting in a particular mining situation. 3b. Draw a stress distribution profile around various mine openings. 3c. Identify rock failure conditions.	3.1 Stresses involved in mining with its different types. 3.2 Pressure arch theory- Distribution of various stresses around mine openings: Rectangular opening, Circular shaft, & Long wall panel working. 3.3 Rock failure- Creep, Convergence, Rock burst, & coal bumps with its drilling yield test.
Unit-IV **Rock Testing**	4a. Prepare specimen sample for rock testing. 4b. Adopt suitable procedure to find various strength tests in lab.	4.1 Sampling, Sample preparation, & Specimen. 4.2 Compressive Strength Tests- Uniaxial compressive strength test: Impact Strength Index, Protodykanov's strength index

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
	4c. Perform In-situ strength tests in field conditions. 4d. Measure various types of rock deformations.	4.3 Tensile Strength Tests- Brazilian tests; Bending tests; & Flexural strength test both Three -point & Four-point load test. 4.4 Shear Strength Tests- Shear box test, Block shear test, & Punch shear test. 4.5 Rock durability test 4.6 In Situ tests- 4.5.1 Roof Load Measurement by Flat jack & load cells; 4.5.2 Rock Deformation Measurement- Roof Sag Measurement by using Extensometer; Strain measurement by Strain gauges; Stress measurement by Flat jack
Unit-V **Rock Mass Classification, Support requirement & Subsidence**	5a. Identify the strength characteristics of Intact rock. 5b. Select suitable supports system for particular condition. 5c. Describe elements of subsidence. 5d. Adopt suitable measure against subsidence.	5.1 Rock Mass Classification – its objectives, engineering classification of intact rock mass given by Deer & Miller; geomechanics classification of jointed rock mass & requirement of supports depending on rock mass rating (RMR). 5.2 Subsidence- Elements of subsidence: Subsidence factor, Angle of draw, line of break; Critical area, Sub-critical area, Super critical area, factors governing subsidence & protective measures against Subsidence.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction & Rock Exploration	6	5	3	2	10
II	Rock Properties	6	7	0	3	10
III	Rock Pressure & its Failure	8	7	3	3	13
IV	Rock Testing	12	6	8	6	20
V	Rock Mass Classification, Support requirement, & Subsidence	10	6	7	4	17
	Total	**42**	**31**	**21**	**18**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Collect various rock samples for making specimen for testing.
b) Undertake micro-project.
c) Conduct a group discussion on various issues of rock strength affecting parameters.
d) Visit nearby mine an make a report on rock testing, techniques adopted by them.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4*** means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environ and sustainability
g) Expert lecture by practicing valuer on Valuation techniques, methods and criteria of any property.
h) Expert lecture on latest software for Estimating and costing

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Prepare a chart showing classification of rock mass.
b) Presentation on any case study related with support design.

c) Prepare a poster showing various structure defects in rock mass.
d) Prepare a schematic diagram showing elementary features of subsidence due to mine openings.
e) Collect core sample of various types of rock.
f) Prepare a chart on Mohr's scale of hardness for various rocks.
g) Prepare a chart showing durability index of various rocks.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Rock Mechanics for Engineers	Dr. B. P. Verma	Khanna Publishers, Delhi ISBN: 9789387394155
2	Modern Coal Mining Technology	S. K. Das	Lovely Prakashan, Dhanbad

14. LEARNING WEBSITES

a) Rock Mechanics: NPTEL Course by IIT Kharagpur:
https://archive.nptel.ac.in/courses/105/105/105105212/
b) Sample Preparation:
Part 1: https://www.youtube.com/watch?v=lqF3PhFcbbI
Part 2: https://www.youtube.com/watch?v=mPs_6v5H5Cg
Part 3: https://www.youtube.com/watch?v=dc7Cx1ublU4
Part 4: https://www.youtube.com/watch?v=IUQfluSVguA
Part 5: https://www.youtube.com/watch?v=CrKUEUfS9mA
c) Slake Durability Index of Rock:
https://www.youtube.com/watch?v=zMIZ1-3avu0
d) Uniaxial Compressive Strength:
Part 1: https://www.youtube.com/watch?v=kIm97vmVjiw
Part 2: https://www.youtube.com/watch?v=kUcpRSCV4zY
e) Protodykonov Strength Index:
https://www.youtube.com/watch?v=Jgpp1vemff0
f) Tensile strength Test (By Brazilian test):
Part 1: https://www.youtube.com/watch?v=pEGBGZ0rYMM
Part 2: https://www.youtube.com/watch?v=pvpoczG0CF0
Part 3: https://www.youtube.com/watch?v=wM1GXoPEdxE
g) Shear strength Test (By Shear box):
https://www.youtube.com/watch?v=LrSkl_GRA3g
h) Point load strength index:
Part 1: https://www.youtube.com/watch?v=3rFi4DkSypk
Part 2: https://www.youtube.com/shorts/hFvwQr1iXYs

15. PO-COMPETENCY-CO MAPPING

Semester V	Rock Mechanics (Course Code: 4352203)								
	POs and PSOs								
Competency & Course Outcomes	**PO 1** Basic & Discipline specific knowledge	**PO 2** Problem Analysis	**PO 3** Design/ development of solutions	**PO 4** Engineering Tools, Experimentation &Testing	**PO 5** Engineering practices for society, sustainability & environment	**PO 6** Project Management	**PO 7** Life-long learning	**PSO 1**	**PSO 2**
Competency	• Identify the risk of rock failure conditions due to overcoming stresses. • Adopt suitable mitigation measures to make underground working safe.								
Course outcome CO1: Identify the strength quality of rock.	2	-	-	2	-	-	2	-	-
CO2: Define physical and mechanical properties of rock.	3	-	-	-	-	-	2	-	-
CO3: Justify the rock failure conditions surrounded by various stresses.	3	-	-	-	1	-	1	-	-
CO4: Select suitable rock strength testing procedure.	2	-	-	2	-	-	2	-	-
CO5: Classify various types of rock for its strength quality.	3	-	-	-	-	-	2	-	-

Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1	Shri S. G. Srivastav Head of Department (Mining Engineering)	Govt. Polytechnic-Bhuj	99981 31511	shivkumarsrivastav11@gmail.com
2	Shri P. Y. Trivedi Lecturer (Mining Engineering)	Govt. Polytechnic-Bhuj	99042 19747	pranavytrivedi@gmail.com
3	Shri C. V. Thakor Lecturer (Mining Engineering)	Govt. Polytechnic-Bhuj	70690 52545	chiragthakor4u@gmali.com