GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Semester-II

Course Title: Engineering Mechanics

(Course Code: 4300008)

Diploma programme in which this course is offered	Semester in which offered
Automobile Engineering, Civil Engineering, Environment Engineering, Fabrication Technology, Mechanical Engineering, Mechatronics Engineering, Metallurgy Engineering, Mining Engineering.	Second Semester

1. RATIONALE

The primary purpose of the study of Engineering Mechanics is to develop the capacity to predict the effects of force while carrying out the creative design functions of engineering. This course is an introduction to learning and applying the principles required to solve engineering mechanics problems. The course addresses the modeling and analysis of static equilibrium problems with an emphasis on real world engineering applications and problem solving. It bridges the gap between physical theory and its application to technology.

2. COMPETENCY

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

- **Use the principle of Engineering Mechanics to solve broad-based engineering related problems.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Identify the force systems for given conditions by applying the basics of mechanics.
b) Determine unknown force(s) of different engineering systems.
c) Find the centroid and centre of gravity of various components in engineering Systems.
d) Apply the principles of friction in various conditions for useful purposes.
e) Select the eco-friendly relevant simple lifting machine(s) for given purposes.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	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	Verify and calculate resultant force through Law of Parallelogram using analytical and graphical methods.	II	02*
2	Verify Law of Triangle using analytical and graphical methods.	II	02*
3	Verify and calculate resultant force through Polygon Law of Forces using analytical and graphical methods.	II	04*
4	Verify and calculate the value of unknown force through Lami's Theorem.	II	02*
5	Verify and calculate support reactions of a simply supported beam using analytical and graphical methods.	III	02*
6	Calculate centroid of a lamina having regular and irregular shapes.	IV	04*
7	Calculate angle of repose for different surfaces – Wood , Glass, Steel, plastic, wrought iron etc.	V	02*
8	Calculate coefficient of sliding Friction for different surfaces – Wood , Glass, Steel, plastic, wrought iron etc.	V	02*
9	Verify and calculate theoretical and practical velocity ratios of any four simple lifting machines. (Simple wheel and axle, Differential axle and wheel, simple screw jack, worm and worm wheel. Single purchase crab, Double purchase crab.)	VI	04*
10	Derive and draw a graph of law of machine for any two simple lifting machines and verify the effort required to lift a particular load. (Simple wheel and axle, Differential axle and wheel, simple screw jack, worm and worm wheel. Single purchase crab, Double purchase crab.)	VI	04*
	Total hours		**28 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Identify components	10
2	Prepare experimental setup.	20
3	Operate the equipment setup.	20
4	Follow safe practices .	10
5	Record observations correctly.	20
6	Interpret the result and conclude.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Apparatus for Law of Parallelogram.	1,2 & 4
2	Universal Force table with all accessories.	3
3	Beam reaction apparatus with two circular dial types supports having 10 kg capacity each.	5
4	Stand, Regular Lamina, Irregular Lamina, Inextensible string, weight	6
5	Friction apparatus with scale on it, with wood, glass, steel, plastic surfaces, dish, string, weights	7,8
6	Simple wheel and axle, Differential axle and wheel Single and double purchase crab, simple screw jack, worm and worm wheel. Vernier caliper, weights, dish, string	9,10

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Basics of Mechanics	1a. Define scope of Engineering Mechanics. 1b. Use the relevant units of various quantities in the given situation. 1c. Explain effect of force on given object. 1d. Identify the force system in given situation.	1.1 Significance and relevance of Mechanics, Applied mechanics, Statics, Dynamics. Space, time, mass, particle, flexible body and rigid body. 1.2 Scalar and vector quantity, Units of measurement (SI units) - Fundamental units and derived units. 1.3 Force – unit, representation as a vector and by Bow's notation, characteristics and effects of a Force. 1.4 Principle of transmissibility of force, Principle of Superposition 1.5 Force system and its classification.
Unit – II Coplanar Concurrent Forces	2a. Resolve the given single force. 2b. Draw the free body diagram for the given condition. 2c. Use laws and principles of coplanar concurrent forces. 2d. Calculate the resultant of given force system analytically. 2e. Determine graphically the resultant of given force system. 2f. Determine unknown force in given situation using Lami's theorem.	2.1. Resolution of a force - Orthogonal components of a force 2.2. Equilibrium and Equilibrant, Free body and Free body diagram, conditions of equilibrium, 2.3. Resultant of forces using analytical and graphical methods for the forces acting at a point: 1. Law of Parallelogram 2. Law of triangle 3. Law of Polygon 2.4. Lami's Theorem – statement and explanation, Application for various engineering problems.
Unit– III Moment of Force and Parallel Forces	3a. Differentiate Coplanar non - concurrent and parallel forces. 3b. Compute resultant & Equilibrium forces for given coplanar non-concurrent force system. 3c. Identify the types of beam for given situation. 3d. Determine reactions for given types of beam analytically and graphically.	3.1 Moment of a force, Varignon's Theorem, Couple, application, properties of couple, conditions of equilibrium. 3.2 Resultant of force, Equilibrium forces and its position using analytical methods for the coplanar non - concurrent force system. 3.3 Types of beam, supports (simple, hinged, roller and fixed) and loads acting on beam (vertical and inclined point load, uniformly distributed load, couple).

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
		3.4 Beam reaction for cantilever, simply supported beam with or without overhang – subjected to combination of Point load and uniformly distributed load. 3.5 Beam reaction graphically for simply supported beam subjected to vertical point loads only.
Unit– IV Centroid & Centre of Gravity	4a. Differentiate between Centroid and Centre of Gravity. 4b. Calculate Centroid of different geometrical plane and composite figures using first moment of area. 4c. Calculate Centre of Gravity of Simple and Composite Solids using first moment of mass.	4.1 Concept of Centroid, Centre of Gravity. 4.2 Axis of reference and Axis of Symmetry. 4.3 Centroid of One Dimensional geometrical figures using principle of moment. 4.4 Centroid of Two Dimensional geometrical Plane figures (Square, Rectangle, Triangle, Circle, Semi-circle, Quarter-circle) & Composite figures (not more than three figures) using first moment of area. 4.5 Centre of Gravity of Simple solids (Cube, Cuboid, Cone, Cylinder, Sphere, Hemisphere) & Composite solids (not more than two solids) using first moment of mass..
Unit– V Friction	5a. Identify Friction and its engineering application. 5b. Calculate coefficient of friction for different surfaces. 5c. Calculate frictional forces in engineering problems. 5d. Analyse various problems on block friction.	5.1 Friction, Types of Friction and laws of friction, limiting equilibrium, limiting friction. 5.2 Coefficient of friction, angle of friction, angle of repose, relation between coefficient of friction and angle of friction. 5.3 Equilibrium of bodies on level surface subjected to force parallel and inclined to plane. 5.4 Equilibrium of bodies on inclined plane subjected to force parallel to the plane only.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– VI Simple Lifting Machines	6a. Describe the components of the given lifting machine. 6b. Determine mechanical advantage, velocity ratio, efficiency and law of the given simple lifting machines. 6c. Compare reversible & irreversible machines. 6d. Select the relevant eco-friendly lifting machine required for the given purpose with justification.	6.1 Simple lifting machine, load, effort, mechanical advantage, applications and advantages. Velocity ratio, efficiency of machines. 6.2 Application of law of machine. Ideal machine, friction in machine, maximum Mechanical advantage and efficiency. 6.3 Reversible and non-reversible machines, conditions for reversibility. 6.4 Velocity ratios of Simple wheel and axle, Differential axle and Wheel and, Worm and worm wheel, Single purchase and double purchase crab winch, Simple screw jack. Relevant problems on simple lifting machines.

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	**Basics of Mechanics**	**04**	**4**	**2**	**0**	**06**
II	**Coplanar concurrent Forces**	**08**	**2**	**4**	**8**	**14**
III	**Moment of Force and Parallel forces**	**08**	**2**	**4**	**8**	**14**
IV	**Centroid and Centre of gravity**	**06**	**2**	**2**	**6**	**10**
V	**Friction**	**06**	**2**	**2**	**8**	**12**
VI	**Simple Lifting Machines**	**10**	**2**	**4**	**8**	**14**
Total		**42**	**14**	**18**	**38**	**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 to 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 slightly vary 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 five different situations with photographs indicating concurrent, parallel, general force system in equilibrium.
b) Collect five different situations with photographs where law of moment plays an important role.
c) Prepare charts showing various types of supports.(hinged, roller and fixed)
d) Prepare models in the form of geometrical figures and solids and locate centroid and centre of gravity of them.
e) Prepare a chart for friction examples which you are facing in day to day life and also interpret whether it is useful and harmful.
f) Prepare a list with photographs of simple lifting machines used in your daily life in your branch.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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 are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, 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 duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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 spreadsheet or computer program to calculate the resultant force by the law of parallelogram and the law of polygon.
b) Using Drafting software calculate graphically the resultant force by the law of parallelogram and the law of polygon for at least five different conditions.
c) Prepare a spreadsheet or computer program to find out reactions for at least five different loading conditions on a simply supported beam.
d) Prepare spreadsheet or computer program to calculate centroid and centre of gravity for different geometrical sections.
e) Compare coefficient of sliding Friction for different surfaces (Wood , Glass, Steel, plastic, wrought iron etc.) with & without lubricant
f) Compare a suitable simple lifting machine used in your daily life in your branch.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Engineering Mechanics	R. S. Khurmi	S. Chand , New Delhi. (2019) ISBN: 978-93-5283-396-2
2	Engineering Mechanics	D. S. Kumar	S. K. Kataria & Sons, New Delhi (2021 reprint) ISBN: 978-93-5014-311-7
3	Engineering Mechanics 7th edition	Bear & Johnston	New media-McGraw Hill (India), Noida (1999) ISBN: 978-00-7239-513-6
4	Applied Mechanics	Dr. H. J. Shah & S.B. Junnarkar	CHAROTAR Publication, Anand (2013) ISBN: 978-93-803-5861-1
5	Engineering Mechanics	D.S. Bedi	Khanna Publications, New Delhi (2019) ISBN: 978-93-861-7326-3

14. SOFTWARE/LEARNING WEBSITES

a) https://youtube.com/playlist?list=PLD85An3RPybx5psW5HwPtUGH7AXtBjhLm (Bisag Video Lectures by DTE, Gujarat)
b) https://youtube.com/playlist?list=PLyqSpQzTE6M_MEUdn1izTMB2yZgP1NLfs (NPTEL Video Lectures by IIT, Kanpur)
c) https://nptel.ac.in/courses/122/104/122104015/ (NPTEL Video Lectures by IIT, Madras)
d) www.vlab.co.in (Virtual Lab by Ministry of Education, Government of India)

15. PO-COMPETENCY-CO MAPPING

Semester II	Engineering Mechanics (Course Code: 4300008)						
	POs						
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
Competency	Use the principles of Engineering Mechanics to solve broad-based engineering related problems.						
Course Outcomes COa) Identify the force systems for given conditions by applying the basics of mechanics.	3	2	-	3	2	2	2
COb) Determine unknown force(s) of different engineering systems.	2	3	-	3	2	2	2
COc) Find the centroid and centre of gravity of various components in engineering systems.	2	3	-	3	2	2	2
COd) Apply the principles of friction in various conditions for useful purposes.	2	3	-	3	2	2	2
COe) Select the eco-friendly relevant simple lifting machine(s) for given purposes.	2	3	-	3	3	2	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Shri P.V. Rayjada, HOD	G.P.Rajkot	9824281646	satwikpr@gmail.com
2.	Dr. J.B.Oza, Sr. Lecturer	G.P.Rajkot	9429048253	jiteshboza@gmail.com
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4.	Ms. Bhruguli H. Gandhi, Lecturer	G.P. Himatnagar	9099076555	bhruguli@gmail.com
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GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Mechanics of Structures
(Course Code: 4330602)

Diploma programme in which this course is offered	Semester in which offered
Civil Engineering, Environment Engineering	Third Semester

1. RATIONALE

After learning Mechanics of rigid bodies in the second semester as a course Engineering Mechanics, Mechanics of Structures mainly deals with analysis of deformable structures. The primary purpose of the study of this course is to understand the behavior of various structural elements like beams, columns and truss members (struts/ties) under direct and transverse loads. Study of slope and deflection of beams will give insight to students about 'Stiffness', a very important property of the structure. This course enables the student to analyse the determinate structure and this will be helpful for safe and economical design of Steel & Concrete Structures used in Civil Engineering construction. Hence, this course is also a prerequisite of design of structure.

2. COMPETENCY

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

- **Use the principle of Mechanics of Structures to solve broad-based engineering related problems.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Analyse structural behaviour of various materials under axial loading.
b) Determine moment of inertia of a symmetrical and asymmetrical section about a given axis.
c) Draw and Interpret shear force and bending moment diagrams and determine the bending and shear stresses in beams for various types and loading conditions.
d) Determine slope and deflection in cantilever and simply supported beams.
e) Determine axial forces in the members of simple truss.
f) Analyse the column for axial load with various end conditions.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	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	Conduct tension test on a given sample of mild steel and draw stress-strain curve.	I	04*
2	Determine Young's Modulus of wire of given material.	I	02*
3	Find out Compressive Strength of Cast Iron, Mild Steel, Wooden specimen with parallel & perpendicular to grains & Concrete cube.	I	04*
4	Determine Izod impact value and Charpy impact value of given materials.	I	04*
5	Compute Polar Moment of Inertia of Fly Wheel.	II	02*
6	Conduct flexural test on wooden beam and find out ultimate bending stress.	III,IV	02*
7	Conduct shear test (Single and Double shear) on mild steel and cast iron specimen.	III,IV	02*
8	Find out deflection of cantilever beam for end point load and simply supported beam for central point load	V	02*
9	Analyse at least two simple trusses using analytical method (method of joints) and verify with graphical method.	VI	04*
10	Demonstrate End Conditions of Column.	VII	02*
	Total hours		**28 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Identify components	10
2	Prepare experimental setup.	20
3	Operate the equipment setup.	20

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
4	Follow safe practices .	10
5	Record observations correctly.	20
6	Interpret the result and conclude.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Universal Testing Machine with beam and shear attachment.	1,6 &7
2	Searl's apparatus to find Young's modulus of wire	2
3	Compression Testing Machine.	3
5	Izod & Charpy Impact Test Apparatus	4
4	Fly Wheel for polar moment of inertia	5
7	Deflection of beam apparatus	8
8	Working Model of End conditions of column	10

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Direct Stress & Strain	1a. Evaluate Material properties Under Longitudinal and Lateral Loads. 1b. Calculate stress and strain under thermal variation. 1c. Interpret stress strain curve for various material. 1d. Analyse composite & compound section for stress and strain. 1e. Compute Strain Energy under different types of loading on elements.	1.1 Direct stress, Linear strain, Elasticity, Elastic limit, Hook's law, Modulus of Elasticity or Young's modulus, Stress Strain curve for mild steel bar under tension with numerical problems. 1.2 Lateral stress and strain, Poisson's ratio, Volumetric strain, Bulk modulus, relation between three moduli and numericals. 1.3 Basics Concepts of Shear Stress , Shear Strain & Modulus of rigidity. 1.4 Concept of composite and compound section, modular ratio and numericals. 1.5 Concept of Thermal stress and strain, Thermal stresses for non-yielding and yielding condition with numericals. 1.6 Stresses due to gradual, sudden and impact load, corresponding deformation, Strain energy, Resilience, Proof resilience and Modulus of resilience with numericals.
Unit – II Moment of Inertia	2a. Locate the axis of symmetry & Centroidal axis in symmetrical & asymmetrical solid and hollow sections 2b. Apply Parallel axis theorem to determine moment of inertia, for symmetrical & asymmetrical sections about centroidal axis and any other reference axis. 2c. Apply Perpendicular axis theorem to determine Polar Moment of Inertia of a section.	2.1. Importance of Moment of Inertia. 2.2. Axis of symmetry, Centroidal axis and axis of reference. 2.3. Parallel Axis Theorem & Perpendicular Axis Theorem 2.4. Formulas to calculate Moment of Inertia of solid and hollow rectangle, square, circle, triangle shapes (without derivations). 2.5. Moment of Inertia of symmetrical and asymmetrical I-section, Channel section, T-section, Angle section, Hollow sections and Built up sections about Centroidal axis and any other reference axis using Parallel axis theorem. 2.6. Polar Moment of Inertia of solid & hollow circular sections.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– III **S.F. & B. M. in Beam**	3a. Identify statically determinate and statically indeterminate beams. 3b. Analyse statically determinate beam for Bending Moment and Shear Force. 3c. Draw Shear Force and Bending Moment diagram for statically determinate beams. 3d. Interpret Shear Force and Bending Moment diagram of statically determinate beams.	3.1 Statically Determinate and statically indeterminate beam examples. 3.2 Concept of Bending Moment and Shear Force in beam. 3.3 Sagging and Hogging Bending Moment. Positive and Negative Shear Force. 3.4 Calculation of Bending Moment and Shear Force at various sections of beam for cantilever simply supported and overhang beam subjected to point load and/ or u.d.l. 3.5 S.F. & B.M. Diagram for above beams 3.6 Point of Contra-flexure & its importance.
Unit– IV Bending & Shear Stress in Beam	4a. Determine Bending stress at a particular section of beam using the bending equation. 4b. Draw a Bending stress distribution diagram for a particular beam section. 4c. Determine Shear stress at a particular section of beam using the shear equation. 4d. Draw a Shear stress distribution diagram for a particular beam section. 4e. Identify factors affecting Bending and Shear stress.	4.1 Concept and theory of pure bending, assumptions, Bending equation (without derivation), Section Modulus, Bending stresses and their nature, Bending stress distribution diagram. 4.2 Concept of moment of resistance and simple numerical problems using bending equation. 4.3 Shear stress equation (without derivation), relation between maximum and average Shear stress for rectangular and circular section. 4.4 Shear stress distribution for square, rectangular, circle, hollow square, rectangular, circular, angle sections, channel section, I-section, T section. Simple numerical problems based on Shear equation.
Unit– V Slope and Deflection	5a. Differentiate between strength and stiffness of structural member. 5b. Calculate maximum slope and deflection in cantilever and simply supported beams under symmetrical loads. 5c. Identify factors affecting slope and deflection.	5.1 Concept of Slope & Deflection of beams. 5.2 Flexural rigidity and its significance. 5.3 Formulas (without derivation) of maximum slope & deflection for cantilever beams subjected to point load at free end and u.d.l. Over the entire span. 5.4 Formulas (without derivation) of maximum slope & deflection for simply supported beams subjected to point load at center and u.d.l. over the entire span.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– VI Analysis of Truss	6a. Suggest the type of truss for given situation with proper justification. 6b. Differentiate perfect, deficient and redundant truss 6c. Analyse the simple truss using the method of joints. 6d. Analyse the simple truss using a graphical method.	6.1 Type of truss - Simple, fink, compound fink, Howe truss, Pratt truss, North light truss, king post truss, queen post truss, French truss. Compare the simple truss with the beam. 6.2 Perfect, deficient and redundant truss. 6.3 Analysis of different trusses to find out axial forces in members using analytical method (method of joint) and graphical method.
Unit– VII Column & Strut	7a Interpret various column end conditions 7b Analyse column for load carrying capacity with Euler's theory 7c Analyse column for load carrying capcity with Rankine's theory	7.1 Column and Strut, radius of gyration, slenderness ratio, Short Column and Long Column. 7.2 End conditions & effective length of column. Mode of failure in column. 7.3 The limitations of Euler's theory for short column, Euler's formula for crippling load of long columns and numericals. 7.4 Rankin's formula for buckling load of short & long columns and numericals.

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	**Direct Stress & Strain**	**10**	**2**	**4**	**8**	**14**
II	**Moment of Inertia**	**04**	**2**	**2**	**4**	**08**
III	**S.F. & B. M. in Beam**	**08**	**2**	**4**	**8**	**14**
IV	**Bending & Shear Stress in Beam**	**06**	**2**	**2**	**6**	**10**
V	**Slope and Deflection**	**04**	**2**	**2**	**4**	**08**
VI	**Analysis of Truss**	**06**	**2**	**2**	**6**	**10**
VII	**Column & Strut**	**04**	**2**	**2**	**2**	**06**
Total		**42**	**14**	**18**	**38**	**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 to 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 slightly vary 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 different situations with photographs of a structural members where axial force is predominant.
b) Collect the photographs of steel structural elements made of I-section, angle section, channel section and built-up section.
c) Collect different situations with photographs of a structural members where bending moment and shear force are predominant
d) Collect the photographs of five different types of truss in the field.
e) Collect the information with photographs of structural failure due to excessive axial load.
f) Collect the information with photographs of structural failure due to excessive bending moment
g) Collect the information with photographs of structural members having excessive deflection (beyond permissible limit)
h) Collect the information with photographs of failure of columns due to earthquake.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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 are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, 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 duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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 spreadsheet or computer program to calculate the stresses in the composite section.
b) Compare tensile strength and cost of three locally available structural steel bars.
c) Compare modulus of elasticity of wires of three different materials using Searle's apparatus.
d) Prepare spreadsheet or computer program to calculate the support reactions of statically determinate beams.
e) Prepare spreadsheet or computer program to calculate the bending stress and shear stress in a beam having a rectangular or circular section.
f) Analyse statically determinate beam using freeware software.
g) Prepare spreadsheet or computer program to calculate slope and deflection of simply supported beam and cantilever beam for various load cases.
h) Calculate modulus of elasticity of a material by measuring deflection of beam.
i) Using drafting software, analyse the truss graphically.
j) Analyse the truss using freeware software.
k) Prepare spreadsheet or computer program to calculate safe load on column using Euler's and Rankine's formula.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Mechanics of Structures (Vol.-I)	Dr. H.J. Shah & S.B. Junnarkar	Charotar Publication, Anand. (2016) ISBN: 97-893-850-392-70
2	Strength of Materials (Mechanics of Solids)	R.S.Khurmi N. Khurmi	S Chand Publishing, Delhi (2019) ISBN: 97-893-528-339-79
3	Strength of Materials	Dr. R.K.Bansal	Laxmi Publications(P) Ltd. New Delhi(2005) ISBN: 97-881-700-814-70
4	Strength of Materials	S. Ramamrutham & R.Narayanan	Dhanpat Rai Publishing Company (2011) ISBN:97-881-874-335-45
5	Theory of Structures	R.S.Khurmi	S Chand Publishing, Delhi (2000) ISBN: 97-881-219-052-06

14. SOFTWARE/LEARNING WEBSITES

a) https://nptel.ac.in/courses/105104160 (NPTEL Course :- Mechanics of Solids by IIT, Kanpur)

b) https://www.youtube.com/watch?v=GkFgysZC4Vc&list=PL27C4A6AEA552F9E6 (NPTEL Video Lectures by IIT, Kharagpur)

c) www.vlab.co.in (Virtual Lab by Ministry of Education, Government of India)

15. PO-COMPETENCY-CO MAPPING

Semester III	**Mechanics of Structures (Course Code: 4330602)**						
	POs						
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**
Competency	Use the principle of Mechanics of Structures to solve broad-based engineering related problems.						
Course Outcomes COa) Analyse structural behaviour of various materials under axial loading.	2	3	-	3	2	2	2
COb) Determine moment of inertia of a symmetrical and asymmetrical section about a given axis.	2	3	-	2	2	2	2
COc) Draw and Interpret shear force and bending moment diagrams and determine the bending and shear stresses in beams for various types and loading conditions.	2	3	-	-	2	2	2

COd) Determine slope and deflection in cantilever and simply supported beams.	2	3	-	3	2	2	2
COe) Determine axial forces in the members of simple truss.	2	3	-	-	2	2	2
COf) Analyse the column for axial load with various end conditions.	2	3	-	2	2	2	2

*Legend: '**3'** for high, '**2**' for medium, **'1'** for low and **'-'** for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Shri P.V. Rayjada, HOD Applied Mechanics	G.P.Rajkot	9824281646	satwikpr@gmail.com
2.	Dr. J.B.Oza, Sr. Lecturer Applied Mechanics	G.P.Rajkot	9429048253	jiteshboza@gmail.com
3.	Ms. Bhruguli H. Gandhi, Sr. Lecturer Applied Mechanics	G.P. Himatnagar	9099076555	bhruguli@gmail.com
4.	Shri S.M.Kondhiya, Sr. Lecturer Applied Mechanics	G.P. Rajkot	9825764005	sharadkondhiya@gmail.com
5.	Shri R.R. Makwana, Lecturer Applied Mechanics	L.E. College, Morbi (Polytechnic)	9824128087	rakesh_mak@rediffmail.com

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Strength of Materials
(Course Code: 4331904)

Diploma programme in which this course is offered	Semester in which offered
Mechanical Engineering, Mechatronics Engineering, Marine Engineering	Third Semester

1. RATIONALE

After learning Mechanics of rigid bodies in second semester as course Engineering Mechanics, students will now learn the fundamentals of Mechanics of deformable bodies in this course as Strength of Materials. This course deals with this behavior of solid materials by studying the distribution of internal forces, the stability and deformation of the materials under the applied loads or forces. To choose proper material by keeping its strength and suitability in mind is very important stage in production and design level in the field of Mechanical Engineering. Hence the course is prerequisite for understanding principles of machine design at various levels.

2. COMPETENCY

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

- **Use the principle of Mechanics of deformable bodies to solve broad-based engineering related problems.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Analyse structural behaviour of various materials under axial loading.
b) Determine moment of inertia of a symmetrical and asymmetrical section about a given axis.
c) Draw and Interpret shear force and bending moment diagrams and determine the bending and shear stresses in beams for various types and loading conditions.
d) Determine slope and deflection in cantilever and simply supported beams.
e) Determine stresses in the shaft and springs under twisting moments.
f) Select suitable material(s) for given purposes in engineering**.**

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	

3	0	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 subcomponents 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	Conduct tension test on a given sample of mild steel and draw stress-strain curve.	I	04*
2	Determine Young's Modulus of wire of given material.	I	02*
3	Find out Compressive Strength of Cast Iron, Mild Steel, Wooden specimen with parallel & perpendicular to grains.	I	04*
4	Compute Polar Moment of Inertia of Fly Wheel.	II	02*
5	Conduct flexural test on wooden beam and find out ultimate bending stress.	III,IV	02*
6	Conduct shear test (Single and Double shear) on mild steel and cast iron specimen.	III,IV	02*
7	Find out deflection of cantilever beam for end point load and simply supported beam for central point load	V	02*
8	Conduct Torsion test on cast iron, mild steel specimen.	VI	02*
9	Verify stiffness of springs in series and parallel	VI	02*
10	Determine Izod impact value and Charpy impact value of given materials.	VII	04*
11	Determine Brinell and Rockwell hardness of given materials.	VII	02*
	Total hours		**28 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Identify components	10
2	Prepare experimental setup.	20
3	Operate the equipment setup.	20
4	Follow safe practices .	10

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
5	Record observations correctly.	20
6	Interpret the result and conclude.	20
	Total	**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Universal Testing Machine with beam and shear attachment.	1,5&6
2	Searl's apparatus to find Young's modulus of wire	2
3	Compression Testing Machine.	3
5	Fly Wheel for polar moment of inertia	4
6	Deflection of beam apparatus	7
7	Torsion Testing Machine	8
8	Spring stiffness testing apparatus.	9
4	Izod & Charpy Impact Test Apparatus	10
7	Brinell Hardness Testing Machine	11
8	Rockwell Hardness Testing Machine	11

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Direct Stress & Strain	1a. Evaluate Material properties Under Longitudinal and Lateral Loads. 1b. Calculate stress and strain under thermal variation. 1c. Interpret stress strain curve for various material. 1d. Analyse composite & compound section for stress and strain. 1e. Compute Strain Energy under different types of loading on elements.	1.1 Direct stress, Linear strain, Elasticity, Elastic limit, Hook's law, Modulus of Elasticity or Young's modulus, Stress Strain curve for mild steel bar under tension with numerical problems. 1.2 Lateral stress and strain, Poisson's ratio, Volumetric strain, Bulk modulus, relation between three moduli and numericals. 1.3 Basics Concepts of Shear Stress , Shear Strain & Modulus of rigidity. 1.4 Concept of composite and compound section, modular ratio and numericals. 1.5 Concept of Thermal stress and strain, Thermal stresses for non-yielding and yielding condition with numericals. 1.6 Stresses due to gradual, sudden and impact load, corresponding deformation, Strain energy, Resilience, Proof resilience and Modulus of resilience with numericals.
Unit – II Moment of Inertia	2a. Locate the axis of symmetry & Centroidal axis in symmetrical & asymmetrical solid and hollow sections 2b. Apply Parallel axis theorem to determine moment of inertia, for symmetrical & asymmetrical sections about centroidal axis and any other reference axis. 2c. Apply Perpendicular axis theorem to determine Polar Moment of Inertia of a section.	2.1. Importance of Moment of Inertia. 2.2. Axis of symmetry, Centroidal axis and axis of reference. 2.3. Parallel Axis Theorem & Perpendicular Axis Theorem 2.4. Formulas to calculate Moment of Inertia of solid and hollow rectangle, square, circle, triangle shapes (without derivations). 2.5. Moment of Inertia of symmetrical and asymmetrical I-section, Channel section, T-section, Angle section, Hollow sections and Built up sections about Centroidal axis and any other reference axis using Parallel axis theorem. 2.6. Polar Moment of Inertia of solid & hollow circular sections.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– III **S.F. & B. M. in Beam**	3a. Identify statically determinate and statically indeterminate beams. 3b. Analyse statically determinate beam for Bending Moment and Shear Force. 3c. Draw Shear Force and Bending Moment diagram for statically determinate beams. 3d. Interpret Shear Force and Bending Moment diagram of statically determinate beams.	3.1 Statically Determinate and statically indeterminate beam examples. 3.2 Concept of Bending Moment and Shear Force in beam. 3.3 Sagging and Hogging Bending Moment. Positive and Negative Shear Force. 3.4 Calculation of Bending Moment and Shear Force at various sections of beam for cantilever simply supported and overhang beam subjected to point load and/ or u.d.l. 3.5 S.F. & B.M. Diagram for above beams 3.6 Point of Contra-flexure & its importance.
Unit– IV Bending & Shear Stress in Beam	4a. Determine Bending stress at a particular section of beam using the bending equation. 4b. Draw a Bending stress distribution diagram for a particular beam section. 4c. Determine Shear stress at a particular section of beam using the shear equation. 4d. Draw a Shear stress distribution diagram for a particular beam section. 4e. Identify factors affecting Bending and Shear stress.	4.1 Concept and theory of pure bending, assumptions, Bending equation (without derivation), Section Modulus, Bending stresses and their nature, Bending stress distribution diagram. 4.2 Concept of moment of resistance and simple numerical problems using bending equation. 4.3 Shear stress equation (without derivation), relation between maximum and average, Shear stress for rectangular and circular section. 4.4 Shear stress distribution for square, rectangular, circle, hollow square, rectangular, circular, angle sections, channel section, I-section, T section. Simple numerical problems based on Shear equation.
Unit– V Slope and Deflection	5a. Differentiate between strength and stiffness of structural member. 5b. Calculate maximum slope and deflection in cantilever and simply supported beams under symmetrical loads. 5c. Identify factors affecting slope and deflection.	5.1 Concept of Slope & Deflection of beams. 5.2 Flexural rigidity and its significance. 5.3 Formulas (without derivation) of maximum slope & deflection for cantilever beams subjected to point load at free end and u.d.l. over the entire span. 5.4 Formulas (without derivation) of maximum slope & deflection for simply supported beams subjected to point load at center and u.d.l. over the entire span.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– VI Torsion & Springs	6a. Calculate torque and power transmitted by a shaft in the given situation. 6b. Compute shear stress and angle of twist in a shaft for the given power to be transmitted. 6c. Determine the diameter of shaft for the given shear stress and angle of twist for maximum transmission of power. 6d. Analyse the Closed Coiled Helical spring spring for stresses.	6.1 Torque or turning moment or twisting moment, Angle of twist, Shear stress in shaft, strength of shafts, Polar moment of inertia, Torsional rigidity, assumptions in the theory of torsion. 6.2 Equation of Torsion (without derivation) and related numericals. 6.3 Relationship of H.P. , Torsion and RPM and related numericals 6.4 Springs: Stiffness of a spring(s)- Individual, in series and in parallel, Uses of springs, Types of springs. 6.5 Calculation of main dimensions of Closed Coiled Helical spring.
Unit– VII Mechanical Properties of Material	7a. Identify various materials used in Mechanical Engineering 7b. Evaluate different mechanical properties of materials used. 7c. Compare and select the material for their utility point of view.	7.1. Classification of engineering materials. 7.2. Physical properties of material:- Elasticity, Plasticity, Ductility, Brittleness, Malleability, Fatigue, Creep, Toughness, Hardness etc. 7.3. Testing of materials for impact value (Izod impact and charpy impact test) and hardness (Brinell and Rockwell hardness test) 7.4. Factors affecting selection of materials.

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	**Direct Stress & Strain**	**10**	**2**	**4**	**8**	**14**
II	**Moment of Inertia**	**04**	**2**	**2**	**4**	**08**
III	**S.F. & B. M. in Beam**	**08**	**2**	**4**	**8**	**14**
IV	**Bending & Shear Stress in Beam**	**06**	**2**	**2**	**6**	**10**
V	**Slope and Deflection**	**04**	**2**	**2**	**4**	**08**
VI	**Torsion & Springs**	**06**	**2**	**2**	**6**	**10**
VII	**Mechanical Properties of Material**	**04**	**2**	**2**	**2**	**06**
Total		**42**	**14**	**18**	**38**	**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 to 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 slightly vary 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 different situations with photographs of machine components where axial force is predominant.
b) Collect the photographs of machine component made of I-section, angle section, channel section and built-up section.
c) Collect different situations with photographs of machine components where bending moment and shear force are predominant.
d) Collect the information with photographs of machine component where check for deflection is important.
e) Collect different situations with photographs of machine components where torsion is predominant.
f) Collect different situations with photographs of machine components where impact force is predominant.
g) Collect the information of machine components where hardness and important and also collect required hardness for that.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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 are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, 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 duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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 spreadsheet or computer program to calculate the stresses in the composite section.
b) Compare tensile strength and cost of three locally available steel bars.
c) Compare modulus of elasticity of wires of three different materials using Searle's apparatus.
d) Prepare spreadsheet or computer program to calculate the support reactions of statically determinate beams.
e) Prepare spreadsheet or computer program to calculate the bending stress and shear stress in a beam having a rectangular or circular section.
f) Prepare spreadsheet or computer program to calculate slope and deflection of simply supported beam and cantilever beam for various load cases.
g) Calculate modulus of elasticity of a material by measuring deflection of beam.
h) Prepare spreadsheet or computer program to calculate dia. of shaft for given data.
i) Measure dia. of shaft in at least three power transmitting machines and justify it.
j) Compare chart for any 5 material regarding their Mechanical properties.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Strength of Materials (Mechanics of Solids)	R.S.Khurmi N. Khurmi	S Chand Publishing (2019) ISBN: 97-893-528-339-79
2	Strength of Materials	Dr. R.K.Bansal	Laxmi Publications (P) Ltd. New Delhi (2005) ISBN: 97-881-700-814-70
3	Strength of Materials	S. Ramamrutham & R.Narayanan	Dhanpat Rai Publishing Company (2011) ISBN:97-881-874-335-45
4	Strength of Materials (Mechanics of Materials)	R.S. Laheri A.S. Laheri	S.K. Karatia & Sons, Delhi. (2010) ISBN: 97-881-857-494-40

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
5	Strength of Materials	Dr. Sadhu Singh	Khanna Publishers , New Delhi.(2018) ISBN: 97-893-810-686-18

14. SOFTWARE/LEARNING WEBSITES

a) https://nptel.ac.in/courses/105104160 (NPTEL Course :- Mechanics of Solids by IIT, Kanpur)

b) https://www.youtube.com/watch?v=GkFgysZC4Vc&list=PL27C4A6AEA552F9E6 (NPTEL Video Lectures by IIT, Kharagpur)

c) www.vlab.co.in (Virtual Lab by Ministry of Education, Government of India)

15. PO-COMPETENCY-CO MAPPING

Semester III	Strength of Materials (Course Code: 4331905)						
	POs						
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
Competency	Use the principle of Mechanics of deformable bodies to solve broad-based engineering related problems.						
Course Outcomes COa) Analyse structural behaviour of various materials under axial loading.	2	3	-	3	2	2	2
COb) Determine moment of inertia of a symmetrical and asymmetrical section about a given axis.	2	3	-	2	2	2	2
COc) Draw and Interpret shear force and bending moment	2	3	-	-	2	2	2

diagrams and determine the bending and shear stresses in beams for various types and loading conditions.							
COd) Determine slope and deflection in cantilever and simply supported beams.	2	3	-	3	2	2	2
COe) Determine stresses in the shaft and springs under twisting moments.	2	3	-	3	2	2	2
COf) Select suitable material(s) for given purposes in engineering.	2	3	-	2	2	2	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Shri P.V. Rayjada, HOD Applied Mechanics	G.P.Rajkot	9824281646	satwikpr@gmail.com
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GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Soil Engineering
(Course Code: 4340602)

Diploma programme in which this course is offered	Semester in which offered
Civil Engineering	4th Semester

1. RATIONALE

After learning Mechanics of deformable bodies and Hydraulics in 3rd semester, this subject "Soil Engineering" is introduced in 4th semester, as it deals with the natural material "Soil" whose behavior is somewhat intermediate between solids and fluids. Soil Engineering involves study of Soil, its behavior and application as an engineering material. Design of foundation of building, dams, towers, embankments, roads, railways, retaining wall, bridges is mainly governed by characteristics and behavior of Soil, hence this subject is very important for civil engineering students.

2. COMPETENCY

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

- **Evaluate and interpret test results for selection of proper Soil as a construction material and as a strata for foundation.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Identify types of Soil according to mode of deposition and mode of transportation.
b) Determine the physical and index properties of soil to estimate behaviour and other important engineering properties for given construction activities.
c) Classify coarse grained and fine grained soil by IS method
d) Determine Coefficient of permeability and shear parameters of soil and apply results in foundation analysis and other construction activities.
e) Determine O.M.C. and M.D.D. values of soil and select suitable method of soil stabilization.
f) Compute bearing capacity of soil and earth pressure and interpret results.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	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 subcomponents 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	Determine moisture content of soil by oven drying method	I	02*
2	Determine field density and dry density of soil by Core cutter method	I	02*
3	Determine field density and dry density of soil by Sand replacement method	I	02*
4	Determine specific gravity of soil by pycnometer/density bottle	I	02*
5	Classification of soil by sieve analysis method	II	04*
6	Determine Liquid limit, Plastic limit and Shrinkage limit of soil	III,IV	04*
7	Determine Permeability of soil by constant head method	III,IV	02*
8	Determine Permeability of soil by falling head method	V	02*
9	Determine Shear parameters of soil by Direct Shear test	VI	04*
10	Determine OMC & MDD of soil by standard proctor test [Light compaction Test]	VII	04*
	Total hours		**28 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Identify components	10
2	Prepare experimental setup.	20
3	Operate the equipment setup.	20
4	Follow safe practices .	10
5	Record observations correctly.	20
6	Interpret the result and conclude.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Assembly of Core cutter for In-situ density determination.	02
2	Assembly of Sand replacement for In-situ density determination.	03
3	Sieve set & sieve shaker for mechanical analysis of soil.	05
4	Standard Proctor test apparatus for OMC & MDD determination of soil.	10
5	Density bottles/ Pycnometer for specific gravity determination.	04
6	Direct shear test apparatus.	09
7	Permeability test apparatus for constant water head.	07
8	Permeability test apparatus for falling water head.	08
9	Casagrande apparatus for Liquid limit determination.	06
10	Shrinkage Limit test apparatus.	06
11	Hot air oven with temperature control	01 to 10
12	Electronic weighing balance.	01 to 10

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year

ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Overview of Soil Engineering	1a. Identify the types of soil according to mode of deposition and mode of transportation 1b. Identify structures where soil is used as construction material 1c. Identify structures where soil is used as a strata/foundation to safely bear loads. 1d. Locate the major soil deposits in India.	1.1 Definition of Soil, Soil Mechanics, Soil Engineering, Importance of Soil engineering 1.2 History of Soil Engineering 1.3 Soil formation in Geological cycle 1.4 List of Structures where soil is used as construction material 1.5 Types of Soil according to mode of Transportation 1.6 Major Soil deposits of India
Unit – II Physical and Index properties of Soil	2a. Identify physical and index properties of soil and their relevance with important engineering properties. 2b. Interpret two and three phase of soil from given conditions. 2c. Derive interrelationships among different properties of soil from phase diagrams. 2d. Perform tests for determining properties of soil using relevant IS Code and interpret test results 2e. Calculate physical properties of soil from given data using interrelationships	2.1. Soil as a three phase system, assumptions for drawing two phase & three phase diagrams, 2.2. Fundamental definitions of physical properties- Water content, Bulk density, Dry density, Saturated density, Submerged density, Density of solids, Specific gravity-Absolute & Mass specific gravity, void ratio, porosity, Degree of saturation, Air content, Percentage air voids, Relative density 2.3. Derivation of following relations from phase diagrams and numericals on each : 2.3.1 e= n/n-1, n=e/1+e 2.3.2 w×G =e×sr 2.3.3 Ɣd=Ɣb/1+w 2.3.4 Ɣd=Ɣb/1+w 2.3.5 Ɣsat= (G+e)Ɣw/(1+e) 2.3.6 Ɣsub=(G-1)Ɣw/(1+e) 2.3.7 Ɣd= G Ɣw/1+e 2.4. Methods to determine moisture content of soil. 2.5. Determination of Bulk & Dry density

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
		of soil by Core Cutter method and Sand Replacement method. 2.6. Determination of Specific Gravity of soil by pycnometer.
Unit– III **Classification of Soil**	3a. Use different methods of Classification. 3b. Interpret the particle size distribution curve for given soil samples. 3c. Analyse fine grained Soil based on Consistency Limits. 3d. Classify given soil samples by IS method.	3.1 Classification of soil as per grain size by IS method. Basic criteria of classification of soils. 3.2 Difference between coarse grained and fine grained soil on the basis of their size and engineering properties. Mechanical Analysis of coarse grained soil. Sedimentation analysis of fine grained soil. 3.3 Particle size distribution curve. Nature of various grading Curves. Coefficients of uniformity and curvature. 3.4 Classification of soil on the basis of plasticity. Atterberg's limits of consistency: Liquid limit, plastic limit and shrinkage limit. Plasticity index, Liquidity Index and Consistency Index. 3.5 Determination of Liquid limit, Plastic limit and Shrinkage limit as per IS.
Unit– IV Permeability and Seepage	4a. Identify the factors affecting the permeability for a given type of soil sample. 4b. Compute coefficient of Permeability for given type of soil sample. 4c. Interpret the concept of seepage pressure.	4.1 Definition of permeability, permeable and impermeable soil, Darcy's law of permeability. 4.2 Factors affecting the permeability of soil. Coefficient of permeability, Difference between flow through pipe and flow through soil. 4.3 Laboratory Methods to determine Coefficient of Permeability- Constant Head Method and Falling Head method. 4.4 Field methods to determine Coefficient of Permeability: Pumping-out tests and Pumping-in tests. 4.5 Definition of Seepage and seepage pressure. Quick sand condition. Types of flow net. Characteristics and application of flow net.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit– V Compaction and Stabilization of Soil	5a. Apply the principle of Compaction and choose the method of compaction for different soils. 5b. Differentiate phenomenon of compaction from consolidation of soil. 5c. Determine optimum moisture content and maximum dry density of soil in the laboratory. 5d. Suggest suitable method of Soil stabilization for ground improvement in a given situation.	5.1 Concept of compaction and its effect on various soil properties like density, permeability, shear strength & bearing capacity. 5.2 Factors affecting compaction like water content, types of soil, nature of soil, method of compaction, admixtures. 5.3 Optimum moisture content (O.M.C) and maximum dry density (M.D.D.) by IS standard compaction test- Light and Heavy compaction test(Proctor Test). Standard compaction curves. 5.4 Method of field compaction. Various compaction equipment, role of O.M.C. in field. 5.5 Concept and requirements of soil stabilization. Different methods of soil stabilization–Mechanical soil stabilization and Chemical soil stabilization (Use of cement, lime, fly ash, bitumen). Use of Geo-Synthetic as a stabilizing material. 5.6 Necessity of site investigation and sub soil exploration. Types and purpose of exploration. Basic field identification test of soil.
Unit– VI Shear Strength of Soil	6a. Interpret various shear parameters of soil. 6b. Compute shear strength of soil for given condition. 6c. Identify shear failure of soil in various situations.	6.1 Cohesion, Angle of internal friction, shear strength. 6.2 Coulomb's law for shear strength. 6.3 Different methods to find shear strength of soil in the laboratory. Procedure to find shear strength using Box shear test. 6.4 Types of soil- C-soil, ø-soil and C-ø soil. Mohr's circle method to find shear envelope and shear strength parameters.
Unit– VII Bearing capacity of Soil and Earth Pressure	7a Identify the factors affecting Bearing Capacity of soil. 7b Determine bearing capacity of different soils. 7c Suggest type of foundation for the given situation of soil. 7d Calculate earth pressure by Rankine's formula.	7.1 Concept of bearing capacity. Types of Bearing capacity- Ultimate bearing capacity, Safe bearing capacity, Net bearing capacity and Allowable bearing pressure. Influence of water table on bearing capacity. 7.2 I.S. method to determine bearing capacity of soils. Different theoretical

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
		methods to determine bearing capacity of soils. Introduction to Terzaghi's analysis. Assumptions and limitations of Terzaghi's theory. Different field methods for determination of bearing capacity – Plate load Test and Standard Penetration Test. 7.3 Different types of footings. Types of shear failure of footings. Methods to improve bearing capacity of soils. 7.4 Define Earth Pressure. Active and passive earth pressure for no surcharge condition. Rankine's formula to determine coefficient of earth pressure. 7.5 Liquefaction: Definition, Causes, Effect and Remedy of Liquefaction.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Over view of soil engineering**	**02**	**02**	**02**	**00**	**04**
II	**Physical and Index properties of soil**	**08**	**02**	**04**	**06**	**12**
III	**Classification of Soil**	**06**	**02**	**02**	**06**	**10**
IV	**Permeability and Seepage**	**06**	**02**	**02**	**06**	**10**
V	**Compaction and Stabilization of Soil**	**08**	**02**	**04**	**08**	**14**
VI	**Shear Strength of Soil**	**06**	**02**	**02**	**06**	**10**
VII	**Bearing Capacity ofSoil and Earth Pressure**	**06**	**02**	**02**	**06**	**10**
Total		**42**	**14**	**20**	**36**	**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 to 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 slightly vary 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 different photographs of a nearby soil deposit by natural formation.
b) Collect the photographs of different types of footings/foundations being constructed nearby with their primary details.
c) Collect different photographs of structural members where compaction of soil is being done before construction.
d) Collect the photographs of five different types of soil wrt classification of soil.
e) Collect the information with photographs of structural failure due to issue of soil stability.
f) Collect the information with photographs of soil improvement by different methods available in field.
g) Collect the information with photographs of structural members having excessive settlement of soil nearby.
h) Collect the information with photographs of failure of soil due to liquefaction.
i) Collect the information with photographs of different geo-synthetics.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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 semester, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be field application based, internet-based, workshop-based, laboratory-based or theory 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 duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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) Determine void ratio of soil by performing necessary tests in the laboratory.
b) Compare specific gravity of fine grained soil, coarse grained soil and Aggregate.
c) Compare OMC and MDD values of two different types of soil available nearby.
d) Prepare spreadsheet or computer program to calculate the OMC and MDD of given soil sample by standard compaction method.
e) Prepare spreadsheet or computer program to determine type of soil using particle size distribution curve and mechanical sieve analysis.
f) Prepare spreadsheet or computer program to determine Liquid Limit and Plastic Limit of given soil sample.
g) Compare coefficient of permeability values of two different types of soil available nearby.
h) Classify the soil from one source by performing necessary tests in the laboratory.
i) Prepare spreadsheet or computer program to calculate shear parameters of soil by performing direct shear test in the laboratory.
j) Prepare a working model of liquefaction of soil.
k) Calculate Bearing Capacity of Soil performing necessary tests in the laboratory.
l) Prepare and Compare working models of embankment filling with and without geo-synthetics.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Soil Mechanics and Foundations	Dr. B.C.Punamia	Laxmi Publications Pvt. Ltd. NewDelhi ISBN: 81-700-808-19
2	Soil mechanics and Foundation Engineering	Dr. P.N.Modi	Standard Book House, New Delhi ISBN: 978-81-89401-30-6
3	Soil Mechanics and Foundation Engineering	S.K.Garg	Khanna Publishers, Delhi ISBN: 81-7409-104-1
4	Soil Mechanics and Foundation engineering	Dr. K.R. Arora	Standard Publishers ISBN-13: 978-8180141126
5	A Textbook of Soil Mechanics and Foundation Engineering	Murthy V.N.S.	CBS Publishers & Distributors Pvt. Ltd., New Delhi ISBN : 9788123913629

14. SOFTWARE/LEARNING WEBSITES

a) NPTEL Course :-Soil Mechanics by IIT, Guwahati
https://nptel.ac.in/courses/105103097

b) NCTEL Video series for Soil Mechanics laboratory Tests :
https://www.youtube.com/results?search_query=nctel+soil

c) Virtual Lab by Ministry of Education, Government of India www.vlab.co.in

15. PO-COMPETENCY-CO MAPPING

Semester III	Soil Engineering (Course Code: 4340602)						
	POs						
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
Competency	Evaluate and interpret test results for selection of proper soil as a construction material and as a strata for foundation.						
Course Outcomes CO a) Identify types of Soil according to mode of deposition and mode of transportation.	3	-	-	-	2	-	2
CO b) Determine the physical and index properties of soil to estimate behaviour and other important engineering properties for given construction activities.	2	3	-	3	2	2	2
CO c) Classify coarse grained and fine grained soil by IS method	2	3	-	3	2	2	2
CO d) Determine Coefficient of permeability and shear parameters of soil and apply results in foundation analysis and other construction	2	3	-	3	2	2	2

activitieS.							
COe)Determine O.M.C. and M.D.D. values of soil and select suitable method of soil stabilization.	2	3	-	3	2	2	2
COf) Compute bearing capacity of soil and earth pressure and interpret results	2	3	-	-	2	2	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Shri P.V. Rayjada, HOD Applied Mechanics	L.E. College (Diploma), Morbi	9824281646	satwikpr@gmail.com
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GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Concrete Technology
(Course Code: 4350601)

Diploma programme in which this course is offered	Semester in which offered
Civil Engineering	Fifth Semester

1. RATIONALE

After learning Construction material and technology in 3rd semester, this subject "Concrete Technology" is introduced in 5th semester. Concrete is the most widely used man-made construction material in the world and is second only to water as the most utilized substance on the planet. It is the material of choice where strength, impermeability, durability, performance, fire resistance and abrasion resistance are required. It plays an important role in nation building through infrastructure and private building construction. The knowledge of concrete and its properties in the plastic condition and in hardened condition are highly important in order to make Civil Engineering structure safe and serviceable. This course focuses on students' acquisition of knowledge, skills & practices in concrete works and also focuses on the recent advances in the field of concrete technology with emphasis on quality control of concrete.

2. COMPETENCY

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

- **Prepare concrete of required strength and other specifications with quality control measures.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Select suitable concrete materials for different site conditions and required concrete works.
b) Prepare concrete of required specifications under different conditions.
c) Check the quality of concrete.
d) Design concrete mix proportions for required specification.
e) Prepare special concrete using relevant admixture and concreting materials.
f) Apply appropriate repairs and retrofitting techniques for concrete structures.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme	Total Credits	Examination Scheme

(In Hours)			(L+T+P/2)	Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	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 subcomponents 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	Determine Fineness (with sieve) and Soundness of cement.	I	02*
2	Determine compressive strength of cement.	I	02*
3	Determine Flakiness and Elongation index of coarse aggregate	I	02*
4	Determine Impact, Crushing and Abrasion value of coarse aggregate	I	04*
5	Determine specific gravity of fine and coarse aggregate	I	02*
6	Determine grading zone of fine aggregate	I	02*
7	Determine suitable proportion of all-in-aggregate as per grading limits	I	02*
8	Measure workability of concrete by slump test and compaction factor test.	II	02*
9	Determine compressive strength of concrete specimen.	III	02*
10	Determine tensile strength of Concrete specimen (cylinder and beam specimen)	III	02*
11	Non Destructive Test on concrete - Rebound Hammer		02
12	Design concrete mix proportions as per IS: 10262, guidelines	III	04*
	Total hours		**28 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Identify components	10
2	Prepare experimental setup.	20
3	Operate the equipment setup.	20
4	Follow safe practices .	10
5	Record observations correctly	20
6	Interpret the result and conclude.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Le- Chatelier test apparatus and other relevant assembly	01
2	Assembly of compressive strength of cement determination along with a cement cube vibrating machine.	02
3	Thickness gauge with other relevant assembly	03
4	Elongation gauge with other relevant assembly	03
5	Aggregate impact testing machine	04
6	Aggregate crushing test apparatus	04
7	Los Angeles aggregate abrasion testing machine	04
8	Density bottles/ Pycnometer for specific gravity determination.	05
9	Slump cone test apparatus	08
10	Compaction factor test apparatus	08
11	Compression testing machine	2,4,9 and 10
12	Rebound hammer	11
13	Tools and Containers for mixing of concrete mixture	8 to 10 and 12
14	Concrete mixture and other required equipments for mixing	8 to 10 and 12
15	Vibrating table for concrete moulds	9,10 and 12
16	Electronic weighing balance, Different size concrete moulds, Gauging Trowel, Shovel, Sieve set, Small and big Containers etc	1 to 12

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Cement, Aggregates and Water	1a. Determine Physical Properties of Cement. 1b. Select suitable type of cement as per site condition. 1c. Determine Physical properties of Aggregate. 1d. Determine Quality of water to be used for making concrete at site.	1.1 History of cement invention. 1.2 Overview of Cement Manufacturing. 1.3 Bogue's compounds and its functions 1.4 Physical and Chemical properties of cement. 1.5 Testing of cement as per BIS. 1.6 Various Grades and types of cements for different site conditions and its properties. 1.7 Role of Aggregate, types of aggregate and it's source, Classification of aggregate, Soundness of aggregate, Alkali Aggregate Reaction, Grading of aggregate. 1.8 Testing of aggregate as per BIS. 1.9 Quality of water, impurities in mixing water and permissible limits as per BIS.
Unit – II Fresh Concrete	2a. Measure workability of fresh concrete. 2b. Prepare concrete of required workability. 2c. Select suitable method of Batching, mixing, transporting, placing and finishing of fresh concrete as per site condition with	2.1 Concrete chain - Various stages of making fresh concrete at site 2.2 workability, factors affecting workability, Effect of water cement ratio, adjustments of materials to avoid segregation and bleeding , methods of Measurement of workability as per BIS - slump test, compaction factor test, flow table test,

	available resource materials. 2d. Select suitable method of Curing of concrete as per site condition.	vee bee test . 2.3 Methods of Batching, mixing of materials for making fresh concrete - hand mixing and machine mixing, mixing time. 2.4 Methods of Transportation of fresh concrete - conventional and through pumps and pipeline. 2.5 Placing of concrete - formwork stripping time, under water concreting 2.6 Compaction, importance of compaction, methods - hand 2.7 compaction, machine compaction - various vibrators and other equipments, time of vibration, vibrating techniques and precautions. 2.8 Methods of finishing of fresh concrete, Laitance & its removal. 2.9 Curing, importance of curing, period of curing accelerated curing, Conventional methods of curing - water curing methods, Special methods of curing- steam, membrane, Infrared, Electrical.
Unit– III Hardened Concrete	3a. Evaluate Properties of Hardened Concrete 3b. Conduct destructive tests and interpret its results. 3c. Conduct non destructive tests and interpret its results. 3d. Check the quality of concrete as per acceptance criteria.	3.1 Hardened Concrete and its Properties: Compressive Strength, Tensile Strength, Bond Strength, Flexural Strength, Durability and impermeability. 3.2 Factors affecting Compressive Strength. 3.3 IS Test Procedure to find Compressive & Tensile Strength of Concrete, Acceptance Criteria, Mean Strength & Standard Deviation. 3.4 Creep and Shrinkage of Concrete & its effect, factors affecting Creep and shrinkage. 3.5 Durability of Concrete & factors affecting it. 3.6 Importance of NDT. 3.7 Methods of NDT for Concrete- Rebound Hammer Test, Ultrasonic Pulse Velocity Test.
	4a. Differentiate Nominal Mix	4.1 Nominal Mix and Design Mix.

Unit– IV Concrete Mix Design	and Design Mix. 4b. Interpret test results of materials for concrete for concrete mix design 4c. Design concrete mix for required grade of concrete (for ordinary and standard grade)	4.2 Concrete Mix Design and its importance. 4.3 Different methods of Mix Design and its suitability. 4.4 Concrete Mix Design as per IS 10262. 4.5 Example of Mix design as per IS method for ordinary and standard grade of concrete without and with admixtures.
Unit– V Chemical Admixture, Special Concrete and Modern Trends	5a. Use relevant admixture according to purpose of concrete 5b. Prepare special concrete for given purpose 5c. Apply knowledge of modern trends and research in concrete technology in the field.	5.1 Admixtures in concrete: Purpose, properties and application for different types of admixture such as accelerators, retarders, water reducing admixtures, air entraining agents and super plasticizers. 5.2 Special Concrete: Properties, Advantages and limitations of the following types of Special Concretes Self-Compacting Concrete (SCC), Pervious Concrete, Fiber reinforced concrete, Ready mix concrete, Fly ash concrete, Recycled Aggregate Concrete, High performance Concrete, 3D printed Concrete 5.3 Modern trends and research in concrete technology, relevant journals and institutes.
Unit– VI Repair Rehabilitation and Retrofitting of Concrete Structures	6a. Differentiate repair, rehabilitation and retrofitting. 6b. Apply appropriate repair and rehabilitation techniques for damaged concrete structures. 6c. Apply appropriate retrofitting methods to concrete structures.	6.1 Definition of repair, rehabilitation and retrofitting 6.2 Deterioration of concrete, types, causes and prevention. 6.3 Corrosion of reinforcement, causes and prevention. 6.4 Repair and Rehabilitation stages- Removal of damaged concrete, Pretreatment of surfaces and reinforcement, Application of repair materials, Repair Procedure. 6.5 Repair and Rehabilitation material - Cement, Steel and special material like, Shotcrete, Epoxy resins, Epoxy mortar, Gypsum cement mortar, Quick setting cement mortar etc. 6.6 Repair and Rehabilitation techniques - Grouting, Guniting, Routing and

		sealing, Stitching, Drilling and Plugging etc. 6.7 Retrofitting Methods - Adding Steel Bracing, Jacketing Method, External Plate Bonding, Base Isolation Technique, Mass Reduction Technique, Wall Thickening Technique, Fiber Reinforced Polymer (FRP), Adding Shear Wall, Epoxy Injection Method, Section Enlarging Reinforcing Method etc.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Cement, Aggregates and Water**	**06**	**2**	**4**	**4**	**10**
II	**Fresh Concrete**	**08**	**4**	**4**	**6**	**14**
III	**Hardened Concrete**	**08**	**4**	**4**	**6**	**14**
IV	**Concrete Mix Design**	**06**	**2**	**2**	**6**	**10**
V	**Chemical Admixture, Special Concrete and Modern Trends**	**08**	**2**	**4**	**6**	**12**
VI	**Repairs, Rehabilitation and Retrofitting of Concrete Structure**	**06**	**2**	**4**	**4**	**10**
Total		**42**	**16**	**22**	**32**	**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 to 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 slightly vary 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) Conduct a market survey for cement for various companies, cement grade and price.
b) Conduct a market survey for fine aggregate for various types and prices.
c) Conduct a market survey for coarse aggregate for various types and prices.
d) Conduct a market survey for various types of admixtures and price
e) Visit and collect photographs of Batching, mixing, transporting, placing and finishing of fresh concrete from two different construction sites.
f) Visit and collect information and photographs of workability tests carried out on fresh concrete on construction sites.

g) Visit and collect information regarding quality control measures for concrete taken by site engineers on any construction site.
h) Visit the nearby RMC plant.
i) Prepare presentation on at least one research paper related to latest trends of concrete technology from any journal of civil engineering.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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/subtopics.
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.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be field application based, internet-based, workshop-based, laboratory-based or theory 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 a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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) Compare at least two physical properties of cement of two different companies with different prices.
b) Compare at least two properties of fine aggregate from two different sources with different prices.
c) Compare at least two properties of coarse aggregate from two different sources with different prices.
d) Measure the effect of water cement ratio on workability of concrete by slump test.

e) Measure the effect of water cement ratio on workability of concrete by compaction factor test.
f) Measure the effect of water cement ratio on compressive strength of concrete.
g) Measure the effect of curing on the compressive strength of concrete.
h) Measure the effect of admixture on workability and strength of concrete.
i) Prepare special concrete with non conventional material.
j) Measure the quality of concrete at two different places with non-destructive tests.
k) Prepare a computer program or spread sheet for Concrete Mix Design as per IS:10262 .

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Concrete Technology Theory and Practice	M S Shetty	S Chand & Company Ltd, New Delhi ISBN-13:978-9352533800
2	Concrete Technology	Shanthakumar A R	Oxford University Press, New Delhi ISBN-13: 978-0199458523
3	Concrete Technology Theory and Practice	M L Gambhir	McGraw Hill Education (I) Pvt Ltd, New Delhi ISBN-13: 978-1259062551
4	Concrete: Microstructure, Properties, and Materials	P Kumar Mehta Paulo J M Monterio	McGraw Hill Education (I) Pvt Ltd, New Delhi ISBN-13: 978-9339204761
5	Properties of concrete	A M Nevill J J Brooks	Pearson Education ISBN-13: 978-9353436551
6	IS 10262		Bureau of Indian Standards

14. SOFTWARE/LEARNING WEBSITES

a) NPTEL Course :-Concrete Technology by IIT, Delhi https://nptel.ac.in/courses/105102012
b) Concrete Technology laboratory Tests : https://www.youtube.com/playlist?list=PLkyVnO47pDX9YJglk1o2iYzWgABo5I_xA Video series for Concrete Tec
c) Virtual Lab by Ministry of Education, Government of India www.vlab.co.in

15. PO-COMPETENCY-CO MAPPING

Semester V	Concrete Technology (Course Code: 4350601)						
	Pos						
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

Competency	Prepare concrete of required strength and other specifications with quality control measures.						
Course Outcomes COa)Select suitable concrete materials for different site conditions and required concrete works.	2	-	-	3	2	2	2
COb) Prepare concrete of required specifications under different conditions.	2	-	-	3	2	2	2
COc) Check the quality of concrete.	2	-	-	3	2	2	2
COd) Design concrete mix proportions for required specification.	2	2	3	3	2	2	2
COe)Prepare special concrete using relevant admixture and concreting materials.	2	-	-	3	2	2	2
COf) Apply appropriate repairs and retrofitting techniques for concrete structures.	2	-	-	3	2	2	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Shri P. V. Rayjada, HOD Applied Mechanics	L.E. College (Diploma), Morbi	9824281646	satwikpr@gmail.com
2.	Dr D. N. Parekh, Sr Lecturer, Applied Mechanics	Sir BPTI, Bhavnagar	9428408308	dnparekh@gmail.com
3.	Shri V. J. Thekdi, Sr Lecturer Applied Mechanics	R.C.T.I., Ahmedabad	9228415246	vthekadi@gmail.com

4.	Ms. Bhruguli H. Gandhi Sr Lecturer, Applied Mechanics	R.C.T.I., Ahmedabad	9099076555	bhruguli@gmail.com

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Advance Analysis of Structures
(Course Code: 4350609)

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

1. RATIONALE

After learning analysis of determinate structures in semester-III, this elective subject is introduced in 5th semester for those students willing to excel in the structural engineering field. This subject incorporates introduction to indeterminate structures and analysis of indeterminate structural members like fixed beam, continuous beam and portal frame. Analysis of column sections, dam and retaining wall subjected to eccentric loading and checking very important parameter of no tension condition is included. Analysis of structural members under the effect of principal stresses & strains is also incorporated to give an exposure of compound stresses to the students. To keep pace with advanced technology, exposure to computer aided structural analysis and hands-on practice on software is included in this subject. After learning this subject, diploma students will develop in-depth understanding in the field of structural engineering and will be able to apply their knowledge and analytical skills in the construction industry.

2. COMPETENCY

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

- **Analyze complex structural engineering problems manually and with the help of software and interpret results.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Identify determinate & indeterminate structures and compute degree of indeterminacy.
b) Analyse a symmetrically loaded fixed beam with moment area method and draw SF & BM diagrams.
c) Analyse a symmetrically loaded continuous beam and portal frame(without any lateral sway) with Moment Distribution Method and draw SF & BM diagrams.
d) Analyse column , dam and retaining wall subjected to eccentric axial loading to draw stress distribution diagram and check for no tension condition

e) Analyse beam, plane truss and plane frame on structural analysis software and interpret output results.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	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 subcomponents 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	Determine static and kinematic indeterminacy of Beams, Plane Truss, Plane Frame (At Least two problems each)	I	02*
2	Solve at least 4 problems each of load cases &/or combinations for fixed beams, using moment area method, draw SF & BM diagrams and locate Point of contraflexure.	II	04*
3	Analyse continuous beam, at least 3 problems each for various cases of end conditions and symmetrical loads and its combinations to draw SF & BM diagrams , using Moment Distribution Method.	III	04*
4	Analyse a portal frame at least 1 problem each for various cases of end conditions and loads (No sway condition) and its combinations to draw SF & BM diagrams, using Moment Distribution Method.	III	02*
5	Analyse at least 2 problems for the column section subjected to eccentric loading and draw stress distribution diagram.	IV	02*
6	Analyse Dam and Retaining wall for given loading and draw pressure diagram at base and check the stability.	IV	04*
7	Analyse strained structural material with analytical and graphical (Mohr's circle) methods for all cases.	V	04*
8	Analyse Beam, Plane Truss and Plane frame on structural engineering software (freeware/paid) and interpret its output results.	VI	06*
	Total hours		**28 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Understand the problem properly.	20
2	Adopted proper methodology to solve the problem.	20
3	Report writing .	20
4	Answer to questions.	20
5	Timely submission.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Computer Systems.	06
2	Freeware/Paid Structural analysis software.	06

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I **Fundamentals**	1a. Identify types of skeletal structures and continuum structures. 1b. Differentiate determinate and indeterminate structures. 1c. Differentiate stable and unstable structures. 1d. Determine static and kinematic indeterminacy of Beam, Plane Truss and Plane Frame.	1.1 Definition of skeletal structures, types of skeletal structures- Beam, Plane Truss, Plane frame, Grid, Space Truss, Space Frame. 1.2 Definition of continuum structures, types of continuum structures- Plate, Shell, Dams, Retaining Wall, Machine Parts etc. 1.3 Determinate and indeterminate structures. 1.4 Advantages and disadvantages of indeterminate structures. 1.5 Stability of structures- External stability and internal stability. 1.6 Static indeterminacy (External/Internal) of Beam, Plane Truss and Plane Frame only. 1.7 Kinematic indeterminacy of Beam, Plane Truss and Plane Frame only.
Unit – II **Fixed Beams**	2a. Differentiate between fixed beam and simply supported beam. 2b. Analyse a symmetrically loaded fixed beam with uniform flexural rigidity(EI) using the Moment area method. 2c. Draw SF and BM diagrams. 2d. Locate the point of Contra flexure.	2.1 Define a Fixed beam, Advantages of fixed beam over simply supported beam. 2.2 Concept of analysis by Moment area method 2.3 μ and μ' diagram for possible symmetric loading on a fixed beam of span L 2.4 Numericals on calculating SF & BM and drawing SF & BM diagrams for fixed beam with symmetric loading (UDL & Point load only) 2.5 Locate Point of contra flexure.
Unit– III **Moment Distribution Method**	3a. Use fundamentals of Moment Distribution Method in structural analysis problems. 3b. Analyse a symmetrically loaded multi span continuous beam with Moment Distribution Method 3c. Analyse a symmetrical portal	3.1 Define the terms : Stiffness, flexibility, carry over factor, distribution factor, procedure of moment distribution method 3.2 Numerical to analyse two or three span continuous beams having end supports as overhang , fixed and /or hinge and subjected to symmetrical loading (UDL &

	frame (No sway condition) with Moment Distribution Method 3d. Draw SF and BM diagrams, for beams/portals for given load cases and combinations (UDL, point loads only)	Point load only) and draw S.F & B.M Diagram 3.3 Numerical to analyse symmetrical Portal frame (without any lateral sway) having hinged or fixed end supports and subjected to symmetrical vertical loading (UDL & Point load only) and draw S.F & B.M Diagram
Unit– IV **Direct and Bending Stresses**	4a. Analyse Column section for combined direct and bending stresses. 4b. Determine the limit of eccentricity and locate the core of a given section. 4c. Check stability of retaining wall and dam. 4d. Draw stress distribution diagram in column, retaining wall and dam under given types of loads.	4.1 Introduction to axial and eccentric loads on column section. Formulae for combined stresses on sections subjected to eccentric loads considering uniaxial and biaxial eccentricity and stress distribution diagrams. 4.2 Condition for no tension or zero stress at extreme fiber, limit of eccentricity, core of section for rectangular and circular (solid and hollow) cross sections. 4.3 Application of concept of combined stresses to find pressure at base and stability check of rectangular and trapezoidal retaining wall and dam with conditions of stability. 4.4 Numericals based on above topics topics to find combined stresses.
Unit– V **Principal planes and Principal stresses**	5a. Analyse strained structural material for calculation of normal, tangential and resultant stress on a given inclined plane. 5b. Locate the principal plane in a strained structural material. 5c. Compute principal stresses . 5d. Use Mohr's circle method to analyse strained structural material.	5.1 Normal, Tangential & Resultant stresses due to direct orthogonal and shear stresses on a given inclined plane (Only formulae no derivation). Numericals based on this. 5.2 Definition of principal plane and stress. 5.3 Location of principal planes and calculation of principal stresses (Only formulae no derivation) Maximum tangential stress. Numericals based on this. 5.4 Mohr's circle and its application for determination of Normal, Tangential & Resultant stresses due to direct orthogonal and shear stresses on inclined plane. 5.5 Mohr's circle and its application for location of principal planes and determination of principal stresses 5.6 Mohr's circle and its application for determination of maximum tangential stress.

Unit– VI **Introduction to computer aided structural analysis**	6a. Differentiate between static & dynamic structural analysis. 6b. Select suitable structural analysis software. 6c. Prepare input data for static analysis of beam, plane truss and plane frame. 6d. Interpret output result of analysis.	6.1 Difference between static and dynamic analysis, its importance and usefulness. List of static and dynamic loads. (Without Numericals). 6.2 Brief introduction of matrix methods for structural analysis - Stiffness method and Flexibility method for analysis of skeletal structure and suitability of stiffness method for computer programming (Without Numericals). 6.3 Overview of popular structural analysis softwares (Freeware and/or paid). Study of Preprocessor and Postprocessor of software. 6.4 Preparation of input data for static analysis of beam, plane truss and plane frame - Geometry, Supports, Loads and Material properties. 6.5 Interpret output results in the form of - text / diagram /animation for Axial forces, S.F., B.M. and Deflection. 6.6 Study of Stress Contour for continuum structure (Plate/Shell)- (No Analysis)

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Fundamentals**	**05**	**02**	**02**	**04**	**08**
II	**Fixed Beams**	**08**	**04**	**04**	**06**	**14**
III	**Moment Distribution Method**	**10**	**04**	**04**	**08**	**16**
IV	**Direct and Bending Stresses**	**07**	**02**	**04**	**06**	**12**
V	**Principal planes and Principal stresses**	**07**	**02**	**02**	**06**	**12**
VI	**Introduction to computer aided structural analysis**	**05**	**02**	**02**	**04**	**08**
Total		**42**	**16**	**18**	**36**	**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 to 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 slightly vary 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 photographs of determinate & indeterminate structures from nearby locations.
b) Identify different situations with photographs of structural members where combined direct and bending stresses occur in the field.
c) Identify different situations with photographs of nearby retaining structures.
d) Identify situations where in a plane is subjected to complex stresses.
e) List out various softwares available and submit a review report.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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 semester, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be field application based, internet-based, workshop-based, laboratory-based or theory 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 a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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) Analyse and compare B.M. and S.F. values at Supports and Mid span for simply supported beam and fixed beam having same span and loading conditions for three different cases.
b) Prepare a spreadsheet computer program or to analyse fixed beams by moment area method.
c) From a real life problem, calculate loads on a continuous beam (from slab, wall etc) and analyse the beam with a Moment Distribution Method or with structural engineering software.
d) Prepare spreadsheet or computer program to determine combined direct and bending stresses for an eccentric loaded column for given data.
e) Prepare spreadsheet or computer program to determine pressure at base for dam or retaining wall and check the stability for given data.
f) Prepare spreadsheet or computer program to analyse strained structural material and compare answer by graphical method (Mohr's Circle) with AutoCAD
g) Analyse a small building with structural engineering software.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Theory of Structures(SMTS-II)	Dr. B.C.Punamia Ashokkumar Jain Arunkumar Jain	Laxmi Publications Pvt. Ltd. NewDelhi ISBN: 81-700-861-83
2	A Textbook of Strength of Materials (Mechanics of Solids)	R.S.Khurmi N. Khurmi	S Chand Publishing, Delhi (2019) ISBN: 9789352833979
3	Structural Analysis-I	S.S.Bhavikatti	Vikas Publishing House, New Delhi ISBN: 81-947-519-85
4	Matrix Analysis of Framed Structures	William Weaver,Jr. , James M. Gere	CBS Publisher and Distributor Pvt. Ltd. ISBN : 978-8123911519
5	Matrix methods of Structural Analysis	S.S. Bhavikatti	I.K. International Publishing House, Delhi, ISBN : 978-9381141359

14. SOFTWARE/LEARNING WEBSITES

a) NPTEL Course :- Matrix method of Structural Analysis by IIT, Kharagpur
https://archive.nptel.ac.in/courses/105/105/105105180/
b) Free Structural Analysis Softwares :
https://www.dlubal.com/en/education/students-and-schools/free-structural-analysis-software-for-schools
https://skyciv.com/design/free-design-software/

15. PO-COMPETENCY-CO MAPPING

Semester V	Advance Analysis of Structures (Course Code: 4340602)						
	Pos						
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
Competency	Analyse complex structural engineering problems manually and with the help of software and interpret results.						
Course Outcomes COa)Identify determinate & indeterminate structures and compute degree of indeterminacy	3	2	-	-	-	-	2
COb) Analyse a symmetrically loaded fixed beam with moment area method and draw SF & BM diagrams.	2	3	-	-	2	2	2
COc) Analyse a symmetrically loaded continuous beam and portal frame(without any lateral sway) Moment Distribution Method and draw SF & BM diagrams	2	3	-	-	2	2	2
COd) Analyse column , dam and retaining wall subjected to eccentric axial loading to draw stress distribution diagram and check for no tension condition.	2	3	-	-	2	2	2

COe)Analyse beam, plane truss and plane frame on structural analysis software and interpret output results	2	3	-	3	2	2	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
1.	Shri P .V. Rayjada, HOD Applied Mechanics	L.E. College (Diploma), Morbi	9824281646	satwikpr@gmail.com
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3.	Shri S.M.Kondhiya, Sr. Lecturer Applied Mechanics	G.P. Rajkot	9825764005	sharadkondhiya@gmail.com
4.	Shri R.R. Makwana, Sr. Lecturer Applied Mechanics	L.E. College (Diploma), Morbi	9824128087	rrm.applied@gmail.com

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)
Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
VI – Semester
Course Title: Design of Structures
(Course Code: 4360601)

Diploma programme in which this course is offered	Semester in which offered
Civil Engineering	Sixth Semester

1. RATIONALE

After learning Mechanics of rigid bodies in 2nd semester and Mechanics of deformable bodies in 3rd semester, this subject "Design of Structures" introduced in 6th semester, as it deals with the design and analysis of R.C.C. and Steel structures, is the backbone of Civil Engineering Course. The design of prime members like Slabs, Beams, Columns and Footing in R.C.C. and In Steel structures some Introductory topics like design of connections and calculations of various loads on Roof Truss are intended to incorporate in this subject of design of structures.

2. COMPETENCY

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

- **Analyze and Design important structural members of R.C.C. and primary knowledge of bolted and welded connections for Steel structures and various loads for steel structures.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a. Analyze and Design singly reinforced rectangular beam for flexure and shear.
b. Design One way and Two way slabs for simply supported conditions.
c. Design axially loaded short column and pad footing.
d. Design Bolted and Welded Connections for steel structures.
e. Determine Dead Load, Live Load and Wind Load on Roof Truss

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	4	5	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.*

Note: Subject related Indian Standard Codes (1) IS:456-2000 (2) IS:800-2007 (3) IS: 875 (Part- I,II,III) (4) SP-16 Design Aid to IS-456 (5) SP-6 Handbook for Steel Structures will be allowed during Examinations.

5. SUGGESTED ASSIGNMENTS/ EXERCISES :

The following practical outcomes (PrOs) are the subcomponents 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	Interpret IS Code provisions for Limit state R.C.C. Design from IS:456-2000 and SP-16	I	02 *
2	Analyse Singly Reinforced Beams for Moment of Resistance from given data (2-Problems).	II	04*
3	Design of singly reinforced beams for flexure and shear and apply necessary checks from given data (1-Problem).	II,III	04 *
4	Design of One way simply supported slabs and apply necessary checks from given data (1-Problem).	IV	04*
5	Draw sketches (not to scale) showing reinforcement details of singly and doubly reinforced beams and one way simply supported slab in longitudinal and cross sectional view.	II,III,IV	02*
6	Draw structural details of the designed beam , simply support a one way slab in A2 size drawing sheet with scale. (Sheet-1)	II,III,IV	04*
7	Design of Two way simply supported slabs and apply necessary checks from given data. (Corners not held down condition only)-(1-Problem)	IV	04*
8	Analyse and design axially loaded short square column and design pad footing of same column from given data.	V	06*
9	Draw sketches (not to scale) showing reinforcement details of axially loaded short rectangular, Circular columns and isolated pad and slope footing in plan and sectional view in longitudinal and cross sectional view.	IV,V	02*
10	Draw structural details of the designed two way slab, column and footing in A2 size drawing sheet with scale. (Sheet-2)	IV,V	04*
11	Interpret IS Code provisions for Limit state Steel Design from IS:800-2007 and SP-6	VI	02 *
12	Draw sketches (not to scale) showing details for standard rolled steel sections, built up sections, Beam to Beam and Beam to Column connections (Bolted and Welded).	VI,VII	02*
13	Design a bolted connection for the given data of steel section as per IS: 800-2007.	VII	04*

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
14	Design a welded connection for the given data of steel section as per IS: 800-2007.	VII	04*
15	Interpret IS provision for dead load, live load and wind load for steel roof truss from IS 875 (Part- I to III)	VIII	02*
16	Draw sketches (not to scale) for types of roof trusses, components of roof truss and important four joints like ridge joint, eave joint, bottom middle joint and intermediate joint.	VIII	02*
17	Calculate dead load, live load and wind load for the given data of steel roof truss with graphical method (sheet-3) and prepare a force table.	VIII	04*
	Total hours		**56 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Interpretation of given data and its understanding.	10
2	Selection of sketches/Process of designing of the given structural components using relevant I.S.codes and preparing of report of site visit..	30
3	Presentation of sketches in sketchbook, neatness and cleanliness of sheets and writing reports.	30
4	Individual work, work as a team-member	10
5	Completion and submission of work in time.	20
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Drawing tools and other design aids (for all PrOs)
1	Drawing boards and drawing instruments.
2	Scientific calculator and all relevant IS codes.
3	Computers and Printers.
4	Available CAD software(Not mandatory)

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize the importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I Fundamentals of R.C.C. Design	1a. Identify components and their characteristics for RCC structures. 1b. Use limit states conditions for analysis and design of RCC structures. 1c. Use IS Code provisions for General Design Consideration.	1.1 Reinforced Cement Concrete, necessity of steel in concrete, normal location of steel in beams, slabs, column & footing. 1.2 Limit State, Limit State of Collapse-Flexure, Shear, Compression, Torsion, Limit State of Serviceability-deflection and Cracking. 1.3 Characteristic Strength of concrete and steel, partial safety factor of concrete and steel and partial safety factors for loads. 1.4 Nominal Cover, Effective depth, Effective span.
Unit – II Singly Reinforced Beam	2a. Differentiate types of RC beams. 2b. Calculate moment of resistance for given type of section. 2c. Design a singly RC beam section for given condition. 2d. Apply check for deflection 2e. Draw reinforcement detailing for the designed beam section as per IS provision.	2.1. Types of beam: Singly reinforced beam, Doubly reinforced beam, T-beam, L-beam. Difference among various beams. 2.2. Stress-strain diagram for singly RC section. Under reinforced, over reinforced and balanced section. 2.3. Analysis of Singly RC beam: Determination of lever arm, total tension, total compression, percentage area of reinforcement and Moment of resistance. Numerical based on this.

		2.4. Design and detailing of Singly RC beam: Determination size of section, area and number of reinforcement bars. Combination of different diameters of reinforcement bars. Check for spacing and cover. Numerical based on this with checking design for deflection.
Unit– III **Shear and Development Length**	3a. Identify the pattern of shear failure in beams and slabs. 3b. Design shear reinforcement in beams as per given Conditions. 3c. Calculate development length as per given conditions. 3d. Check for development length in R.C.C. Design	3.1 Shear: Definition of shear, IS code specifications, single legged and two legged shear reinforcement. 3.2 Vertical stirrups, Incline stirrups, benefit of bent up of main tension reinforcement. Spacing of stirrups. Numerical based on this. 3.3 Effect of shear in slabs. IS code provision. 3.4 Development Length: Definition of development length, IS provision for determination of development length for tension and compression zone. Numerical based on this.
Unit– IV **Slabs**	4a. Suggest types of slab for given support conditions. 4b. Design one way and two way simply supported slabs as per given data. 4c. Examine suitability of designed slab by applying deflection and cracking criteria. 4d. Draw reinforcement detailing for the designed slab as per IS provision.	4.1 Slab: Types of slabs. One way simply supported slab. Two way slab and one way continuous slab. 4.2 IS provision for main reinforcement, distribution reinforcement, minimum and maximum steel area, effective span, effective depth, effective cover. 4.3 Depth of Slab from deflection criteria, Dead Load, Live Load and Floor finish load on Slab. Bending moment due to loads. 4.4 Design and detailing of one way simply supported and cantilever slabs. Check limit state of serviceability. Numerical based on this. 4.5 Design and detailing of two way simply supported slab (only corners not held down condition). Check the limit state of serviceability. Numerical based on this.
Unit– V **Axially loaded short column and pad footing.**	5a. Identify the type of column based on load condition. 5b. Analyze and Design axially loaded short columns. 5c. . Design Isolated Pad Footing for column. 5d. Draw reinforcement details of column and footing.	5.1 Column: Types of column, Long Column, Short column, Axially loaded column, uniaxially loaded column and biaxially loaded column. 5.2 Limit state of collapse: Compression, assumptions, effective length, slenderness ratio, minimum eccentricity. IS provision for reinforcement in

		column, lateral reinforcement as tie only for column, 5.3 Load analysis of axially loaded short columns. 5.4 Design of axially loaded short columns. Check for minimum eccentricity. 5.5 Footing: Types of isolated footing, pad and sloped footing. IS specification for reinforcement in pad footing only. 5.6 Design of isolated pad footing. Check for bending, one way shear and two way shear, check for development length in footing. Numerical based on this with reinforcement details.
Unit– VI Fundamental of Steel Design	6a. Identify relevant steel structure from given condition. 6b. Identify the components of the given steel structure. 6c. Choose properties of the given steel section.	6.1 Steel versus RCC as a building material. Advantages and disadvantages of steel. Types of steel sections normally in use. 6.2 Characteristic strength and design strength, Stress-strain curve for mild steel. Partial safety factors for load and materials as per IS provision. 6.3 Limit state of strength and serviceability.
Unit– VII Bolted and Welded connections	7a. Select type of connection for the given steel structure. 7b. Compute the strength of bolted and welded connection for the given condition. 7c. Design bolted and welded connection for given condition.	7.1 Types of connections in steel structures Bolted connection: Types of bolts, Black Bolts, Turned Bolts, HSFG Bolts, Grade of Bolts Lap and Butt Joint, Minimum and Maximum Pitch, Tack Bolting, Edge Distance, Gauge Distance, Bolt Hole. 7.2 Shear Capacity of Bolt – Vdsb, Bearing Capacity of Bolt – Vdpb as per IS-800-2007, Bolt Value, Efficiency of Joint. 7.3 Analysis and design of bolted connection of plate and Angle sections. Numericals based on this. 7.4 Welded connection: Types of weld, Fillet Weld and its symbol, tack welding, minimum and maximum size of weld, effective throat thickness, end returns. 7.5 Analysis and design of Fillet weld in plate and angle section as per IS-800-2007. Numericals based on this.
Unit– VIII Load Calculation for Roof Truss	8a. Identify the type of steel roof truss. 8b. Compute dead load, live load and wind load per panel point	8.1 Types of Truss for various spans, Pitch of Truss, Rise, Spacing of Truss, Members of Truss: Purlin, Principal Rafter, Main Tie, Sag Tie. Joints: eave

	as per given condition. 8c. Derive design load and check load from different load combinations.	joint, ridge joint, intermediate joint and middle bottom joint. Roofing material- GI and AC Sheets. 8.2 Types of load and load combinations for roof truss as per IS 875 codal provisions. 8.3 Dead Load of Truss per panel point: self weight ,weight of Purlin , Wind Bracing , and weight of Roofing Material . 8.4 Live Load per panel point on purlin and Truss. 8.5 Wind Load per panel point on roof truss 8.6 Numericals on dead load, live and wind load for roof truss.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Fundamentals of R.C.C. Design**	**02**	**00**	**02**	**02**	**04**
II	**Singly Reinforced Beam**	**08**	**02**	**04**	**06**	**12**
III	**Shear and Development Length**	**04**	**02**	**02**	**04**	**08**
IV	**Slabs**	**08**	**02**	**04**	**06**	**12**
V	**Axially loaded short column and pad footing.**	**06**	**02**	**04**	**04**	**10**
VI	**Fundamentals of Steel Design**	**02**	**00**	**02**	**02**	**04**
VII	**Bolted and Welded connections**	**06**	**02**	**02**	**06**	**10**
VIII	**Load Calculation for Roof Truss**	**06**	**02**	**02**	**06**	**10**
Total		**42**	**12**	**24**	**34**	**70**

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

Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to 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 slightly vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the conventional teaching and 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 different photographs of nearby structures (RCC or Steel) showing different components clearly to create a self site visit.
b) Collect the photographs of different types of footings/foundations being constructed nearby with their primary details.
c) Collect different photographs of steel structural members (by visiting railway station, warehouse or industrial sheds) where connections can be shown actually implemented at site.
d) Collect the photographs of five different types of rolled steel sections.
e) Collect the information with photographs of structural failure of RCC components due to any reason.
f) Collect the information with photographs of world famous steel structures from journals or websites.
g) Collect the information with photographs of structural members having well known structures of India.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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/subtopics.
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.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be field application based, internet-based, workshop-based, laboratory-based or theory (analysis or design) 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 a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro-project should be about **14**-**16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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) Determine the moment of resistance of different cross sections for beams having the same area and different grades of concrete.
b) Compare the price of different grades of steel bars by actual market survey and prepare the report.
c) Prepare spreadsheet or computer program to determine moment of resistance of singly reinforced beam for three grades of steel and concrete.
d) Prepare spreadsheet or computer program to determine development length for different grades of steel , concrete, dia. of bar in tension and compression.
e) Prepare spreadsheet or computer program to calculate load carrying capacity of axially loaded short RC column.
f) Prepare drawing in Autocad for Dead load, Live load and Wind Load for given roof truss and compare answers with manual drawing.
g) Carry out market survey for steel sections which are available in market but not included in steel table or SP:6.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Design of Reinforced Concrete Structures	N Krishna Raju	CBS Publishers & Distribution Pvt. Ltd. NewDelhi ISBN: 9789385915369
2	Design of Reinforced Concrete Structures	N Subramanian	Oxford Publisher ISBN: 0198086946
3	Reinforced Concrete Vol.I	Dr.H.J.Shah	Charotar Publication ISBN: 9789385039478
4	Design of Steel Structures By Limit State Method as per IS:800-2007	S.S.Bhavikatti	Dreamtech press New Delhi ISBN:9389307058
5	Limit State design of Steel structures	S.K.Duggal	Mc Graw Hill ISBN: 9353164877
6	Limit State design of Steel structures As per IS:800-2007	S.Kanthimathinathan	Dreamtech press New Delhi ISBN:9389447577
7	IS:456-2000- Plain and Reinforced concrete code of practice.	BIS, New Delhi	BIS, New Delhi
8	IS:800-2007-Indian Standard Code of practice for use of structural steel in general building	BIS, New Delhi	BIS, New Delhi

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
	construction.		
9	IS: 875 part 1 to 5, Indian Standard Code for Loading Standards	BIS, New Delhi	BIS, New Delhi
10	SP:16-Design Aids for reinforced concrete to IS:456	BIS, New Delhi	BIS, New Delhi
11	SP:6-Handbook for Structural Engineers(Structural Steel Sections)	BIS, New Delhi	BIS, New Delhi
12	SP:34-Handbook on Concrete Reinforcement and Detailing	BIS, New Delhi	BIS, New Delhi

14. SOFTWARE/LEARNING WEBSITES

a) NPTEL Course :-Reinforced Cement Concrete by IIT, Kharagpur
https://archive.nptel.ac.in/courses/105/105/105105105/

b) NPTEL Video series for Steel design by IIT, Kharagpur
https://archive.nptel.ac.in/courses/105/105/105105162/

15. PO-COMPETENCY-CO MAPPING

Semester III	Design of Structures (Course Code: 4360601)						
	POs						
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
Competency	Analyze and Design important structural members of R.C.C. and primary knowledge of bolted and welded connections for Steel structures and various loads for steel structures.						
Course Outcomes COa) Analyze and Design singly reinforced rectangular beam for flexure and shear.	3	3	3	2	3	2	2
COb) Design One way and Two way slabs for	2	3	3	2	2	2	2

simply supported conditions.							
COc) Design axially loaded short column and pad footing.	2	3	3	2	2	2	2
COd) Design Bolted and Welded Connections for steel structures.	2	3	3	3	2	2	2
COe) Determine Dead Load, Live Load and Wind Load on Roof Truss.	2	3	3	3	2	2	2

*Legend: '**3'** for high, '**2**' for medium, **'1'** for low and **'-'** for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
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4.	Shri R.R. Makwana, Sr. Lecturer Applied Mechanics	L.E. College (Diploma), Morbi	9824128087	rrm.applied@gmail.com

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

VI – Semester

Course Title: Advance Design of Structures

(Course Code: 4360609)

Diploma program in which this course is offered	Semester in which offered
Civil Engineering	Sixth Semester

1. RATIONALE

After learning advance analysis of structures in fifth semester, this elective subject is introduced in 6th semester for those students willing to excel in the structural engineering field. This subject incorporates in depth knowhow for design of structural elements pertaining to Steel structures and Reinforced Concrete structures. In Steel structures, design of Tension member, Compression member and flexural member is included. Slab base foundation for steel column and under advance RCC design topics i.e. Doubly reinforced beam, T - Beam and Continuous slab are also incorporated. After learning this subject, diploma students will develop enhanced , in-depth, understanding of analysis and design of the structural members in the field of structural engineering and will be able to apply their knowledge ,design and analytical skills in the construction industry.

2. COMPETENCY

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

- **Analyse and Design important structural elemental members of R.C.C. and Steel structures.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

a) Analyse and Design Tension and Compression members of Truss .
b) Design axially loaded steel column and slab base foundation.
c) Design Laterally restrained steel beam and purlin.
d) Analyse RC T-Beam & Doubly reinforced beam and design Doubly Reinforced rectangular beam.
e) Design a three span one way continuous RC slab.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	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.*

Note: Subject related Indian Standard Codes (1) IS 456-2000 (2) IS 800-2007 (3) SP-16 Design Aid to IS-456 (4) SP-6 Handbook for Steel Structures will be allowed during Examinations.

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the subcomponents 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	Analyse and Design Axially Loaded Tension Member made up of Angle Section Specify Equal or Unequal, ISA or 2ISA (1-Problem Each)	I	02*
2	Analyse and Design Strut made up of Angle Section (1-Problem Each)	II	02 *
3	Design Axially Loaded Steel Column (One ISHB Section) and Slab Base Foundation for that. (1-Problem)	II, IV	04*
4	Design laterally restrained steel beam and purlin.(1-Problem Each)	III	02*
5	Draw longitudinal and sectional view designed Tension Member , Compression member and Laterally restrained beam. Draw Plan and c/s Elevation of Slab Base Foundation under column made up of H section. Sheet No:01 – A2 Size	I, II, III, IV	02*
6	Analyse and Design Doubly reinforced rectagular beam.(1-Problem Each)	V	04*
7	Analyse T-Beam (1-Problem)	VI	02*
8	Design three span one way continuous slab (1-Problem)	VII	04 *
9	Draw longitudinal and sectional view of designed doubly reinforced beam. Draw designed three span One Way Continuous Slab in Plan and in Longitudinal cross section Sheet No:02 – A2 Size	VI,VII	02*
10	Hands on Practice session/ Interactive Seminar for design , Analysis of Structural components (steel and/or RCC) on relevant software	I TO VII	04 *
	Total hours		**28 Hrs.**

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.*

ii. *The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Interpretation of given data and its understanding.	10
2	Selection of sketches/Process of designing of the given structural components using relevant I.S.codes and preparing of report of site visit..	40
3	Presentation of sketches in sketchbook, neatness and cleanliness of sheets and writing reports.	20
4	Individual work, work as a team-member	15
5	Completion and submission of work in time.	15
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Drawing tools and other design aids (for all PrOs)
1	Drawing boards and drawing instruments.
2	Scientific calculator and all relevant IS codes.
3	Computers and Printers.
4	Available CAD software(Not mandatory)

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 fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using equipment.
c) Realize importance of green energy. (Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I **Tension Member**	1a. Suggest the type of steel section to be used as tension member for given data. 1b. Compute the load carrying capacity of given tension member with given condition. 1c. Design given tension member for given data and condition.	1.1 Types of sections used as Tension Members in Steel Structures. 1.2 Design strength of Tension Member governed by Yielding, rupture of critical section and Block shear in Angle section according to provision of IS: 800-2007 1.3 Analysis and Design of Axially loaded tension members - Single and Double angle section with Bolted and welded connections. 1.4 Numerical of Analysis and design of tension members for single and double angle sections with bolted and welded connections.
Unit – II **Compression Member (Strut & Column)**	2a. Suggest the type of steel section to be used as compression member for given data. 2b. Compute the load carrying capacity of given compression member with given end conditions. 2c. Design the compression member for given data and condition.	2.1 Type of sections to be used as compression members in steel structures. Calculation of effective length, radius of gyration, slenderness ratio and its permissible value as per IS:800-2007. 2.2 Cross section classification, Buckling class, Imperfection factors as per IS:800-2007 2.3 Design compressive strength of (i) Axially loaded compression members (ii) Single angle struts (iii) Double angle struts as per IS:800-2007 2.4 Numerical of Analysis and design of compression members for single angle section, double angle section, with bolted and welded connections. 2.5 Numericals for Analysis and Design of Column (made up of single H section i.e. ISMB,ISHB only No Built Up Section)
Unit– III **Laterally Restrained Beam and Purlin**	3a. Design laterally restrained simply supported beams(only ISHB or ISMB 3b. Design Purlin made up of Unequal Angle Section	3.1 Main Beam , Secondary Beam , Standard I Sections , Laterally restrained and unrestrained beam (only) symmetrically loaded with UDL and/or point load. 3.2 Plastic Section Modulus – Annexure –H , IS-800-2007 , Section classification as per Table 2 – IS-800-2007 , Shear buckling , Shear Strength and Bending

		Strength of Section as per Cl. 8.4.1 and Cl. 8.2.1.2 of IS-800-2007 , Deflection as per Table-6 of IS-800-2007 , Shear Leg Effect , Web Crippling
Unit– IV **Slab Base Foundation**	4a. Identify different types of column bases foundation. 4b. Design of Slab Base Foundation for Axially Loaded Column made up of Indian Standard Heavy Beam Section	4.1 Schematic comparison of various Slab Bases for Axially loaded columns. 4.2 Procedure to design Slab Base Foundation for axially loaded column made up of ISHB Section with bolted connection only. 4.3 Numerical to design slab base foundation for given data.
Unit– V **Doubly Reinforced Beam**	5a. Differentiate types of RC beams. 5b. Calculate moment of resistance of doubly reinforced beam. 5c. Design a Rectangular Doubly reinforced beam. 5d. Draw reinforcement detailing for the designed doubly reinforced beam section as per IS provision.	5.1 Requirements and conditions for providing doubly reinforced sections. 5.2 Stress diagram for doubly reinforced beam. Stress in compression reinforcement (f_{sc}) in doubly reinforced beams for different values of d'/d ratio. 5.3 Analysis and design of doubly reinforced section using IS:456-2000 method, SP:16 table method and SP: 16 chart method. 5.4 Numerical of Moment of resistance and Area of steel (tension and compression) for doubly reinforced beam.
Unit– VI **T-Beam**	6a. Identify importance of reinforced concrete flanged beams. 6b. Analyze T-beam for Flexure.	6.1 Concept of flanged beam-T-beam & L-beam. Requirement and advantage of T-beam. Effective width of flange. 6.2 Conditions for the beam to act as T-Beam i.e. (i) Neutral axis lies in flange[$X_u < D_f$] (ii) Neutral axis lies in web [$X_u > D_f$] Stress strain diagram of T- beam. 6.3 Numerical to find Limiting Moment of Resistance of Tee Beam using IS:456-2000 and SP-16.
Unit– VII **One-Way Continuous Slab**	7a. Identify conditions to use one way continuous slab. 7b. Design one way continuous slab as per given data and condition. 7c. Draw reinforcement details for the designed one way continuous slab as per IS provision.	7.1 Definition and requirement to use one way continuous slab. 7.2 IS 456:2000 provisions for three span one way Continuous Slab. Various coefficients of Bending moment and shear force for dead load and imposed load. 7.3 Numerical to design three span one way continuous slab only.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Tension Member**	**08**	**02**	**04**	**06**	**12**
II	**Compression Member (Strut & Column)**	**10**	**02**	**04**	**08**	**14**
III	**Laterally Restrained Beam and Purlin**	**06**	**02**	**04**	**04**	**10**
IV	**Slabs Base Foundation**	**04**	**02**	**02**	**02**	**06**
V	**Doubly Reinforced Beam**	**05**	**02**	**04**	**04**	**10**
VI	**T-Beam**	**04**	**02**	**02**	**04**	**08**
VII	**One-Way Continuous Slab**	**05**	**02**	**04**	**04**	**10**
Total		**42**	**14**	**24**	**32**	**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 to 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 slightly vary 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) Identify different situations with photographs of steel structural members where tensile force is predominant in the field.(bridge, Railway station)
b) Identify different situations with photographs of steel structural members connection (Bolted & welded connection)
c) Identify different situations with photographs of steel structural members where compressive force is predominant in the field.(Suspension bridge, Railway bridge)
d) Identify different situations with photographs of RCC Structural components such as column ,doubly beams , continuous slabs etc..
e) List out various softwares available for steel and RCC design and submit a review report.
f) Use of computer program (software or excel worksheets) to compare the results of design and analysis problems solved manually

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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/subtopics.
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.9***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Guide students for using data manuals.

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-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be field application based, internet-based, workshop-based, laboratory-based or theory 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 a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro-project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students 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) Compare the design and analysis done manually with computer software or excel worksheets for at least one of the list below
    a. Steel Design and analysis for Axially loaded Tension member, Axially loaded compression member,Simply Supported laterally restrained beams, Purlins and Slab base Foundation.
    b. RCC Design and analysis of Doubly reinforced rectangular beam, 3 span one way continuous slab,T beam.
b) Prepare a spreadsheet computer program to design at least one of the following
    a. Steel Design for Axially loaded Tension member, Axially loaded compression member, Simply Supported laterally restrained beams, Purlins and Slab base Foundation.
    b. RCC Design of Doubly reinforced rectangular beam, 3 span one way continuous slab.
c) Prepare a spreadsheet computer program for at least one of the following
    a. Steel Design for Axially loaded Tension member, Axially loaded compression member,Simply Supported laterally restrained beams, Purlins and Slab base Foundation.
    b. Doubly reinforced rectangular beam, 3 span one way continuous slab.

d) Analyse and design a steel roof truss or a residential block building with structural engineering software.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Design of Reinforced Concrete Structures	N Krishna Raju	CBS Publishers & Distribution Pvt. Ltd. NewDelhi ISBN: 9789385915369
2	Design of Reinforced Concrete Structures	N Subramanian	Oxford Publisher ISBN: 0198086946
3	Reinforced Concrete Vol.I	Dr.H.J.Shah	Charotar Publication ISBN: 9789385039478
4	Design of Steel Structures By Limit State Method as per IS:800-2007	S.S.Bhavikatti	Dreamtech press New Delhi ISBN:9389307058
5	Limit State design of Steel structures	S.K.Duggal	Mc Graw Hill ISBN: 9353164877
6	Limit State design of Steel structures As per IS:800-2007	S.Kanthimathinathan	Dreamtech press New Delhi ISBN:9389447577
7	IS:456-2000- Plain and Reinforced concrete code of practice.	BIS, New Delhi	BIS, New Delhi
8	IS:800-2007-Indian Standard Code of practice for use of structural steel in general building construction.	BIS, New Delhi	BIS, New Delhi
9	SP:16-Design Aids for reinforced concrete to IS:456	BIS, New Delhi	BIS, New Delhi
10	SP:6-Handbook for Structural Engineers(Structural Steel Sections)	BIS, New Delhi	BIS, New Delhi
11	SP:34-Handbook on Concrete Reinforcement and Detailing	BIS, New Delhi	BIS, New Delhi

14. SOFTWARE/LEARNING WEBSITES

a) NPTEL Course :-Reinforced Cement Concrete by IIT, Kharagpur https://archive.nptel.ac.in/courses/105/105/105105105/

b) NPTEL Video series for Steel design by IIT, Kharagpur https://archive.nptel.ac.in/courses/105/105/105105162/

15. PO-COMPETENCY-CO MAPPING

Semester VI	Advance Analysis of Structures (Course Code: 4360609)						
	Pos						
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
Competency	Analyse and Design important structural elemental members of R.C.C. and Steel structures.						
Course Outcomes COa) **Analyse and Design Tension and Compression members of Truss**	2	3	3	2	2	2	2
COb) **Design Axially loaded steel column and slab base foundation.**	2	3	3	2	2	2	2
COc) **Design laterally restrained steel beam and purlin.**	2	3	3	2	2	2	2
COd) **Analyse RC T-beam and Doubly reinforced beam and Design doubly reinforced rectangular beam**	2	3	3	2	2	2	2
COe) **Design a three span one way continuous RC slab.**	2	3	3	2	2	2	2

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low and '**-**' for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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