Program Name : **Civil Engineering Program Group**

Program Code : **CE/CR/CS**

Semester : **Third**

Course Title : **Mechanics of Structures**

Course Code : **22303**

1. RATIONALE

Design and analysis of structure and its components, needs the basic understanding and application of mechanical properties of material and their behavior under different loading and stress conditions. Concepts and principles of structural analysis shall be well understood by students, which is important for design of reinforced cement concrete and steel structures and the same has been covered in this course. Analysis of determinate structure under action of transverse loading along with analysis of members under direct loading will also be studied in this course. The approach of teaching the course shall focus on development of students' analytical and critical thinking while solving structural problems.The experiments expected to be conducted in laboratory will integrate knowledge and required skills as regards to the structural behavior of components and materials.

2. COMPETENCY

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

- **Analyze structural components using different methods.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Articulate practical applications of moment of inertia of symmetrical and unsymmetrical structural sections.
b. Interpret structural behaviour of materials under various loading conditions.
c. Select material considering engineering properties for various structural applications.
d. Interpret shear force and bending moment diagrams for various types of beams and loading conditions.
e. Determine the bending and shear stresses in beams under different loading conditions.
f. Check the column safety for various loading and end conditions.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme													
				Theory							Practical						
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total		
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
3	2	2	7	3	70	28	30*	00	100	40	25@	10	25	10	50	20	

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

during the semester for the assessment 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,* ***ESE*** *- End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

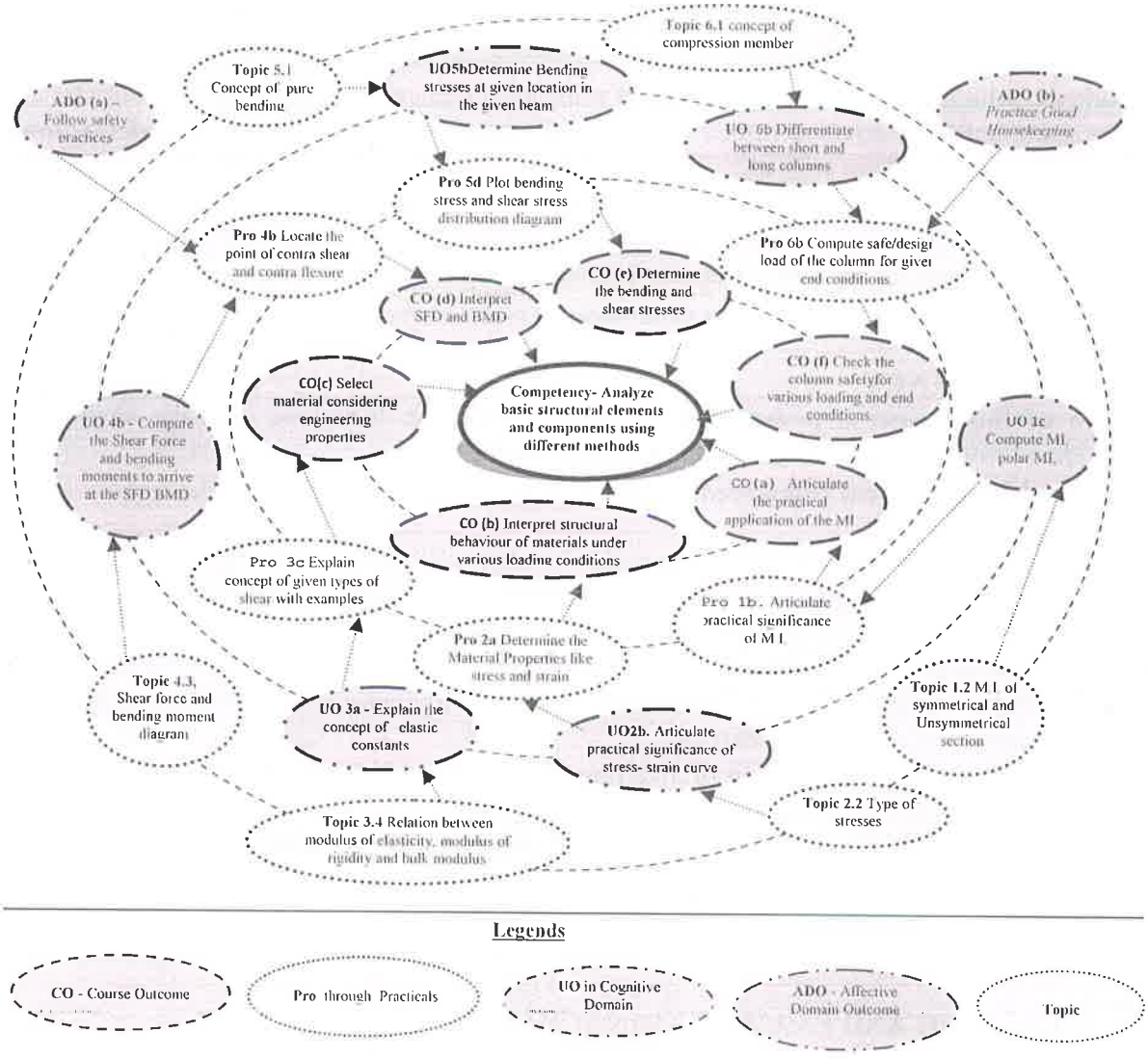

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1.	Conduct compressive and tensile tests on sample test pieces using Universal Testing Machine along with introduction to other tests to be conducted on UTM.	II	02
2.	Conduct compression test on sample test piece using Compression Testing Machine.	II	02
3.	Perform Tension test on mild steel as per IS:432(1)	II	02*
4.	Perform tension test on Tor steel as per IS:1608,IS:1139	II	02
5.	Conduct Izod Impact test on three metals. E.g. mild steel/ brass/aluminum/ copper /cast iron etc as per IS:1598	II	02
6.	Conduct Charpy Impact test on three metals. E.g. mild steel/ brass/aluminum/ copper /cast iron etc as per IS:1757	II	02*
7.	Determine Water Absorption on bricks per IS:3495 (part II), IS:1077 or tile IS:1237	II	02*
8.	Determine Compressive strength of dry and wet bricks as per IS:3495(part I), IS:1077	II	04*
9.	Conduct Abrasion Test on flooring tiles (any one) e.g. Mosaic tiles, Ceramic Tiles as per IS: 13630(part7), Cement Tile as per IS: 1237	II	02
10.	Perform Single Shear and double shear test on any two metals e.g. Mild steel/ brass/aluminum/copper / cast iron etc as per IS:5242	III	02*
11.	Conduct Compression test on timber section along the grain and across the grain as per IS:2408	II,VI	02
12.	Plot Shear force and Bending Moment diagrams of cantilever, simply supported and overhanging beams for different types of loads two problems on each type of beam	IV	06
13.	Conduct Flexural test on timber beam on rectangular section in both orientation as per IS:1708, IS:2408	I,V	02*
14.	Conduct Flexure test on floor tiles IS:1237,IS:13630 or roofing tiles as per IS:654,IS:2690	V	02
15.	Field test on TMT bars.	II	02
	Total		**34**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S.No	Performance Indicators	Weightage in %
a.	Preparation of experimental set up	20
b.	Setting and operation	20

S.No	Performance Indicators	Weightage in %
c.	Safety measures	10
d.	Observations and recording	10
e.	Interpretation of results and conclusion	20
f.	Answer to sample question	10
g.	Submission of report in time	10
		100

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S.No.	Equipment Name with Broad Specifications	PrO. S.No
1	Universal Testing machine of capacity 1000kN, 600 kN/400kN, analog type/digital type with all attachments and accessories.	1,3,4, 10,13
2	Extensometer with least count 0.01mm, maximum extension 25 mm with dial gauge/ digital display suitable for various gauge length.	3,4
3	Compression testing machine of capacity 2000kN/1000kN, analog /digital type with all attachments and accessories.	2,8,11
4	Tile abrasion testing machine confirming to IS:1237 and IS :1706 for determining resistance to wear and abrasion of flooring tiles complete with dial gauges , revolution counter, thickness measurement holder and abrasion powder.	9
5	Izod/Charpy impact testing machine confirming to IS: 1757.	5,6
6	Tile flexural testing machine confirming to IS:654,capacity 200Kg with uniform loading rate of 45 to 55 Kg/minute provided with lead shots	13
7	Hot Air Oven with thermostatic control having temp. range 100 to 105° C	7
8	Accessories: venire caliper, meter scale, weighing balance, weights, punch, file, hammer, screw driver, pliers ,etc.	All

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– I Moment of Inertia	1a. Compute Moment of Inertia, polar moment of inertia section modulus of given section. 1b. Articulate practical significance of M.I. for given section and loading condition(s). 1c. Compute Moment of Inertia, polar moment of inertia, section modulus of given standard section. 1d. Compute Moment of Inertia of given unsymmetrical section.	1.1 Moment of inertia (M.I.): definition, M.I. of plane lamina, radius of gyration, section modulus, parallel and perpendicular axes theorems (without derivation), M.I. of rectangle, square, circle, semi circle, quarter circle and triangle section(without derivation). 1.2 M.I. of symmetrical and unsymmetrical I-section, channel section, T-section, angle section, and hollow sections and built up section about centroidal axes and any other reference axis. 1.3 Polar Moment of Inertia of solid circular sections.
Unit –II Simple Stresses and Strains	2a. Articulate practical significance of stress- strain curve for given materials under given loading conditions for their relevant use. 2b. Compute stresses and load shared by given Composite section subjected to direct load. 2c. Calculate modulus of elasticity, modulus of rigidity and axial deformation under given conditions for given material. 2d. Compute stresses induced in given homogeneous sections under temperature variations for given conditions.	2.1 Concept of rigid, elastic and plastic bodies, deformation of elastic body under various forces, definition of stress, strain, elasticity, Hook's law, elastic limit, modulus of elasticity, SI units. 2.2 Type of stresses-normal, direct, bending and shear and nature of stresses i.e. tensile and compressive stresses. 2.3 Standard stress strain curve for mild steel bar and tor steel bar under tension test, Yield stress, proof stress, ultimate stress, breaking stress, and working stress, strain at various critical points, percentage elongation and Factor of safety. 2.4 Deformation of body due to axial force, forces applied at intermediate sections, deformation of body of stepped cross section due to axial load, maximum stress and minimum stress induced. 2.5 Concept of composite section, conditions to have a section composite, stresses induced and load shared by materials under axial loading. 2.6 Concept of temperature stresses and strain, stress and strain developed due to temperature variation in homogeneous simple bar.(no composite section) Introduction to strain energy and types of loadings such as gradually applied load,

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
		suddenly applied load and impact load only.
Unit–III Elastic Constants	3a. Explain the concept of elastic constants for given situation and their significance. 3b. Calculate change in volume of members for given stress condition. 3c. Explain concept of given types of shear with examples. 3d. Compute shear stress, shear strain and modulus of rigidity for given section.	3.1 Longitudinal and lateral strain, Poisson's ratio, biaxial and triaxial stresses, volumetric strain, change in volume, Bulk modulus. 3.2 Shear stress and strain, modulus of rigidity, simple and complementary shear stress. 3.3 Concept of single shear, double shear and punching shear. 3.4 Relation between modulus of elasticity, modulus of rigidity and bulk modulus.
Unit-IV Shear Force and Bending Moment	4a. Interpret the given types of support(s) and load(s). 4b. Interpret with simple sketch(s) of the given type(s) of beam, load and end conditions, relevant to the actual field situations. 4c. Compute the Shear Force and bending moments to arrive at the Shear force diagram, Bending Moment Diagram for given beam and load conditions. 4d. Locate the point of contra shear and point of contra flexure for the given SFD and BMD.	4.1 Types of supports, beams and loads. 4.2 Concept and definition of shear force and bending moment , relation between load, shear force and bending moment 4.3 Shear force and bending moment diagram for cantilever and simply supported beams subjected to point loads, uniformly distributed loads and couple, point of contra shear and point of contra flexure. 4.4 Shear force and bending moment diagram for overhanging beams subjected to, point loads, uniformly distributed loads only. Point of contra shear and point of contra flexure.
Unit-V Bending and Shear Stresses in beams	5a. Identify with justification nature of bending stresses for given situation. 5b. Determine Bending stresses and shear stresses at given location in the given beam. 5c. Design the beam section for the given data. 5d. Plot bending and shear stress distribution diagram for given beam section and given type of loading.	5.1 Concept and theory of pure bending, assumptions, flexural, meaning of term used in equation, bending stresses and their nature, bending stress distribution diagram. 5.2 Concept of moment of resistance and using flexure equation. 5.3 Shear stress equation, meaning of term used in equation, relation between maximum and average shear stress for rectangular and circular section, shear stress distribution diagram. 5.4 Shear stress distribution for square, rectangular, circle, hollow square, rectangular, circle, angle sections, channel

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
		section, I-section, T sections.
Unit-VI Columns	6a. Differentiate between short and long columns based on given criteria. 6b. Compute safe/design load of the column for given different end conditions. 6c. Calculate the limitations of Euler's theory for the given data. 6d. Compute safe/design load of long column using Rankin's formula for given conditions.	6.1 Concept of compression member, short column, long column, effective length, radius of gyration, slenderness ratio, type of end conditions for columns, buckling of axially loaded columns. 6.2 Euler's theory, assumptions made in Euler's theory and its limitations. application of Euler's equation to calculate buckling load. 6.3 Rankin' s formula and its application to calculate crippling load. 6.4 Concept of working load/safe load, design load and factor of safety.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.*

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	Moment of Inertia	08	02	04	04	10
II	Simple stress and strain	10	04	04	06	14
III	Elastic constants	06	02	02	04	08
IV	Shear force and bending moment	12	02	04	12	18
V	Bending and shear stresses in beams	08	02	06	06	14
VI	Columns	04	02	02	02	06
Total		**48**	**14**	**22**	**34**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may 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. Compare stability of different geometric shapes.
b. Correlate the actual field situations about various members subjected to different types of loading.

c. Select appropriate shape, type and material of member from day to day situations for various types of stress and strain.
d. Correlate the actual field situations with various types of beams (such as cantilever means canopy of a building, overhanging beam means slab with balcony provision). Shapes of various structural components resembling with shear force and bending moment diagrams of simple structures subjected to different types of loading. Identify the type of failure with respect to the shape.
e. Study the mode of failures due to flexure and shear from field situations and prepare a report.
f. Visit site/ design office and collect the data from day to day situation about stability and strength of column for buckling load.
g. Search the software / freeware on the course content and prepare the detailed report stating their applications.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.
f. Assign unit wise tutorials to group of 4 to 5 students for solving problems unit wise.
g. Assign micro projects to group of 4 to 5 students and let them prepare and present the project through PPT. Group shall submit a report which is limited to 5 pages.
h. Use of video animation films to explain concept, Facts and applications related to Mechanics of Structures.
i. In respect of item 10 above teacher needs to ensure to create opportunity and provisions for such co curricular activities.

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. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

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

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. Collect the IS related to methods of testing and specifications for five materials used in actual practice.
b. Select ten materials from day to day life and compare their mechanical properties and present it in a format of report.
c. Prepare prototype model of various types of support, beams and loading.
d. Prepare a report about beam sections subjected to bending and shear stresses from actual field/design office along with photographs and its justification.
e. Collect photographs along with justification about failure of short and long columns from actual field situations.

13. SUGGESTED LEARNING RESOURCES

S.No.	Title of Book	Author	Publication
1	Strength of Materials, Vol. I	Timoshenko, S.	CBS; 3 New Delhi; 2015, ISBN 978-8123910307
2	Strength of Materials	Khurmi, R.S.	S Chand and Co. Ltd. New Delhi, 2015, ISBN 978-8121928229
3	Strength of Materials	Ramamurtham, S	Dhanpat Rai and sons, New Delhi, 2015, ISBN 9788187433545
4	Strength of Materials	Punmia B C	Laxmi Publications (p) Ltd. New Delhi, 2015, ISBN-13: 978-8131809259
5	Strength of Materials	Rattan S.S.	McGraw Hill Education; New Delhi 2016, ISBN-13: 978-9385965517

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. https://www.youtube.com/watch?v=-JG9IEqRzQ4
b. https://www.youtube.com/watch?v=4VIhh6sGkrI
c. https://www.youtube.com/watch?v=EcPGKLUE04I
d. https://www.youtube.com/watch?v=-ndT35aqDfAQ
e. https://www.youtube.com/watch?v=ZJn_Mj2HeNM
f. https://www.youtube.com/watch?v=KU1gHy8Adrc
g. www.slideshare.net/nell0511/columns-and-struts
h. nptel.ac.in/courses/IIT-MADRAS/Strength_of_Materials/Pdfs/4_1.pdf
i. https://www.youtube.com/watch?v=nNcfzNjIifU
extofvideo.nptel.iitm.ac.in/105105108/lec28.pdf
j. http://nptel.ac.in/courses/Webcourse-contents/IIT-KANPUR/engg_mechanics/ui/Course_home_9.htm