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

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