ADVANCED SOLID MECHANICS (GR20D5002)

I-M.Tech – I Semester

(AY 2021-22)

Mr. K. Veera Babu

Assistant Professor

Department of Civil Engineering

Gokaraju Rangaraju Institute of Engineering and Technology

Bachupally, Kukatpally, Hyderabad – 500 090.

Gokaraju Rangaraju Institute of Engineering and Technology

Department of Civil Engineering

Advanced Solid Mechanics

Course File Check List

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INSTITUTE OF ENGINEERING AND TECHNOLOGY
Department of Civil Engineering
ADVANCED SOLID MECHANICS

Course **Code: GR20D5002** I Year I Semester

Course **Prerequisites:** Mathematics and Strength of Materials

UNIT I:

Introduction to Elasticity : Notation for forces and stresses - Components of stresses - Components of strain — Hooke's law, Strain and Stress Fields, Stress and strain at a Point, Stress Components on an Arbitrary Plane, Hydrostatic and Deviatoric Components, Saint- Venant's principle.

UNIT II:

Equations of Elasticity in Two-dimensional problems in rectangular and polar coordinates: Equations of Equilibrium, Stress- Strain relations, Strain —Displacement and Compatibility Relations, Boundary conditions, Plane stress and plane strain analysis - stress function -Two dimensional problems in rectangular coordinates - solution by polynomials.

UNIT III:

Analysis of stress and strain in three dimensions in rectangular and polar coordinates - principal stresses - stress ellipsoid-determination of principal stresses - max shear stresses- equations of equilibrium in terms of displacements.

UNIT IV:

Torsion of Prismatic Bars: Saint Venant's Method, Prandtl's Membrane Analogy, Torsion of Rectangular Bar, use of soap films in solving torsion problems, Bending of Prismatic Bars: Stress function - bending of cantilever — circular cross section.

UNIT V:

Concepts of plasticity, Plastic Deformation, Strain Hardening, Idealized Stress- Strain curve, Yield Criterions, Plastic Stress-Strain Relations.

References:

1. Theory of Elasticity, Timoshenko S. and GoodierJ. N., McGraw Hill, 1961.
2. Elasticity, Sadd M.H.,E1sevier,2005.
3. Engineering Solid Mechanics, RagabA.R., BayoumiS.E., CRC Press,1999.
4. Computational Elasticity, AmeenM., Narosa, 2005.
5. Solid Mechanics, KazimiS. M. A., Tata McGraw Hi11,1994.
6. Advanced Mechanics of Solids, SrinathL.S., Tata McGraw Hi11,2000.

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DEPARTMENT OF CIVIL ENGINEERING

TIME TABLE

I YEAR I SEMESTER

I M.Tech (GR20) - I Semester **AY: 2021-22**

DAY/ HOUR	9:00-10:00	10:00-11:00	11:00-12:00	12:00-01:00	01:00-02:00	02:00-03:00	03:00-04:00
Monday			ASM	**LUNCH BREAK**			
Tuesday					ASM		
Wednesday							
Thursday	ASM	ASM					
Friday							
Saturday							

Program Educational Objectives(PEO's)

PEO1: Graduates of the program will equip with professional expertise on the theories, process, methods and techniques for building high-quality structures in a cost-effective manner.

PEO2: Graduates of the program will be able to design structural components using contemporary softwares and professional tools with quality practices of international standards

PEO3: Graduates of the program will be effective as both an individual contributor and a member of a development team with professional, ethical and social responsibilities.

PEO4: Graduates of the program will grow professionally through continuing education, training, research, and adapting to the rapidly changing technological trends globally in structural Engineering

Program Outcomes(PO's):

PO 1: An ability to independently carry out research /investigation and development to solve practical problems.

PO 2: An ability to write and present a substantial technical report/document.

PO 3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelors.

PO 4: Possess critical thinking skills and solve core, complex and multidisciplinary structural engineering problems.

PO 5: Assess the impact of professional engineering solutions in an environmental context along with societal, health, safety, legal, ethical and cultural issues and the need for sustainable development.

PO 6: Recognize the need for life-long learning to improve knowledge and competence.

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COURSE OBJECTIVES

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

On completion of this Subject/Course the student shall be able to:

S.No	Objectives
1	To explain the theory, concepts and principles of Elasticity
2	To generalize the equations of elasticity for two-dimensional problems of elasticity interms of Cartesian and polar coordinates.
3	To demonstrate the equations of elasticity for two-dimensional problems of elasticity in terms of Cartesian and polar coordinates
4	To apply principles of elasticity to analyze the torsion and bending in prismatic bars
5	To extend the principles of stress/strain for plastic deformation to study the modes of failure

Signature of HOD Signature of faculty

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COURSE OUTCOMES

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

The expected outcomes of the Course/Subject are:At the end of the course, the student will be able to

S.No	Outcomes
1	Have a good understanding of the theory, concepts, principles and governing equations of Elasticity principles.
2	Develop equations of equilibrium and draw relations among stress, strain and displacement and utilize the equilibrium equations, compatibility equations and various boundary conditions to analyze elastic problems.
3	Gain the understating of three-dimensional problems of elasticity in Cartesian coordinates system ad able to determine principal stresses and planes of 3D problems.
4	Apply the principles of elasticity to solve torsional problems in prismatic bars and tubes.
5	Use the concepts of stresses and strains for plastic deformation to comprehend the yield criteria of materials.

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STUDENT ROLL LIST

M.Tech Structural Engg. I Year-I Sem- Section A(GR20) 2021-22

S.No	Reg No	Student Name
1	21241D2001	ATKAPURAM PRASHANTH
2	21241D2002	BANDI SRI RAM GOPAL
3	21241D2003	CHALLA MADHAVI
4	21241D2004	PAMMI DIVYA
5	21241D2005	DUMMA UMESH KUMAR
6	21241D2006	K LATHASREE
7	21241D2007	MARIYALA VAISHNAVI
8	21241D2008	MAVOORI PRANAV
9	21241D2009	MITTAPALLI NAGA ASHWINI
10	21241D2010	RAVULA VENKATA SURAJ REDDY
11	21241D2011	REPATI MOHAN BABU
12	21241D2012	CHERUKU SANDHYA
13	21241D2013	SHAIK FEROZ
14	21241D2014	S K SAI CHANDRA
15	21241D2015	THOTA HARSHAVARDHAN
16	21241D2016	VARIKUPPULA LALITHA
17	21241D2017	YAMBA RAMA GNANENDRA SAI
18	21241D2018	YENUMALA DEVESH GOUD
19	21241D2019	S PRASHANTH KUMAR
20	21241D2020	BAVANDLAPELLI THARUNTEJA
21	21241D2021	G NITISH KUMAR

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GUIDELINES TO STUDY THE COURSE/SUBJECT

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Guidelines to students

Guidelines to study the Course: Advanced Solid Mechanics

The course helps the students to learn and understand the importance of geotechnical engineering in different phases of construction. One can learn to determine the various engineering properties of soils. This course makes the students to understand about index properties, consistency of clays, permeability, compaction, consolidation, shear strength, etc of various types of soils.

So the students should have the prerequisites

- knowledge of Mathematics
- knowledge of Strength of Materials

To become expertise in this course, students need to be perfect with the basic concepts of Solid Mechanics to understand and analyse the behaviour of Materials

Where will this subject help?

- Useful in foundation engineering, analyzing type structures.
- This course let the students to work with various types of materials
- This course let the students to determine the engineering properties of materials

Books / Material

1. Theory of Elasticity, Timoshenko S. and GoodierJ. N., McGraw Hill, 1961.
2. Elasticity, Sadd M.H.,E1sevier,2005.
3. Engineering Solid Mechanics, RagabA.R., BayoumiS.E., CRC Press,1999.

REFERENCES

1. Computational Elasticity, AmeenM., Narosa, 2005.
2. Solid Mechanics, KazimiS. M. A., Tata McGraw Hi11,1994.
3. Advanced Mechanics of Solids, SrinathL.S., Tata McGraw Hi11,2000.

Websites:

www.nptel.ac.in/courses/civilengineering/advancedsoilidmechanics/1051030198/
www.google.co.in

Course Design and Delivery System (CDD):

- The Course syllabus is written into number of learning objectives and outcomes.
- These learning objectives and outcomes will be achieved through lectures, assessments, assignments, experiments in the laboratory, projects, seminars, presentations, etc.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books, journals, etc.

The faculty be able to –

- Understand the principles of Learning
- Understand the psychology of students
- Develop instructional objectives for a given topic
- Prepare course, unit and lesson plans
- Understand different methods of teaching and learning
- Use appropriate teaching and learning aids
- Plan and deliver lectures effectively
- Provide feedback to students using various methods of Assessments and tools of Evaluation
- Act as a guide, advisor, counselor, facilitator, motivator and not just as a teacher alone

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COURSE SCHEDULE

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

The Schedule for the whole Course / Subject is:

S. No.	Description	Duration (Date)		Total No. Of Periods
		From	To	
1.	**UNIT I:** Introduction to Elasticity	15-11-2021	02-12-2021	12
2.	**UNIT II:** Equations of Elasticity	06-12-2021	28-12-2021	12
3.	**UNIT III:** Analysis of stress and strain in 3D	30-12-2021	20-01-2022	13
4.	**UNIT IV:** Torsion of Prismatic bars	24-01-2022	17-02-2022	13
5.	**UNIT V:** Plasticity	21-02-2022	10-03-2022	12

Total No. of Instructional periods available for the course: 62 Hours / Periods

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SCHEDULE OF INSTRUCTIONS
COURSE PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

S.No.	Date	Unit No.	Session Duration	Topics
1	15/11/2021	I	1	Introduction to ASM
2	16/11/2021	I	1	Elasticity ,Notation forces
3	18/11/2021	I	1	Components of Stress
4	18/11/2021	I	1	Components of Stress
5	22/11/2021	I	1	Components of strain
6	23/11/2021	I	1	Hook's law
7	25/11/2021	I	1	Derivation of Hook's law
8	25/11/2021	I	1	Problems
9	29/11/2021	I	1	Stress on Arbitrary plane
10	30/11/2021	I	1	Problems
11	02/12/2021	I	1	Hydrostatic state of stress, pure shear
12	02/12/2021	I	1	St.Vanant's Principle
13	06/12/2021	II	1	Displacement Components
14	07/12/2021	II	1	Equations of Equilibrium
15	09/12/2021	II	1	Problems

16	09/12/2021	II	1	2D and 3D Problems
17	13/12/2021	II	1	Introduction to Polar Coordinate System
18	14/12/2021	II	1	2D and 3D equations in polar system
19	16/12/2021	II	1	Stress function, Airy's
20	16/12/2021	II	1	Boundary conditions
21	20/12/2021	II	1	Solutions by polynomials
22	21/12/2021	II	1	Problems
23	23/12/2021	II	1	Problems
24	27/12/2021	II	1	Problems
25	27/12/2021	III	1	Analysis of Stress
26	28/12/2021	III	1	Principle stress
27	30/12/2021	III	1	Problems of principle stress
28	30/12/2021	III	1	Problems
29	03/01/2022	III	1	Stress function problems
30	04/01/2022	III	1	Compatibility equations
31	06/01/2022	III	1	Stress Ellipsoid
32	06/01/2022	III	1	Pure bending of beam
33	10/01/2022	III	1	Cantilever beam with end load
34	11/01/2022	III	1	Equations of displacements
35	11/01/2022	III	1	Problems
36	24/01/2022	III	1	Problems
37	25/01/2022	III	1	Problems
38	27/01/2022	IV	1	Introduction to Torsion
39	27/01/2022	IV	1	Basic Equations
40	31/01/2022	IV	1	Problems
41	01/02/2022	IV	1	St.Venant's method
42	03/02/2022	IV	1	Prandtls method

43	03/02/2022	IV	1	Membrane Analogy
44	07/02/2022	IV	1	Soap film concept
45	08/02/2022	IV	1	Problems
46	10/02/2022	IV	1	Bending of beam
47	10/02/2022	IV	1	Torsion equation for circular c/s
48	14/02/2022	IV	1	Torsion equation for Elliptical c/s
49	15/02/2022	IV	1	Problems
50	17/02/2022	IV	1	Problems
51	17/02/2022	V	1	Introduction to Plasticity
52	21/02/2022	V	1	Yield criteria
53	22/02/2022	V	1	Methods of Failure
54	24/02/2022	V	1	Methods of Failure
55	28/02/2022	V	1	Strain Hardening
56	01/03/2022	V	1	Idealized stress strain cure
57	04/03/2022	V	1	True stress and strain
58	04/03/2022	V	1	Problems
59	07/03/2022	V	1	Problems
60	08/03/2022	V	1	Problems
61	10/03/2022	V	1	Revision
62	10/03/2022	V	1	Revision

Note: 1. Ensure that all topics specified in the course are mentioned.
2. Additional topics covered, if any, may also be specified in bold
3. Mention the corresponding course objective and out come numbers against each topic.

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SCHEDULE OF INSTRUCTIONS
UNIT PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

UNIT I

Lesson No.	Unit No.	Date	No. of Periods	Topics	Course Objectives & Outcomes	References Text Book Page No.
1	I	15/11/2021	1	Introduction to ASM	COb-1 & CO-1	Theory of Elasticity, Timoshenko S. and GoodierJ. N., McGraw
2		16/11/2021	1	Elasticity ,Notation forces	COb-1 & CO-1	
3		18/11/2021	1	Components of Stress	COb-1 & CO-1	
4		18/11/2021	1	Components of Stress	COb-1 & CO-1	
5		22/11/2021	1	Components of strain	COb-1 & CO-1	
6		23/11/2021	1	Hook's law	COb-1 & CO-1	
7		25/11/2021	1	Derivation of Hook's law	COb-1 & CO-1	
8		25/11/2021	1	Plane Stress and Strain	COb-1 & CO-1	

9		29/11/2021	1	Stress on Arbitrary plane	COb-1 & CO-1	
10		30/11/2021	1	Problems	COb-1 & CO-1	
11		02/12/2021	1	Hydrostatic state of stress, pure shear	COb-1 & CO-1	
12		02/12/2021	1	St.Vanant's Principle	COb-1 & CO-1	

UNIT II

Lesson No.	Unit No.	Date	No. of Periods	Topics	Course Objectives & Outcomes	References Text Book
1	II	06/12/2021	1	Displacement Components	COb-2 CO-2	Theory of Elasticity, Timoshenko S. and GoodierJ. N., McGraw
2		07/12/2021	1	Equations of Equilibrium	COb-2 CO-2	
3		09/12/2021	1	Problems	COb-2 CO-2	
4		09/12/2021	1	2D and 3D Problems	COb-2 CO-2	
5		13/12/2021	1	Introduction to Polar Coordinate System	COb-2 CO-2	
6		14/12/2021	1	2D and 3D equations in polar system	COb-2 CO-2	
7		16/12/2021	1	Stress function, Airy's	COb-2 CO-2	
8		16/12/2021	1	Boundary conditions	COb-2 CO-2	
9		20/12/2021	1	Solutions by polynomials	COb-2 CO-2	
10		21/12/2021	1	Bhirmonic Equation	COb-2 CO-2	
11		23/12/2021	1	Problems	COb-2 CO-2	

12		27/12/2021	1	Lame's Ellipsoid	COb-2 CO-2	

UNIT III

Lesson No.	Unit No.	Date	No. of Periods	Topics	Course Objectives & Outcomes	References Text Book
1	III	27/12/2021	1	Analysis of Stress	COb-3 CO-3	Theory of Elasticity, Timoshenko S. and GoodierJ. N., McGraw
2		28/12/2021	1	Principle stress	COb-3 CO-3	
3		30/12/2021	1	Problems on principle stress concept	COb-3 CO-3	
4		30/12/2021	1	Stress Transformation	COb-3 CO-3	
5		03/01/2022	1	Stress Transformation	COb-3 CO-3	
6		04/01/2022	1	Stress function problems	COb-3 CO-3	
7		06/01/2022	1	Stress Ellipsoid	COb-3 CO-3	
8		06/01/2022	1	Pure bending of beam	COb-3 CO-3	
9		10/01/2022	1	Cantilever beam with end load	COb-3 CO-3	
10		11/01/2022	1	Compatibility equations	COb-3 CO-3	
11		11/01/2022	1	Boundary Conditions	COb-3 CO-3	
12		24/01/2022	1	3D Equations of polar system	COb-3 CO-3	
13		25/01/2022	1	Equations of displacements	COb-3 CO-3	

UNIT IV

Lesson No.	Unit No.	Date	No. of Periods	Topics	Course Objectives & Outcomes	References Text Book
1	IV	27/01/2022	1	Introduction to Torsion	COb-4 & CO-4	Theory of Elasticity, Timoshenko S. and GoodierJ. N., McGraw
2		27/01/2022	1	Basic Equations	COb-4 & CO-4	
3		31/01/2022	1	Problems	COb-4 & CO-4	
4		01/02/2022	1	St.Venant's method	COb-4 & CO-4	
5		03/02/2022	1	Prandtls method	COb-4 & CO-4	
6		03/02/2022	1	Membrane Analogy	COb-4 & CO-4	
7		07/02/2022	1	Soap film concept	COb-4 & CO-4	
8		08/02/2022	1	Problems	COb-4 & CO-4	
9		10/02/2022	1	Bending of beam	COb-4 & CO-4	
10		10/02/2022	1	Torsion equation for circular c/s	COb-4 & CO-4	
11		14/02/2022	1	Torsion equation for Elliptical c/s	COb-4 & CO-4	
12		15/02/2022	1	Problems	COb-4 & CO-4	
13		17/02/2022	1	Problems	COb-4 & CO-4	

UNIT V

Lesson No.	Unit No.	Date	No. of Periods	Topics	Course Objectives & Outcomes	References Text Book
1	V	17/02/2022	1	Introduction to Plasticity	COb-5 CO-5	Theory of Elasticity, Timoshenko S. and GoodierJ. N., McGraw
2		21/02/2022	1	Yield criteria	COb-5 CO-5	
3		22/02/2022	1	Methods of Failure	COb-5 CO-5	
4		24/02/2022	1	Methods of Failure	COb-5 CO-5	
5		28/02/2022	1	Strain Hardening	COb-5 CO-5	
6		01/03/2022	1	Idealized stress strain cure	COb-5 CO-5	
7		04/03/2022	1	True stress and strain	COb-5 CO-5	
8		04/03/2022	1	Problems Solving	COb-5 CO-5	
9		07/03/2022	1	Problems Solving	COb-5 CO-5	
10		08/03/2022	1	Problems Solving	COb-5 CO-5	
11		10/03/2022	1	Revision	COb-5 CO-5	
12		10/03/2022	1	Revision	COb-5 CO-5	

Signature of HOD

Signature of faculty

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 1 Duration of Lesson: 1hr
Lesson Title: Introduction to Elasticity

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Express about Elasticity concept
2.Discuss the importance of Advanced Solid Mechanics in Civil Engineering

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Elasticity
- Stress and Strain Relationship
- Civil Engineering
- Advanced Solid Mechanics

Assignment / Questions:

1.Explain about importance of Advanced Solid Mechanics in Civil Engineering.

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Note: Mention for each question the relevant Objectives and OutcomesNos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 2 Duration of Lesson: 1hr
Lesson Title: Forces in Elastic body

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Discuss about Forces in Elastic body
2.Distinguish between Surface and Body forces
3. Difference between linear and non-linear elasticity

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Linear Elasticity& Non-Linear Elasticity
- Isotropic & Homogeneous
- Body Forces
- Surface Forces

Assignment / Questions:
1. Distinguish between Surface and Body forces
2. Explain about Linear and Non-linear elasticity

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Note: Mention for each question the relevant Objectives and OutcomesNos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 3 Duration of Lesson: 1hr
Lesson Title: Components of Stress

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Express about Stress concept
2. Discuss about Components of stress
3.Distinguish between different clay minerals

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Stress
- Stress Tensor
- Components of Stress
- Cartesian Coordinate system
- Equilibrium

Assignment / Questions:
1.Explain about Components of Stress

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Note: Mention for each question the relevant Objectives and OutcomesNos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 4 Duration of Lesson: 1hr

Lesson Title: Components of Stress

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Obtain the Stress Components

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Stress Symmetry
- Stress Tensor
- Equilibrium Equations

Assignment / Questions:
Discuss about Stress tensor and Stress symmetry

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Academic **Y**ear : 2021-22

Semester : I

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Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 5 Duration of Lesson: 1hr

Lesson Title: Components of Strain

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Distinguish between Stress and Strain
2. Derive the Components of Strain

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Strain
- Strain Tensor
- Strain Components
- Equilibrium Equations
- Strain Symmetry

Assignment / Questions:
1. Derive the Components of Strain

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 6 Duration of Lesson: 1hr

Lesson Title: Hooke's Law

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Hooke's law

2.Stress-Strain relationships by Hooke's law

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Hooke's law
- Pure shear
- Poisson's Ratio
- Volumetric Strain

Assignment / Questions:
1.Discuss about Hooke's law.
2. Derive Stress- Strain relationships by using Hooke's law .

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 7 Duration of Lesson: 1hr

Lesson Title: Derivation of Hooke's Law

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Drive the relationship between shear stress and strain by Hooke's law

2.Describe and find the Expression for Lame's Constant

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Shear Stress
- Bulk modulus
- Lame's Constant

Assignment / Questions:
1. Drive the relationship between shear stress and strain by Hooke's law
2. Describe and find the Expression for Lame's Constant

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 8 Duration of Lesson: 1hr

Lesson Title: Plain Stress and Strain

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Distinguish between Plane Stress and Strain
2. Find out stress at a point

TEACHING AIDS : White board, marker

TEACHING POINTS :

- Plane stress
- Plane Strain
- Stress at a point

Assignment / Questions:

1. Distinguish between Plane Stress and Strain

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 9 Duration of Lesson: 1hr
Lesson Title: Stress on an Arbitrary plane

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Assess Stress on an Arbitrary plane
2.Illustrate about Direction Cosines
3. Drive the stresses on an Arbitrary plane

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Arbitrary plane
- Direction Cosines
- Normal Component of stress
- Resultant Stress

Assignment / Questions:
1. Drive the stresses on an Arbitrary plane

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 11 Duration of Lesson: 1hr
Lesson Title: Hydrostatic state of stress, pure shear

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Hydrostatic Stress and Pure shear condition ?
2. Distinguish between Hydrostatic and Deviatoric Stress

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Hydrostatic Stress
- Pure shear
- Deviatoric Stress

Assignment / Questions:
1. Distinguish between Hydrostatic and Deviatoric Stress
2. Find out Component of Hydrostatic and Deviatoric Stress?

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 12 Duration of Lesson: 1hr
Lesson Title: St.Vanant's Principle

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about importance of St.Vanant's Principle
2. Application of St.Vanant's Principle

TEACHING AIDS : White board, marker
TEACHING POINTS :

- St.Vanant's Principle
- Stress Concentration

Assignment / Questions:
1. Explain about importance of St.Vanant's Principle

Signature of faculty

Note: Mention for each question the relevant Objectives and OutcomesNos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 13 Duration of Lesson: 1hr
Lesson Title: Equations of Elasticity

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Elasticity equations
2. Differentiate 2D and 3D equations

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Equations of elasticity
- 2D Equilibrium equitation
- Symmetry of Stresses

Assignment / Questions:

1. Differentiate 2D and 3D equations

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 14 Duration of Lesson: 1hr
Lesson Title: Equations of Equilibrium

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive Equilibrium equations for 2D element in Rectangular Coordinate System

TEACHING AIDS : White board, marker
TEACHING POINTS :

- 2D element
- Rectangular Coordinate system
- Equilibrium Equations in 2D

Assignment / Questions:

1. Derive Equilibrium equations for 2D element in Rectangular Coordinate System

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 15 Duration of Lesson: 1hr
Lesson Title: 3D Equations of Equilibrium

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:
1. Derive Equilibrium equations for 2D element in Rectangular Coordinate System
2. Differentiate 2D and 3D elements

TEACHING AIDS : White board, marker
TEACHING POINTS :

- 3D Element
- Rectangular Coordinate system
- Equilibrium Equations in 2D

Assignment / Questions:
1. Derive Equilibrium equations for 2D element in Rectangular Coordinate System

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 16 Duration of Lesson: 1hr
Lesson Title: Displacement Components

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about displacement components
2. Drive the expression for Displacement component of Stress

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Displacement
- Strain component
- Poisson's ratio

Assignment / Questions:
1. Drive the expression for Displacement component of Stress

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 17 Duration of Lesson: 1hr
Lesson Title: Introduction to Polar Coordinate System

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Discuss about polar coordinate system
2. Derive the Expressions for 2D equilibrium equations in Polar Coordinate system

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Coordinate system
- Polar coordinate system
- Cartesian coordinate system
- 2D Equations in Polar coordinate system

Assignment / Questions:

1. Derive the Expressions for 2D equilibrium equations in Polar Coordinate system
2. Explain importance of Polar Coordinate system

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Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 18 Duration of Lesson: 1hr
Lesson Title: 3D equations in polar system

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Discuss about polar coordinate system
2. Derive the Expressions for 3D equilibrium equations in Polar Coordinate system

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Coordinate system
- Polar coordinate system
- Cartesian coordinate system
- 3D Equations in Polar coordinate system

Assignment / Questions:

1. Derive the Expressions for 3D equilibrium equations in Polar Coordinate system

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 19 Duration of Lesson: 1hr
Lesson Title: Stress function

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Stress function
2. Derive Airy's Stress function

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Stress function
- Boundary conditions
- Airy's Stress function

Assignment / Questions:

1. Derive Airy's Stress function

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 20 Duration of Lesson: 1hr
Lesson Title: Boundary conditions

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Illustrate about boundary conditions
2. Derive the boundary conditions for different stress condition of elements

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Boundary Conditions
- Stress variation
- Cantilever beam
- Simply supported beam

Assignment / Questions:

1. Derive the boundary conditions for Cantilever beam with end load

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 21 Duration of Lesson: 1hr
Lesson Title: Solutions by polynomials

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Discuss about polynomials
2.Importance of polynomials
3. Derive equilibrium equations for elements by using polynomials

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Polynomial
- Degree of freedom
- Types of polynomial equations
- pure shear

Assignment / Questions:
1. Derive equilibrium equations for Simply supported beam with center load by using polynomials

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 22 Duration of Lesson: 1hr
Lesson Title: Biharmonic Equation

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive the Biharmonic equation

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Biharmonic equation
- Stress condition
- Equilibrium equations
- Moment of Inertia

Assignment / Questions:
1. Derive the Biharmonic equation

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 24 Duration of Lesson: 1hr

Lesson Title: Lame's Ellipsoid

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Write about Lame's Ellipsoid
2. Derive the expression for stress on Ellipsoid

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Ellipsoid
- Lame's constant
- Equilibrium equations
- Moment of Inertia

Assignment / Questions:
1. Derive the expression for Lame's Ellipsoid

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 25 Duration of Lesson: 1hr
Lesson Title: Analysis of Stress

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. What are the different types of Stress analysis methods?
2. What are the assumptions in Analytical methods?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Stress analysis
- Analytical methods
- Numerical methods
- Boundary Conditions

Assignment / Questions:
1. What are the different types of Stress analysis methods?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 26 Duration of Lesson: 1hr

Lesson Title: Principal Stress

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Discuss about principle stress and principle plain?
2. Explain about principle plane and failure mechanism?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Principal plane
- Principal stress
- Failure mechanism
- Principle directions

Assignment / Questions:
1. Discuss about principle stress and principle plain?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 28 Duration of Lesson: 1hr

Lesson Title: Problems on principle stress concept

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. what are stress invariants?
2. Solve some numerical on stress invariants?

TEACHING AIDS : White board, marker

TEACHING POINTS :

- Stress invariant
- Trace of matrix
- Characteristic equation
- Cofactor
- Direction cosines

Assignment / Questions:

1. Write the procedure to find principle stress using Stress invariants?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 29 Duration of Lesson: 1hr

Lesson Title: Stress Transformation

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Stress transformation?
2. Solve problems using stress transformation

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Stress transformation
- Stress coordinates
- Transformation matrix
- Resultant stress

Assignment / Questions:
1. Explain about Stress transformation?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 31 Duration of Lesson: 1hr

Lesson Title: Stress Transformation

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Strain transformation?
2. Solve problems using strain transformation

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Strain transformation
- Stress coordinates
- Strain coordinates
- Transformation matrix
- Resultant stress

Assignment / Questions:
1. Explain about Strain transformation and write the application of strain transformation?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 32 Duration of Lesson: 1hr

Lesson Title: Stress function problems

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about stress function?
2. Explain about Airy's Stress function?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Stress function
- Airy's stress function
- Polynomial solutions
- Compatibility equation
- Biharmonic function

Assignment / Questions:
1. Explain about Airy's Stress function?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 34 Duration of Lesson: 1hr

Lesson Title: Stress Ellipsoid

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Stress Ellipsoid ?
2. Write the importance of Lame's Ellipsoid?

TEACHING AIDS : White board, marker

TEACHING POINTS :

- Stress Ellipsoid
- Principal Stress
- Lames constant
- Boundary conditions
- Plane stress

Assignment / Questions:

1. Explain about Stress Ellipsoid/Lame's Ellipsoid ?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 35 Duration of Lesson: 1hr

Lesson Title: Pure bending of beam

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive the expression of bending moment for pure bending of beam

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Pure bending
- Bending moment
- Deflections
- Plane stress condition

Assignment / Questions:
1. Derive the expression of bending moment for pure bending of beam

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Bachupally, Kukatpally, Hyderabad – 500 090. (040) 6686 4440

LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 36 Duration of Lesson: 1hr

Lesson Title: Cantilever beam with end load

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive the expression of bending moment for Cantilever beam with end load

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Cantilever
- Bending moment
- Deflections
- Plane stress condition

Assignment / Questions:
1. Derive the expression of bending moment for Cantilever beam with end load

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 37 Duration of Lesson: 1hr

Lesson Title: Compatibility equations

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Write about compatibility equations?
2. Derive Compatibility equation

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Equilibrium equation
- Compatibility equation
- Bending moment
- Deflections
- Plane stress condition

Assignment / Questions:
1. Derive Compatibility equation

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor\

Lesson No: 39 Duration of Lesson: 1hr

Lesson Title: Boundary Conditions

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Boundary conditions ?
2. Use of boundary conditions

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Equilibrium equation
- Compatibility equation
- Bending moment
- Boundary conditions
- Plane stress condition

Assignment / Questions:
1. Explain and derive Boundary conditions ?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 40 Duration of Lesson: 1hr

Lesson Title: 3D Equations of polar system

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive the Elasticity equilibrium equations in polar coordinates?
2. Derive the 3D Elasticity equilibrium equations in polar coordinates ?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Polar coordinates
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Derive the 3D Elasticity equilibrium equations in polar coordinates ?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 41 Duration of Lesson: 1hr

Lesson Title: Equations of displacements

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive the Equations of displacements in rectangular coordinate system?
2. Explain about Equations of displacements?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Displacements
- Equations of displacements
- Rectangular coordinate
- Strain

Assignment / Questions:
1. Derive the Equations of displacements in rectangular coordinate system?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 42 Duration of Lesson: 1hr

Lesson Title: Equations of displacements

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive the Equations of displacements in rectangular coordinate system?
2. Explain about Equations of displacements?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Displacements
- Equations of displacements
- Rectangular coordinate
- Strain

Assignment / Questions:
1. Derive the Equations of displacements in rectangular coordinate system?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 43 Duration of Lesson: 1hr

Lesson Title: Introduction to Torsion

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Write about Torsional equations?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Torsion
- Equilibrium equation
- Compatibility equation
- Plane stress condition

Assignment / Questions:
1. Write about Torsional equations?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor\

Lesson No: 44 Duration of Lesson: 1hr

Lesson Title: Basic Equations

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain basic equations of torsion?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Torsion
- Compatibility equation
- Bending moment
- Boundary conditions
- Plane stress condition

Assignment / Questions:
1. Explain basic equations of torsion?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 49 Duration of Lesson: 1hr

Lesson Title: Membrane Analogy

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Membrane Analogy and Application?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Membrane Analogy
- St.Venant's method
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Explain about Membrane Analogy and Application?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 50 Duration of Lesson: 1hr

Lesson Title: Soap film concept

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Soap film concept and Application?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Prandtls method
- St.Venant's method
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Explain about Soap film concept and Application?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 51 Duration of Lesson: 1hr

Lesson Title: Bending of beam

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Torsional Bending of beam?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- St.Venant's method
- Equations of equilibrium
- Elasticity

Assignment / Questions:
Explain about Torsional Bending of beam?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 53 Duration of Lesson: 1hr

Lesson Title: Torsion equation for circular c/s

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive Torsion equation for circular c/s?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Prandtls method
- St.Venant's method
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Derive Torsion equation for circular c/s?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 54 Duration of Lesson: 1hr

Lesson Title: Torsion equation for Elliptical c/s

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Derive Torsion equation for Elliptical c/s?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Torsion equation for Elliptical c/s
- St.Venant's method
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Derive Torsion equation for Elliptical c/s?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 55 Duration of Lesson: 1hr

Lesson Title: Introduction to Plasticity

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Plasticity concept?
2. Write applications of Plasticity?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Plasticity
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Explain about Plasticity concept?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 56 Duration of Lesson: 1hr

Lesson Title: Yield criteria

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Yield criteria?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Plasticity
- Yield Criteria
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Explain about Yield criteria?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 58 Duration of Lesson: 1hr

Lesson Title: Methods of Failure

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain about Plasticity concept?
2. Write about Methods of Failure?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Plasticity
- Methods of Failure
- Yield Criteria
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Explain about Plasticity concept?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 59 Duration of Lesson: 1hr

Lesson Title: Strain Hardening

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1.Explain about Strain Hardening?
2.Explain about Yield criteria?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Plasticity
- Strain Hardening
- Yield Criteria
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Explain bout Strain Hardening?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 60 Duration of Lesson: 1hr

Lesson Title: Idealized stress strain cure

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Explain Idealized stress strain cure ?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Plasticity
- Stress and Strain
- Methods of Failure
- Yield Criteria
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Explain about Plasticity concept?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 61 Duration of Lesson: 1hr

Lesson Title: True stress and strain

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Write about True stress and strain?
2. Explain about Strain Hardening?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Plasticity
- Strain Hardening
- Yield Criteria
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Write about True stress and strain?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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LESSON PLAN

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Lesson No: 62 Duration of Lesson: 1hr

Lesson Title: Plastic Stress-Strain Relations

INSTRUCTIONAL/LESSON OBJECTIVES:

On completion of this lesson the student shall be able to:

1. Write about stress and strain relationships?

TEACHING AIDS : White board, marker
TEACHING POINTS :

- Plasticity
- Strain Hardening
- Stress and Strain
- Equations of equilibrium
- Elasticity

Assignment / Questions:
1. Write about stress and strain relationships?

Signature of faculty

Note: Mention for each question the relevant Objectives and Outcomes Nos.

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TUTORIAL SHEET - 1

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Tutorial corresponds to Unit No. - I

1. Q1. Answer the following
   a) What are body forces and surface forces?
   b) State of Pure Shear
   c) What is stress and strain tensor?
   d) Explain the Plane Stress and Plane Strain.
   e) What are Lame's constants?
2. Define principal stress and the principal planes
3. Explain Hooke's law
4. Explain Saint-Venant's Principe.

Objective Nos.: 1
Outcome Nos.: 1

Signature of HOD Signature of faculty

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TUTORIAL SHEET - 2

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Tutorial corresponds to Unit No. - II

1. Develop the differential equations of equilibrium for 2-D and 3-D problems in elasticity using Cartesian coordinate system with detailed Illustrations.
2. Explain the Strain components in polar coordinates.
3. Explain plane stress and plane strain cases
4. Give the basic equations of equilibrium
5. Derive Biharmonic equation in terms of Airy's stress function and State Airy's stress function for beam subjected to pure bending

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Objective Nos.: 2
Outcome Nos.: 2

Signature of HOD Signature of faculty

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TUTORIAL SHEET - 3

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Tutorial corresponds to Unit No. - III

1. The state of stress at a point with respect to x,y,z system is

$$\begin{matrix} 10 & 5 & -15, \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{matrix}$$ kN/sq.m.

Determine the stresses relative to x^1, y^1, z^1 coordinate systems obtained by a rotation through 45^0 about Z axis.

2. The three stress components at a point are given by

$$\begin{pmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{pmatrix}$$ kPa.

Calculate the principal stresses and their directions and maximum shear stress ?

3. Derive the compatibility equations for a 3-D system

Objective Nos.: 3
Outcome Nos.: 3

Signature of HOD Signature of faculty

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TUTORIAL SHEET - 4

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Tutorial corresponds to Unit No. - IV

1. Write a Short note on Strain rosette
2. Derive the expression of bending moment for pure bending of beam
3. Explain Saint Venants semi inverse method for evaluation of torsion in prismatic shafts. Hence calculate torsional moment and shear stresses in terms of stress function.
4. Derive Prandtl's torsion Stress function method for Prismatic bars?
5. Derive the saint venants solution to the problem of Torsion in straight bars and apply this solution to a bar with circular cross section.

Objective Nos.: 4
Outcome Nos.: 4

Signature of HOD Signature of faculty

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Bachupally, Kukatpally, Hyderabad – 500 090. (040) 6686 4440

TUTORIAL SHEET - 5

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Tutorial corresponds to Unit No. - V

1. Explain in detail the different theories of failure and write yield criterion for each.
2. Explain Mohr's theory of failure
3. State and explain the assumptions of Plasticity
4. Write the Significance of the theories of failures?
5. Explain briefly about
    a. Factor of safety in design
    b. yield Criteria
    c. Plasticity
    d. Strain Hardening
    e. Nominal and True Stress and Strain
    f. Resilience and toughness

Objective Nos.: 5
Outcome Nos.: 5

Signature of HOD Signature of faculty

Gokaraju Rangaraju Institute of Engineering and Technology (Autonomous)

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ASSIGNMENT SHEET – 1

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Assignment corresponds to Unit No. - I & Lesson

1. Define Stress and Strain
2. explain stress & strain components.
3. Body forces and surface forces
4. Explain about Linear and Non-Linear elasticity with examples
5. Explain Saint-Venant's Principe and Applications?
6. What do you understand by State of Pure Shear, Hydrostatic and Deviatoric state of stress?

Objective Nos.: 1
Outcome Nos.: 1

Signature of HOD Signature of faculty

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ASSIGNMENT SHEET – 2

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Assignment corresponds to Unit No. - II & Lesson

1. What are 2 dimensional rectangular coordinates.
2. Develop the differential equations of equilibrium for 2-D and 3-D problems in elasticity using Cartesian coordinate system with detailed Illustrations.
3. The state of stress at a point with respect to x,y,z system is

$$\begin{pmatrix} 10 & 5 & -15 \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{pmatrix}$$ kN/sq.m.

Determine the stresses relative to x^1, y^1, z^1 coordinate systems obtained by a rotation through 45^0 about Z axis.

4. Derive the state of stress on an Oblique plane ?

Objective Nos.:2
Outcome Nos.: 2

Signature of HOD Signature of faculty

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ASSIGNMENT SHEET – 3

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Assignment corresponds to Unit No. - III & Lesson

1. Derive Biharmonic equation in terms of Airy's stress function and State Airy's stress function for beam subjected to pure bending
2. The Cartesian stress components at a point are given blow σ_x=150 MPa, σ_y=-100 MPa, σ_z=200 MPa, τ_{xy}= τ_{yx}=75 MPa, τ_{yz}= τ_{zy}=30 MPa, τ_{zx}= τ_{xz}=-50 MPa, Find stress resultant at Q on a plane passing through Q where normal is coincident with the x-axis, also find normal stress (σ_n) and normal shear stress (τ_n)
3. Derive the state of stress on an Octahedral planes ?
4. Derive the compatibility equations for a 3-D system

Objective Nos.: 3
Outcome Nos.: 3

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Bachupally, Kukatpally, Hyderabad – 500 090. (040) 6686 4440

ASSIGNMENT SHEET – 4

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Assignment corresponds to Unit No. - IV & Lesson

1. Explain Saint Venants semi inverse method for evaluation of torsion in prismatic shafts. Hence calculate torsional moment and shear stresses in terms of stress function.
2. Derive Prandtl's torsion Stress function method for Prismatic bars?
3. Derive the saint venants solution to the problem of Torsion in straight bars and apply this solution to a bar with circular cross section.
4. Derive the saint venants solution to the problem of Torsion in straight bars and apply this solution to a bar with Elliptical cross section.

Explain membrane analogy for obtaining behavior of non-circular shafts under torsion
Objective Nos.: 4
Outcome Nos.: 4

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ASSIGNMENT SHEET – 5

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

This Assignment corresponds to Unit No. - V & Lesson

1. Explain in detail the different theories of failure and write yield criterion for each.
2. Explain Mohr's theory of failure
3. State and explain the assumptions of Plasticity
4. Write the Significance of the theories of failures?
5. Explain briefly about
    g. Factor of safety in design
    h. yield Criteria
    i. Plasticity
    j. Strain Hardening
    k. Nominal and True Stress and Strain
    l. Resilience and toughness

Objective Nos.: 5
Outcome Nos.: 5

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(Autonomous)
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EVALUATION STRATEGY

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

1. TARGET:

A) Percentage for pass: 90%

b) Percentage of class:

Total Strength: 21

S.No.	Class / Division	No. of Students
1	First Class with distinction	12
2	First Class	5
3	Pass Class	2

2. COURSE PLAN& CONTENT DELIVERY

S.No	Plan	Brief Description
1	Practice classes	62 Theory classes for Section A
3	Assignments	Assignments for solving numerical problems

3. METHOD OF EVALUATION

3.1 Continuous Assessment Examinations

- Assignments: Assignments to assess the knowledge of the student on the basics and concepts and Numerical Analysis in Advanced Solid Mechanics
- Seminars: To assess the knowledge of the student in Advanced Solid Mechanics.
- Quiz: To assess the knowledge of the student in various concepts and basics of Advanced Solid Mechanics
- Internal Examination: Internal Examinations to assess their overall knowledge in Advanced Solid Mechanics

3.2. Semester/End Examination

To test their abilities in the course Advanced Solid Mechanics and to approve their abilities learnt during the same.

4. List out any new topic(s) or any innovation you would like to introduce in teaching the subjects in this Semester.

Signature of HOD

Signature of faculty

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MAPPING

GR20D5002/ **Advanced Solid Mechanics**	**Course Outcomes**				
Course Objectives	1	2	3	4	5
1	X				
2		X			
3			X		
4				X	
5					X

`

Assessments

1. Assignment 2. Internal Examination 3. External Examination

4. Practical Projects 5. Viva

GR20D5002/ **Advanced Solid Mechanics**	**Course Outcomes**				
Assessments	1	2	3	4	5
1	X	X	X	X	X
2	X	X	X	X	X
3	X	X	X	X	X
4					
5					

GR20D5002/ **Advanced Solid Mechanics**	**Course Objectives**				
Assessments	1	2	3	4	5
1	X	X	X	X	X
2	X	X	X	X	X
3	X	X	X	X	X
4					
5					

CO-PO Mappings:

GR20D5002**/ Advanced Solid Mechanics**						
Course Outcomes	**A**	**B**	**C**	**D**	**E**	**F**
Have a good understanding of the theory, concepts, principles and governing equations of Elasticity principles.		M	H	M		
Develop equations of equilibrium and draw relations among stress, strain and displacement and utilize the equilibrium equations, compatibility equations and various boundary conditions to analyze elastic problems.			H		H	M
Gain the understating of three-dimensional problems of elasticity in Cartesian coordinates system ad able to determine principal stresses and planes of 3D problems.	M		H		H	M
Apply the principles of elasticity to solve torsional problems in prismatic bars and tubes.	M		H		M	M

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RUBRIC TEMPLATE

Academic **Y**ear : 2021-22
Semester : I
Name of the Program: M.Tech Structural Engineering Year: I Section: A
Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering
Designation: Assistant Professor

Objective: To learn basics and concepts of Advanced Solid Mechanics.
Student Outcome: Behavioural studies or analyze the structural elements and study different parameters such as forces, bending moments, shear forces, stresses, strains, Cartesian Coordinate system and Polar Coordinate System in 2D and 3D, Torsion on elements and Plasticity etc.,

			Beginning	**Developing**	**Reflecting Development**	**Accomplished**	**Exemplary**	**Score**
S. No	**Name of the Student**	**Performance Criteria**	**1**	**2**	**3**	**4**	**5**	
1	21241D 2007	Analysis of Stress and Strain	Low level of knowledge on Elasticity and Stress and Strain	Able to discuss the Elasticity and Stress and Strain	Ability to explain the application Elasticity and Stress and Strain	Full knowledge on Elasticity and Stress and Strain	Analyzing and implement in structures	5
		The level of knowledge on types Coordinate Systems i.e Cartesian and Polar	Low level of knowledge on types Coordinate Systems i.e Cartesian and Polar	Able to discuss types of Coordinate Systems i.e Cartesian and Polar	Ability to explain types Coordinate Systems i.e Cartesian and Polar	Full knowledge on types Coordinate Systems i.e Cartesian and Polar	Analysing and application of knowledge on types Coordinate Systems i.e Cartesian and Polar	4
		The level of knowledge to analyse various engineering Elements and Plasticity	Low level of knowledge to analyse various engineering Elements and Plasticity	Ability to discuss and to study the various engineering Elements and Plasticity	Ability to explain various engineering structures.	Full knowledge on various engineering structures.	Analysing and implementing the knowledge of various engineering Elements and Plasticity	3
							Average Score	4

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COURSE COMPLETION STATUS

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Actual Date of Completion & Remarks, if any

Units	**Remarks**	**Objectives Achieved**	**Outcomes Achieved**
Unit I	02-12-2021 Unit covered on time	1	1
Unit II	27-12-2021 Unit covered on time	2	2
Unit III	25-01-2022 Unit covered on time	3	3
Unit IV	17-02-2022 Unit covered on time	4	4
Unit V	10-03-2022 Unit covered on time	5	5

Signature of HOD Signature of faculty

Date: Date:

Note: After the completion of each unit mention the number of Objectives & Outcomes Achieved.

M.TechI Year I Semester Regular Examinations[Modal Paper]

Advanced Solid Mechanics

(M.Tech. Structural Engineering)

Time: 3 hours **Max Marks: 70**

< **Note: T**ype the questions in the given format only, Times New Roman font , size 12 >

Instructions:

1. Question paper comprises of **Part-A** and **Part-B**
2. **Part-A** (for 20 marks) must be answered at one place in the answer book.
3. **Part-B** (for 50 marks) consists of **five questions with internal choice,**answer all questions.

PART – A

(Answer ALL questions. All questions carry equal marks)

2 * 10 = 20 Marks

1. a.	What are plane strain & plane stress problems? (CO1)	**[2]**
b.	Define Stress and Strain tensors?(CO1)	**[2]**
c.	Explain Saint-Venant's Principle.(CO2)	**[2]**
d.	What is strain rosette?(CO2)	**[2]**
e.	What are stress invariants?(CO3)	**[2]**
f.	What is uniqueness theorem?(CO4)	**[2]**
g.	Define warping in torsion.(CO5)	**[2]**
h.	Explain Soap film analogy method.(CO6)	**[2]**
i.	What is (a) Plastic flow (b) Yield surface?(CO7)	**[2]**
j.	Explain the Bauschinger effect on steel?(CO7)	**[2]**

PART – B

(Answer ALL questions. All questions carry equal marks)

10 * 5 = 50 Marks

2.	**(a)** The state of stress at a point is given by $\sigma_{XX} = 10, \tau_{XY} = 8$ $\sigma_{YY} = -6, \tau_{YZ} = 0$ $\sigma_{ZZ} = 4, \tau_{ZX} = 0$ Consider another set of co-ordinate axis X^1, Y^1, Z^1 in which Z^1 coincides with Z-axis and X^1 is rotated by 30° anti-clock wise from the X axis. Determine the stress components in the new system?(CO1) **(b)** Develop the differential equations of equilibrium for the case of 2-D problem in elasticity using polar coordinate system.(CO3)	**[10]**

	OR	
3.	**(a)** Derive strain displacement relations.(CO1) **(b)** Obtain the Cauchy's Stress Formulae. (CO2)	**[10]**
4.	**(a)** Derive Airy's stress function for beam subjected to pure bending.(CO2) **(b)** Derive the relation between the Lame's coefficients and Elastic Constants.(CO2)	**[10]**
	OR	
5.	**(a)** Derive Bi-harmonic equation in terms of Airy's stress function.(CO2) **(b)**The three stress components at a point are given by $\begin{pmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{pmatrix}$ kPa. Calculate the principal stresses and principal planes.(CO2)	**[10]**
6.	**(a)** Write the equation of equilibrium for a 3-D problem in elasticity in terms of displacements.(CO2) **(b)** How does a circular hole effect the stress distribution in a plate under uniform stress distribution .Explain and sketch the distribution?(CO4)	**[10]**
	OR	
7.	**(a)** Derive the differential equations of equilibrium for the case of 3-D problem in elasticity(CO2) **(b)** Derive the compatibility equations for a 3-D system.(CO2)	**[10]**
8.	Develop the differential equation for bending of a cantilever by terminal loads with (i) circular section and (ii) with elliptical section.(CO6)	**[10]**
	OR	
9.	Discuss about Saint Venant's Semi Inverse Method for prismatic bars under torsion and arrive at shear stress and torque values in terms of stress function Ø. Apply the method to a bar of elliptic c/s to obtain distribution of shear stress and warping displacement in c/s.(CO5)	**[10]**
10.	Explain in detail the different theories of failure and write yield criterion for each. (CO7)	**[10]**
	OR	
11.	**(a)** State and explain the assumptions of Plasticity(CO7) **(b)** Explain Mohr's theory of failure(CO7)	**[10]**

*****

GOKARAJU RANGARAJU
INSTITUTE OF ENGINEERING AND TECHNOLOGY
Department of Civil Engineering
I M.Tech. I Semester MID I EXAMINATION February 2022

ADVANCED SOLID MECHANICS (GR20D5002)

Time:75 Minutes **Date of examination 07-02--2022(AN)** **Max. Marks : 15 Marks**
Answer all questions **3x5=15Marks**

Name:_____ **Roll No.** | | | | | | | | | |

1. Answer the following [CO1][BL2]
   a) What are body forces and surface forces?
   b) Give the relation between elastic constants.
   c) What is stress and strain tensor?
   d) Explain the Plane Stress and Plane Strain.
   e) What are Lame's constants?

OR

2. Develop the differential equations of equilibrium for 2-D and 3-D problems in elasticity using Cartesian coordinate system with detailed Illustrations. [CO1][BL2]

3. Derive the state of stress on an Oblique plane ? [CO2][BL3]

OR

4. The three stress components at a point are given by [CO2][BL3]

$$\begin{pmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{pmatrix}$$ kPa. Calculate the principal stresses and their directions and maximum shear stress ?

5. The state of stress at a point with respect to x,y,z system is [CO3][BL4]

$$\begin{pmatrix} 10 & 5 & -15 \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{pmatrix}$$ kN/sq.m.

Determine the stresses relative to x^1, y^1, z^1 coordinate systems obtained by a rotation through 45^0 about Z axis.

OR

6. Derive Biharmonic equation in terms of Airy's stress function and State Airy's stress function for beam subjected to pure bending [CO3][BL4]

GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY

Department of Civil Engineering

I M.Tech. I Semester MID I EXAMINATION February 2022

ADVANCED SOLID MECHANICS (GR20D5002)

Time: 15 Minutes **Date of examination: 07-02--2022 (AN)** **Max. Marks : 5Marks**

Answer all questions **10x1/2=15Marks**

Name:_____ **RollNo.** | | | | | | | | | | |

1. Young's modulus is defined as the ratio of ( )
   a) Volumetric stress and volumetric strain
   b) Lateral stress and lateral strain
   c) Longitudinal stress and longitudinal strain
   d) Shear stress to shear strain
2. When a body is subjected to a direct tensile stress (σx) in one plane accompanied by a simple shear stress (τxy), the minimum normal stress is ( )
   a) $(\sigma x/2) + (1/2) \times \sqrt{(\sigma x^2 + 4\,\tau^2 xy)}$
   b) $(\sigma x/2) - (1/2) \times \sqrt{(\sigma x^2 + 4\,\tau^2 xy)}$
   c) $(\sigma x/2) + (1/2) \times \sqrt{(\sigma x^2 - 4\,\tau^2 xy)}$
   d) $(1/2) \times \sqrt{(\sigma x^2 + 4\,\tau^2 xy)}$
3. The materials which have the same elastic properties in all directions are called ____ ( )
   a) Isotropic b) Brittle c) Homogenous d) Hard
4. As the elastic limit reaches, tensile strain _____ ( )
   a) Increases more rapidly b) Decreases more rapidly
   c) Increases in proportion to the stress d) Decreases in proportion to the stress
5. What the number that measures an object's resistance to being deformed elastically when stress is applied to it? ( )
   a) Elastic modulus b) Plastic modulus c) Poisson's ratio d) Stress modulus
6. Find the strain of a brass rod of length 100mm which is subjected to a tensile load of 50kN when the extension of rod is equal to 0.1mm? ( )
   a) 0.01 b) 0.001 c) 0.05 d) 0.005
7. The law which states that within elastic limits strain produced is proportional to the stress producing it is known as _____ ( )
   a) Bernoulli's law b) Hooke's law c) Stress law d) Poisson's law
8. At the state of pure shear, normal stress value will ( )
   a) maximum b) equal to shear c) zero d) None
9. What is Hooke's law for the 1-D system? ( )
   a) The relation between normal stress and the corresponding strain
   b) The relation between shear stress and the corresponding strain
   c) The relation between lateral strain and the corresponding stress
   d) None of the mentioned
10. The slope of the stress-strain curve in the elastic deformation region is _____ ( )
    a) Elastic modulus b) Plastic modulus c) Poisson's ratio d) None of the mentioned

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INSTITUTE OF ENGINEERING AND TECHNOLOGY

Department of Civil Engineering

I M.Tech. I Semester MID II EXAMINATION March 2022

ADVANCED SOLID MECHANICS (GR20D5002)

Time:75 Minutes **Date of Examination: 14-03-2022 (AN)** **Max. Marks : 15 Marks**

Answer all questions **3 x 5 = 15 Marks**

Question No.		Blooms Levels*	Course Outcome
1	Develop the expression of bending moment for pure bending of beam with near sketch	BL3	CO3
	OR		
2	Describe in detail a). Strain rosette b). Stress at a point in Polar coordinate system	BL1	CO3
3	Develop a torsion equation for prismatic shafts by using Saint Venants semi inverse method with neat sketch.	BL3	CO4
	OR		
4	Derive the saint venants solution to the problem of Torsion in straight bars and apply this solution to a bar with circular cross section.	BL6	CO4
5	Classify the different theories of failure and write yield criterion for each.	BL4	CO5
	OR		
6	Explain briefly about a. Factor of safety in design b. yield Criteria c. Strain Hardening d. Nominal and True Stress and Strain e. Resilience and toughness	BL2	CO5

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INSTITUTE OF ENGINEERING AND TECHNOLOGY

Department of Civil Engineering

I M.Tech. I Semester MID II EXAMINATION March 2022

ADVANCED SOLID MECHANICS (GR20D5002)

Time: 15 Minutes Date of Examination: 14-03-2022 (AN) **Max. Marks : 5 Marks**

Answer all questions **10 x 1/2 = 5 Marks**

Name:_____ **Roll No.** | | | | | | | | | | |

1. Factor of safety is ( )
   e) Tensile stress / Permissible stress
   f) Compressive stress / Ultimate stress
   g) Ultimate stress / Permissible stress
   h) Ultimate stress / Shear stress
2. A brittle material has ( )
   e) No elastic zone c) No plastic zone
   f) Large plastic zone d) None of these
3. The materials which have the same elastic properties in all directions_ ( )
   a) Isotropic b) Brittle c) Homogenous d) Hard
4. Torsional rigidity of a shaft is defined as ( )
   a) G/J b) GJ c) TJ d) T/J
5. When a shaft is subjected to a twisting moment, every cross-section of the shaft will be under ( )
   a) Tensile stress b) Compressive stress
   c) Shear stress d) None of the above
6. The polar moment of inertia of a solid circular shaft of diameter (d) is ( )
   a) $\pi d^2/16$ b) $\pi d^3/32$ c) $\pi d^4/32$ d) $\pi d^4/64$
7. The relationship between the true strain and engineering strain is given as( )
   a) $\varepsilon=e$ b) $\varepsilon=\ln(e)$ c) $\varepsilon=\ln(e+1)$ d) $\varepsilon=\ln(1/(1+e))$
8. At the state of pure shear, normal stress value will ( )
   a) maximum b) equal to shear c) zero d) None
9. Assumptions of Plastic theory ( )
   a) Material is isotropic
   b) There is no Bauschinger effect
   c) Material is incompressible in the plastic range
   d) All of the above
10. . The relationship between Young's modulus (E), Bulk modulus (K) and Poisson's ratio (μ) is given by ( )
    a) $E=2K(1-2\mu)$ b) $E=3K(1-2\mu)$ c) $E=2K(1-2\mu)$ d) $E=2K(1-3\mu)$

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M.Tech StructuralEngg. I yr-I Sem- GR20 2021-22			
ADVANCED SOLID MECHANICSGR20D5002 (MID-I)			
S.No	**Roll No**	**Name of Student**	**Maximum Marks (20 M)**
1	21241D2001	ATKAPURAM PRASHANTH	19
2	21241D2002	BANDI SRI RAM GOPAL	19
3	21241D2003	CHALLA MADHAVI	15
4	21241D2004	PAMMI DIVYA	14
5	21241D2005	DUMMA UMESH KUMAR	16
6	21241D2006	K LATHASREE	14
7	21241D2007	MARIYALA VAISHNAVI	20
8	21241D2008	MAVOORI PRANAV	15
9	21241D2009	MITTAPALLI NAGA ASHWINI	18
10	21241D2010	RAVULA VENKATA SURAJ REDD	12
11	21241D2011	REPATI MOHAN BABU	16
12	21241D2012	ANDHYA CHERUKU	19
13	21241D2013	SHAIK FEROZ	15
14	21241D2014	K SAI CHANDRA	19
15	21241D2015	THOTA HARSHAVARDHAN	16
16	21241D2016	ARIKUPPALA LALITHA	17
17	21241D2017	AMBA RAMA GNANENDRA SAI	16
18	21241D2018	SAI YENUMALA DEVESH GOUD	13
19	21241D2019	RASHANTH KUMAR	11
20	21241D2020	BAVANDLAPELLI THARUN TEJA	12
21	21241D2021	GNITISH KUMAR	14

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M.Tech Structural Engg. I yr-I Sem- GR20 2021-22			
ADVANCED SOLID MECHANICS GR20D5002 (MID-II)			
S.No	**Roll No**	**Name of Student**	**Maximum Marks (20 M)**
1	21241D2001	ATKAPURAM PRASHANTH	17
2	21241D2002	BANDI SRI RAM GOPAL	18
3	21241D2003	CHALLA MADHAVI	14
4	21241D2004	PAMMI DIVYA	17
5	21241D2005	DUMMA UMESH KUMAR	19
6	21241D2006	K LATHASREE	19
7	21241D2007	MARIYALA VAISHNAVI	19
8	21241D2008	MAVOORI PRANAV	15
9	21241D2009	MITTAPALLI NAGA ASHWINI	18
10	21241D2010	RAVULA VENKATA SURAJ REDD	14
11	21241D2011	REPATI MOHAN BABU	15
12	21241D2012	ANDHYA CHERUKU	17
13	21241D2013	SHAIK FEROZ	13
14	21241D2014	K SAI CHANDRA	19
15	21241D2015	THOTA HARSHAVARDHAN	14
16	21241D2016	ARIKUPPALA LALITHA	17
17	21241D2017	AMBA RAMA GNANENDRA SAI	15
18	21241D2018	SAI YENUMALA DEVESH GOUD	15
19	21241D2019	RASHANTH KUMAR	AB
20	21241D2020	BAVANDLAPELLI THARUN TEJA	10
21	21241D2021	GNITISH KUMAR	13

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COURSE COMPLETION STATUS

Academic **Y**ear : 2021-22

Semester : I

Name of the Program: M.Tech Structural Engineering Year: I Section: A

Course/Subject: Advanced Solid Mechanics Course Code: GR20D5002

Name of the Faculty: Mr. K. Veera Babu Dept.: Civil Engineering

Designation: Assistant Professor

Actual Date of Completion & Remarks, if any

Units	**Remarks**	**Objectives Achieved**	**Outcomes Achieved**
Unit I	02-12-2021 Unit covered on time	1	1
Unit II	27-12-2021 Unit covered on time	2	2
Unit III	25-01-2022 Unit covered on time	3	3
Unit IV	17-02-2022 Unit covered on time	4	4
Unit V	10-03-2022 Unit covered on time	5	5

Signature of HOD Signature of faculty

Note: After the completion of each unit mention the number of Objectives & Outcomes Achieved.

Gokaraju Rangaraju Institute of Engineering & Technology

(Autonomous College Affiliated to JNTUH) (12 Pages)

Bachupally, Kukatpally, Hyderabad - 500090

I | II **MID TERM EXAMINATION**

No. 419990

H.T. No. 2 1 2 4 1 D 2 0 0 2

Name of the Examination Branch: M.Tech I Year I Sem Mid I Exam ASM

Course M.Tech STE Branch Civil Date 14-03-2022

14/3/22

Signature of the Invigilator

Q.NO.	1		2		3		4		5		6		TOTAL
	a	b	a	b	a	b	a	b	a	b	a	b	
MARKS	5						5				4		14

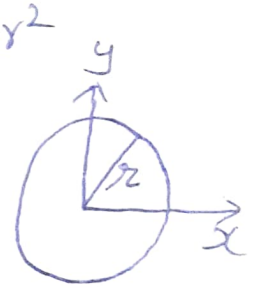
START WRITING FROM HERE

4. Saint Venants solution to the problem of Torsion in straight bars with circular cross section:

The Boundary of the circular crosssection is $x^2+y^2=r^2$

The poisson's ratio and boundary condition are to be satisfied by taking the stress function in the form

$$\phi = e(x^2+y^2-r^2)$$



We know that from

$$\nabla^2\phi = -2G\theta$$

where $\nabla^2\phi = \frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2}$

$$= \frac{\partial^2}{\partial x^2}(e(x^2+y^2-r^2)) + \frac{\partial^2}{\partial y^2}(e(x^2+y^2-r^2))$$

$$= (e(2)) + (e(2))$$

$$= 4e$$

$$\therefore 4e = -2G\theta$$

$$c = \frac{-G\theta}{2}$$

$$\therefore \phi = c(x^2+y^2-r^2)$$

$$= \frac{-G\theta}{2}(x^2+y^2-r^2) \quad -(1)$$

Apply Torque

$$T = 2\iint \phi \, dx\,dy$$

$$= 2\iint \frac{-G\theta}{2}(x^2+y^2-r^2)\,dx\,dy$$

$$= -G\theta\left[\iint x^2 dA + \iint y^2 dA - \iint r^2 dA\right] \quad (\because dx\,dy = dA)$$

$$= -G\theta$$

Here $\iint x^2 dA = I_{yy} = \frac{\pi r^4}{4}$

$\iint y^2 dA = I_{xx} = \frac{\pi r^4}{4}$

$\iint r^2 dA = r^2 \iint dA = r^2 A = r^2(\pi r^2) = \pi r^4$

on substituting

$$T = -G\theta\left[\frac{\pi r^4}{4} + \frac{\pi r^4}{4} - \pi r^4\right]$$

$$= -G\theta\left[-\frac{\pi r^4}{2}\right]$$

$$= G\theta\frac{\pi r^4}{2}$$

We know that $J = \frac{\pi r^4}{2}$ (Polar moment of Inertia)

$$\therefore T = G\theta J$$

$$\boxed{T = GJ\theta} \quad -(2)$$

Shear stress

$$\tau_{zx} = \frac{\partial \phi}{\partial y} = \frac{\partial}{\partial y}\left(-\frac{G\theta}{2}(x^2+y^2-r^2)\right) = -G\theta y$$

$$\tau_{zy} = -\frac{\partial \phi}{\partial x} = -\frac{\partial}{\partial y}\left(-\frac{G\theta}{2}(x^2+y^2-r^2)\right) = +G\theta x$$

We know resultant shear stress $\tau = \sqrt{\tau_{zx}^2 + \tau_{zy}^2}$

$$= \sqrt{(-G\theta y)^2 + (G\theta x)^2}$$

$$= G\theta\sqrt{y^2+x^2} = G\theta\sqrt{r^2} = G r\theta$$

$$\frac{T}{r} = G\theta \quad -③$$

From ② & ③

$$\therefore \boxed{\frac{T}{J} = \frac{\tau}{r} = G\theta}$$

where θ = angle of twist per unit length

Warping constant:

$$\tau_{zx} = -G\theta y$$

$$\tau_{zx} = G\theta\left(\frac{\partial \psi}{\partial x} - y\right) \quad \text{(from Saint Venant's Inverse method)}$$

$$\therefore -G\theta y = G\theta\left(\frac{\partial \psi}{\partial x} - y\right)$$

$$-y = \frac{\partial \psi}{\partial x} - y$$

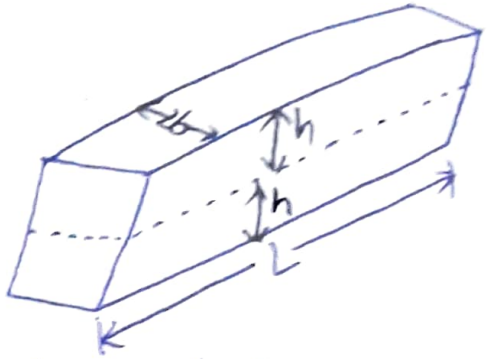
$$\frac{\partial \psi}{\partial x} = -y + y = 0$$

$$\therefore \boxed{\psi = \text{constant}}$$

Circular bar of stress function ψ is '0' only the cross section with zero warping

1. # Pure Bending of Beam :

Consider a rectangular beam of length 'L', width '2b' and of height '2h'



- The polynomial of second degree equation of stress function is given by $\phi = \frac{a_2 x^2}{2} + b_2 xy + \frac{c_2 y^2}{2}$

Stresses are given by $\sigma_x = \frac{\partial^2 \phi}{\partial y^2} = \frac{\partial}{\partial y^2}\left(\frac{a_2 x^2}{2} + b_2 xy + \frac{c_2 y^2}{2}\right)$

$= (0 + 0 + 2 \cdot \frac{1}{2} c_2) = c_2$

$\sigma_y = \frac{\partial^2 \phi}{\partial x^2} = \frac{\partial}{\partial x^2}\left(\frac{a_2 x^2}{2} + b_2 xy + \frac{c_2 y^2}{2}\right)$

$= a_2$

$\tau_{xy} = \frac{-\partial \phi}{\partial x \partial y} = -b_2$

Assume All Constant will be zero except c_2

$\sigma_x = c_2, \quad \sigma_y = 0, \quad \tau_{xy} = 0$

In this it gives a uniform stress function (field). (Moment = 0)

- The polynomial of third degree of stress function is given by

$\phi = \frac{a_3 x^3}{6} + \frac{b_3 x^2 y}{2} + \frac{c_3 xy^2}{2} + \frac{d_3 y^3}{6}$

$$\sigma_x = \frac{\partial^2 \phi}{\partial y^2} = c_3 x + d_3 y$$

$$\sigma_y = \frac{\partial^2 \phi}{\partial x^2} = a_3 x + b_3 y$$

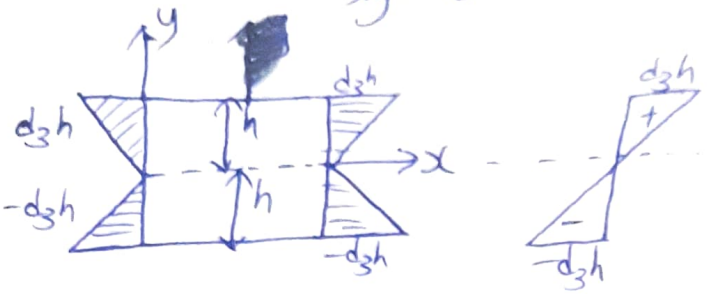
$$\tau_{xy} = \frac{-\partial^2 \phi}{\partial x \partial y} = b_3 x + c_3 y$$

Assume all constant be zero except d_3 This shows pure bending of the beam

$\therefore \sigma_x = d_3 y \Rightarrow$ pure bending of the beam

$\sigma_y = 0$

$\tau_{xy} = 0$



@ $y = -h \quad \sigma_x = -d_3 h$

$y = +h \quad \sigma_x = d_3 h$

Assume all constant be zero except b_3 (a) c_3

$\therefore \sigma_x = 0$

$\sigma_y = b_3 y$ (a) $\sigma_x = c_3 x$

$\tau_{xy} = -b_3 x$ $\sigma_y = 0$

$\tau_{xy} = c_3 y$

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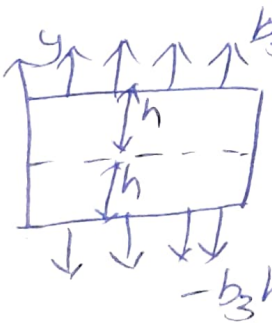
$\tau_{xy} = -b_3 L$



@ $\sigma_y = b_3 h$ @ $y = +h$

$\sigma_y = -b_3 h$ @ $y = -h$

6.

a) **Factor of safety:**

- The factor that to be taken for the consideration of safety of the material under ultimate load (factored load) rather than considering and designing only for the design load (given load)
- The material should be designed for the mode of collapse than the mode of failure (Servicability)
- F.O.S for concrete = 3 and steel = 1-2 (~1.8)

$$F.O.S = \frac{\text{Ultimate stress}}{\text{Corresponding stress}}$$

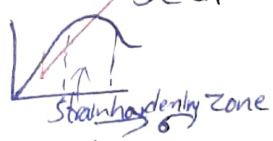
b) **yielding Criteria:**

The criterion for the material for the yielding under the ultimate load acting on it is called yielding criteria.

- The zone in this criteria is called yielding zone

c) **Strain hardening:**

The phase / zone in which the strain will be reaching the higher values like 0.002 in steel is called strain hardening zone.



d) **Nominal and True stress and strain:**

$$\text{Nominal stress } (\sigma_{nominal}) = \frac{\text{Force Applied}}{\text{Area acting}}$$

$$\text{True stress } (\sigma_{True}) = \frac{\text{Resisting force}}{\text{Area acting}}$$

$$\text{Nominal strain } (\varepsilon_{nominal}) = \frac{\delta l}{l} = \frac{\text{Change in length due to Load applied}}{\text{Original length}}$$

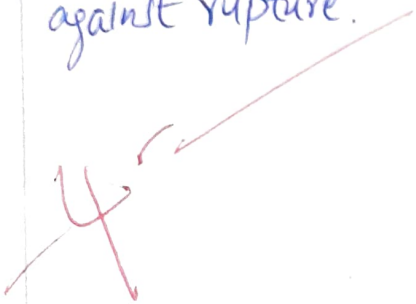
True strain (ε_{true}) = $\frac{\delta l}{l}$ = $\frac{\text{original deformation of length}}{\text{Original length taken}}$

e) Resilience and Toughness:

Resilience is the energy (Response energy) stored under the action of load on the body.

Toughness is the material property (inner surface) to resist the load

- If the material is said to be tough, the material can withstand the higher loads and can compensate the higher resistance against rupture.



4/5

Ram

GOKARAJU RANGARAJU

INSTITUTE OF ENGINEERING AND TECHNOLOGY

Department of Civil Engineering

I M.Tech. I Semester MID II EXAMINATION March 2022

ADVANCED SOLID MECHANICS (GR20D5002)

Time: 15 Minutes Date of Examination: 14-03-2022 (AN) Max. Marks : 5 Marks

Answer all questions 10 x 1/2 = 5 Marks

Name: Bandi Sri Ramgopal **Roll No.** 2 1 2 4 1 D 2 0 0 2

1. Factor of safety is (g/c)
   e) Tensile stress / Permissible stress
   f) Compressive stress / Ultimate stress
   g) Ultimate stress / Permissible stress
   h) Ultimate stress / Shear stress
2. A brittle material has (a)
   e) No elastic zone c) No plastic zone
   d) Large plastic zone d) None of these
3. The materials which have the same elastic properties in all directions_ (a)
   a) Isotropic b) Brittle c) Homogenous d) Hard
4. Torsional rigidity of a shaft is defined as (b)
   a) G/J b) GJ c) TJ d) T/J
5. When a shaft is subjected to a twisting moment, every cross-section of the shaft will be under (c)
   a) Tensile stress b) Compressive stress
   c) Shear stress d) None of the above
6. The polar moment of inertia of a solid circular shaft of diameter (d) is (c)
   a) $\pi d^2/16$ b) $\pi d^3/32$ c) $\pi d^4/32$ d) $\pi d^4/64$
7. The relationship between the true strain and engineering strain is given as (d)
   a) $\varepsilon=e$ b) $\varepsilon=\ln(e)$ c) $\varepsilon=\ln(e+1)$ d) $\varepsilon=\ln(1/(1+e))$
8. At the state of pure shear, normal stress value will (c)
   a) maximum b) equal to shear c) zero d) None
9. Assumptions of Plastic theory (d)
   a) Material is isotropic
   b) There is no Bauschinger effect
   c) Material is incompressible in the plastic range
   d) All of the above
10. The relationship between Young's modulus (E), Bulk modulus (K) and Poisson's ratio (μ) is given by (b)
    a) $E=2K(1-2\mu)$ b) $E=3K(1-2\mu)$ c) $E=2K(1-2\mu)$ d) $E=2K(1-3\mu)$

A 1/2
5

Fail

GOKARAJU RANGARAJU
INSTITUTE OF ENGINEERING AND TECHNOLOGY
Department of Civil Engineering
I M.Tech. I Semester MID I EXAMINATION February 2022

ADVANCED SOLID MECHANICS (GR20D5002)

Time: 15 Minutes **Date of examination: 07-02--2022 (AN)** **Max. Marks : 5Marks**
Answer all questions **10x1/2=15Marks**

Name: M. Vaishnavi Roll No. 2 1 2 4 1 D 2 0 0 7

1. Young's modulus is defined as the ratio of (c)
   a) Volumetric stress and volumetric strain
   b) Lateral stress and lateral strain
   c) Longitudinal stress and longitudinal strain
   d) Shear stress to shear strain
2. When a body is subjected to a direct tensile stress (σx) in one plane accompanied by a simple shear stress (τxy), the minimum normal stress is (b)
   a) $(\sigma x/2) + (1/2) \times \sqrt{(\sigma x^2 + 4\,\tau^2 xy)}$
   b) $(\sigma x/2) - (1/2) \times \sqrt{(\sigma x^2 + 4\,\tau^2 xy)}$
   c) $(\sigma x/2) + (1/2) \times \sqrt{(\sigma x^2 - 4\,\tau^2 xy)}$
   d) $(1/2) \times \sqrt{(\sigma x^2 + 4\,\tau^2 xy)}$
3. The materials which have the same elastic properties in all directions are called ____ (a)
   a) Isotropic b) Brittle c) Homogenous d) Hard
4. As the elastic limit reaches, tensile strain _____ (a)
   a) Increases more rapidly b) Decreases more rapidly
   c) Increases in proportion to the stress d) Decreases in proportion to the stress
5. What the number that measures an object's resistance to being deformed elastically when stress is applied to it? (d)
   a) Elastic modulus b) Plastic modulus c) Poisson's ratio d) Stress modulus
6. Find the strain of a brass rod of length 100mm which is subjected to a tensile load of 50kN when the extension of rod is equal to 0.1mm? (b)
   a) 0.01 b) 0.001 c) 0.05 d) 0.005
7. The law which states that within elastic limits strain produced is proportional to the stress producing it is known as _____ (b)
   a) Bernoulli's law b) Hooke's law c) Stress law d) Poisson's law
8. At the state of pure shear, normal stress value will (C)
   a) maximum b) equal to shear c) zero d) None
9. What is Hooke's law for the 1-D system? (a)
   a) The relation between normal stress and the corresponding strain
   b) The relation between shear stress and the corresponding strain
   c) The relation between lateral strain and the corresponding stress
   d) None of the mentioned
10. The slope of the stress-strain curve in the elastic deformation region is _____ (a)
    a) Elastic modulus b) Plastic modulus c) Poisson's ratio d) None of the mentioned

Gokaraju Rangaraju Institute of Engineering & Technology

(Autonomous College Affiliated to JNTUH)

Bachupally, Kukatpally, Hyderabad - 500090

(12 Pages)

I | II **MID TERM EXAMINATION**

No. 393938

H.T. No. 2 1 2 4 1 D 2 0 0 7

Name of the Examination I MTech I sem I mid, ASM

Course M.Tech Branch SIU Date 07/02/2022

Signature of the Invigilator 10/02/2022

Q.NO.	1		2		3		4		5		6		TOTAL
	a	b	a	b	a	b	a	b	a	b	a	b	
MARKS			5				5		5				15

START WRITING FROM HERE

4. $\begin{bmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{bmatrix}$ KPa.

WKT

$\sigma_p^3 - I_1\sigma_p^2 + I_2\sigma_p - I_3 = 0$

Here, I_1, I_2, I_3 are stress invarintes.

$I_1 = \sigma_x + \sigma_y + \sigma_z$

$= 100 + 80 + 60$

$= 240$

I_2 = cofactor of σ_x + cofactor of σ_y + cofactor of σ_z.

$= \begin{vmatrix} 80 & 100 \\ 100 & 60 \end{vmatrix} + \begin{vmatrix} 100 & 60 \\ 60 & 60 \end{vmatrix} + \begin{vmatrix} 100 & 50 \\ 50 & 80 \end{vmatrix}$

$= -5200 + 2400 + 5500$

$= 2700$

$$|\sigma| = \begin{vmatrix} -120.316 & 50 & 60 \\ 50 & -140.376 & 100 \\ 60 & 100 & -160.316 \end{vmatrix}$$

$$= 35.76$$

$$\sigma_p^2 - 421.128\sigma_p^2 + 42616\sigma_p - 35.76 = 0$$

$$a = 8.39 \times 10^{-4}$$

$$b = 252.05 \qquad K = \frac{1}{\sqrt{a^2+b^2+c^2}} = 1.191 \times 10^{-5}$$

$$c = 169.07$$

Direction cosine of σ_{P_2}.

$$[\sigma_2] = \begin{vmatrix} 100-51.293 & 50 & 60 \\ 50 & 80-51.293 & 100 \\ 60 & 100 & 50-51.293 \end{vmatrix}$$

$$= \begin{vmatrix} 48.707 & 50 & 60 \\ 50 & 28.707 & 100 \\ 60 & 100 & -1.293 \end{vmatrix}$$

$$I_1 = 48.707 + 28.707 - 1.293$$

$$= 76.121$$

$$I_2 = \begin{vmatrix} 28.707 & 100 \\ 100 & -1.293 \end{vmatrix} + \begin{vmatrix} 48.707 & 60 \\ 60 & -1.293 \end{vmatrix} + \begin{vmatrix} 48.707 & 50 \\ 50 & 28.707 \end{vmatrix}$$

$$= -10037.118 - 3662.978 + 1101.768$$

$$= -14801.864$$

$$I_3 = \begin{vmatrix} 48.707 & 50 & 60 \\ 50 & 25707 & 100 \\ 60 & 100 & -1.293 \end{vmatrix} = 11009.386$$

$\sigma_p^3 - 76.1219\sigma_p^2 - 14801.864\sigma_p - 11009.386 = 0$

a = 165.797

b = −0.746

c = −88.93

$k = \frac{1}{\sqrt{a^2+b^2+c^2}} = 6.04 \times 10^{-3}$

Direction cosine σ_{p3} or σ_3

$$[\sigma_3] = \begin{bmatrix} 100+81.67 & 50 & 60 \\ 50 & 80+31.67 & 100 \\ 60 & 100 & 60+31.67 \end{bmatrix} = \begin{bmatrix} 131.67 & 50 & 60 \\ 50 & 111.67 & 100 \\ 60 & 100 & 91.67 \end{bmatrix}$$

$I_1 = 131.67 + 111.67 + 91.67$

$= 335.01$

$$I_2 = \begin{vmatrix} 111.67 & 100 \\ 100 & 91.67 \end{vmatrix} + \begin{vmatrix} 131.67 & 60 \\ 60 & 91.61 \end{vmatrix} + \begin{vmatrix} 131.67 & 50 \\ 50 & 111.67 \end{vmatrix}$$

$= 236.789 + 8470.189 + 12203.589.$

$= 20909.967.$

$$I_3 = \begin{vmatrix} 131.67 & 50 & 60 \\ 50 & 111.67 & 100 \\ 60 & 100 & 91.67 \end{vmatrix}$$

$= -9.005.$

$\sigma_p^3 - 335.01\sigma_p^2 + 20909.967\sigma_p + 9.005 = 0.$

a = 252.05

b = 52.95

c = 4.306×10^{-4}

$k = \frac{1}{\sqrt{a^2+b^2+c^2}}$

$= 3.768 \times 10^{-3}$

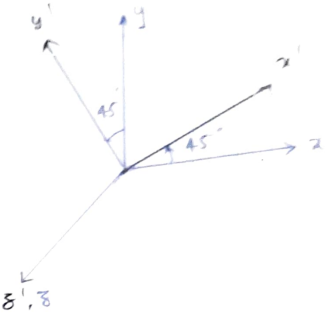
Maximum shear stress

$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2}$

$= \frac{226.376 - (-31.71)}{2}$

$= 126.023 \text{ kPa}$

5. $\begin{bmatrix} 10 & 5 & -15 \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{bmatrix}$



Axis	x	y	z
x'	45	45	90
y'	135	45	90
z'	90	90	0

$Q = \begin{bmatrix} \cos 45 & \cos 45 & \cos 90 \\ \cos 135 & \cos 45 & \cos 90 \\ \cos 90 & \cos 90 & \cos 0 \end{bmatrix} = \begin{bmatrix} \sqrt{2}/2 & \sqrt{2}/2 & 0 \\ -\sqrt{2}/2 & \sqrt{2}/2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$[\bar{T}] = [Q][T][Q]^T$

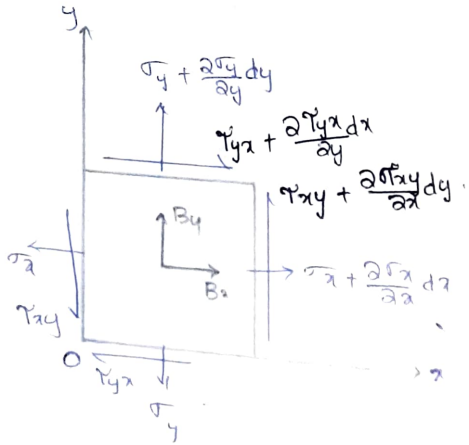
$= \begin{bmatrix} 0.707 & 0.707 & 0 \\ -0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 10 & 5 & -15 \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{bmatrix} \begin{bmatrix} 0.707 & -0.707 & 0 \\ 0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

5

$$[\sigma]' = \begin{bmatrix} 14.995 & 0 & 3.535 \\ 0 & 4.998 & 24.745 \\ 3.535 & 24.745 & 25 \end{bmatrix} \text{MPa (or) } KN/m^2.$$

2. Differential equations for 2D & 3D.

In 2D. consider a plane xy.



Taking moments about 'O' (clockwise +ve', counter clock wise -ve')

$$-\sigma_x (dy \times dz) \frac{dy}{2} + \left(\sigma_x + \frac{\partial \sigma_x}{\partial x} dx\right) dy \times dz \times \frac{dy}{2} + \tau_y \times dx \times dz \times \frac{dx}{2}$$

$$- \left(\sigma_y + \frac{\partial \sigma_y}{\partial y} dy\right) dx \times dz \times \frac{dx}{2} + \left(\tau_{yx} + \frac{\partial \tau_{yx}}{\partial x} dx\right)(dy \times dz) \times dy \times dx$$

$$- \left(\tau_{xy} + \frac{\partial \tau_{xy}}{\partial y} dy\right)(dx \times dz) \times dy + B_x \times dx \times dy \times \frac{dy}{2} = 0.$$

$dx\,dy\,dz$, $\frac{dx^2 dy}{2}$, $\frac{dx\,dy^2}{2}$ are neglected as they give small values i.e. equal to zero

We get

$\tau_{yx}\, dy\, dx\, dz - \tau_{xy}\, dx\, dy\, dz = 0$

$\tau_{yx}\, dy\, dx - \tau_{xy}\, dx\, dy = 0$

$\Rightarrow \boxed{\tau_{xy} = \tau_{yx}}$

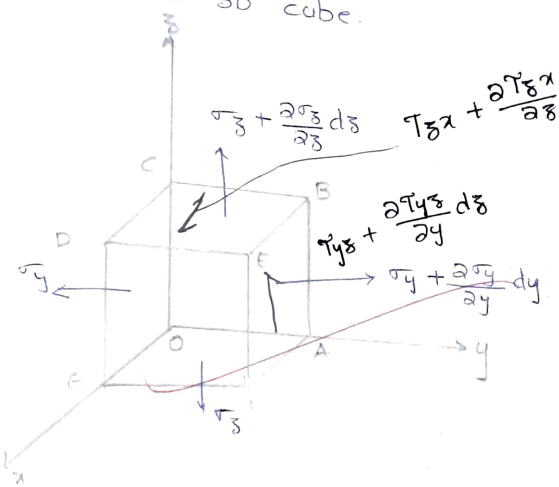
Similarly in xz and yz plane we get

$$\boxed{\tau_{xz} = \tau_{zx}}$$

$$\boxed{\tau_{yz} = \tau_{zy}}$$

3D.

Consider a 3D cube.



Consider plane

OABC $\longrightarrow$ σ_x acts, τ_{xy}, τ_{yz}, τ_{zx} ; OAGF $\longrightarrow$ σ_z , OCDG $\longrightarrow$ σ_y , τ_{yz}.

DEFG $\longrightarrow$ $\sigma_x + \frac{\partial \sigma_x}{\partial x} dx$, $\tau_{xy} + \frac{\partial \tau_{xy}}{\partial x} dy$

ABEF $\longrightarrow$ $\sigma_y + \frac{\partial \sigma_y}{\partial y} dy$, $\tau_{yz} + \frac{\partial \tau_{yz}}{\partial y} dz$

BCDE $\longrightarrow$ $\sigma_z + \frac{\partial \sigma_z}{\partial z} dz$, $\tau_{xy} + \frac{\partial \tau_{zx}}{\partial x} dx$

Taking moments about O

$$-\sigma_y \times dx\,dy\,dz + \left(\sigma_y + \frac{\partial \sigma_y}{\partial y} dy\right) dx\,dz\,dx$$

$$-\left(\sigma_z + \frac{\partial \sigma_z}{\partial z} dz\right) dy\,dx\,dy + \sigma_z\, dy\,dx\,dz$$

$$+ \sigma_x\, dx\,dy\,dz - \left(\sigma_x + \frac{\partial \sigma_x}{\partial x} dx\right) dz\,dy\,dz) \times$$

We know that by 2D equation.

$\tau_{xy} = \tau_{yx}$, $\tau_{yz} = \tau_{zy}$, $\tau_{xz} = \tau_{zx}$.

To be in equilibrium, we have two condition

$\Sigma f_x = 0 \quad \rightarrow 1.$

In 2D condition.

$$\left(\sigma_x + \frac{\partial \sigma_x}{\partial x} dx\right) dz\,dy - (\sigma_x)\, dz\,dy + \left(\tau_{yx} + \frac{\partial \tau_{yx}}{\partial y} dx\right) dz\,dy$$

$$- (\tau_{yx})\, dy\,dz + B_x\, dx\,dy\,dz = 0$$

$$\frac{\partial \sigma_x}{\partial x} dx\,dy + \frac{\partial \tau_{yx}}{\partial y} dx\,dy + B_x\, dx\,dy = 0$$

$(\because dx\,dy \neq 0)$

we get

$$\boxed{\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + B_x = 0}$$

$$\boxed{\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} + B_y = 0}$$

$$\frac{\partial \sigma_z}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + B_z = 0$$

Incase we consider

In 3D condition

$\Sigma f_x = 0$

$$\left(\sigma_x + \frac{\partial \sigma_x}{\partial x} dx\right) dy dz - \sigma_x dx dy dz + \tau_{zx} \cdot \left(\tau_{zx} + \frac{\partial \tau_{zx}}{\partial z} dz\right) dx dy - (\tau_{zx}) dx dy dx + \left(\tau_{xy} + \frac{\partial \tau_{xy}}{\partial y} dy\right) dx dz - \tau_{xy} dx dy dz + B_x dx dy dz = 0$$

$$\frac{\partial \sigma_x}{\partial x} dx dy dz + \frac{\partial \tau_{xy}}{\partial y} dy dx dz + \frac{\partial \tau_{xz}}{\partial z} dx dy dz + B_x dx dy dz = 0$$

$(\because dx dy dz \neq 0)$

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} + B_x = 0$$

$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{yx}}{\partial x} + \frac{\partial \tau_{yz}}{\partial z} + B_y = 0$$

$$\frac{\partial \sigma_z}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + B_z = 0$$

(5)

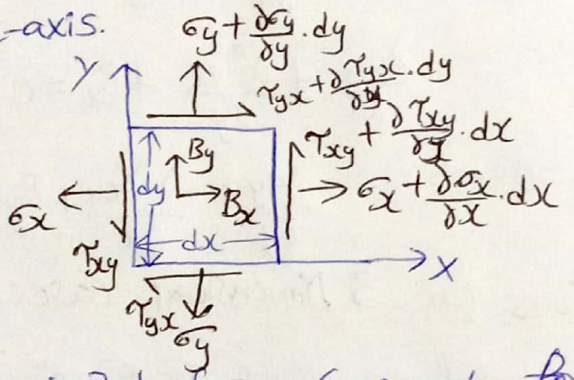
Advanced Solid Mechanics
Assignment-1

B Sri Ram Gopal
212410002
M.Tech (I/II)

1. Develop the differential equations of equilibrium for 2-D and 3-D problems in elasticity using Cartesian coordinate system with detailed illustrations.

2-Dimensional (2D) Differential Equation:

- If the body is in equilibrium, then a small representative part is also in equilibrium.
- In a stressed body components of stresses will vary from point to point.
- In 2D case the stresses acting are σ_x, σ_y, τ_{xy} & τ_{yx}. These stresses donot vary through the thickness because they are independent of z-axis.



$B_x, B_y \Rightarrow$ Body forces Components per unit volume in x & y directions.

Moment of force along point 'o'.

$$\left(\sigma_y + \frac{\partial \sigma_y}{\partial y}.dy\right).(dx \times 1).\frac{dx}{2} - (\sigma_y).(dx \times 1).\frac{dx}{2} - \left(\sigma_x + \frac{\partial \sigma_x}{\partial x}.dx\right)(dy \times 1).\left(\frac{dy}{2}\right)$$

$$+(\sigma_x).(dy \times 1).\left(\frac{dy}{2}\right) + \left(\tau_{xy} + \frac{\partial \tau_{xy}}{\partial x}.dx\right)(dy \times 1)(dx) - \left(\tau_{yx} + \frac{\partial \tau_{yx}}{\partial y}.dy\right).$$

$$(dx \times 1)(dy) - B_x(dx\,dy).\frac{dy}{2} + B_y(dx\,dy).\frac{dx}{2} = 0$$

$$\frac{\partial \sigma_y}{\partial y}\frac{dx^2}{2}dy - \frac{\partial \sigma_x}{\partial x}.dx\frac{dy^2}{2} + (\tau_{xy} - \tau_{yx})(dx\,dy) +$$

$$\left(\frac{\partial \tau_{xy}}{\partial x}dx - \frac{\partial \tau_{yx}}{\partial y}dx\right)dx\,dy - B_x\,dx\frac{dy^2}{2} + B_y\frac{dx^2}{2}dy = 0$$

By neglecting Triple products

$$(\tau_{xy} - \tau_{yx})\,dx\,dy = 0 \Rightarrow \boxed{\tau_{xy} = \tau_{yx}}$$

Similarly $\tau_{yz} = \tau_{zy}$

$\tau_{zx} = \tau_{xz}$

For this element in equilibrium has to satisfy the two conditions

i) Sum of forces in each direction must be '0'.

ii) Sum of Moments of force about the reference axis should be '0'

For equilibrium of forces we can write $\Sigma F_x = 0$

$$\left(\sigma_x + \frac{\partial \sigma_x}{\partial x} dx\right)(dy \times 1) - (\sigma_x)(dy \times 1) + \left(\tau_{yx} + \frac{\partial \tau_{yx}}{\partial y} dy\right)(dx \times 1) - \tau_{yx}(dx \times 1) + B_x (dx\,dy) = 0$$

$$\frac{\partial \sigma_x}{\partial x} dx\,dy + \frac{\partial \tau_{yx}}{\partial y} dx\,dy + B_x\,dx\,dy = 0$$

$$\therefore \quad \frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + B_x = 0$$

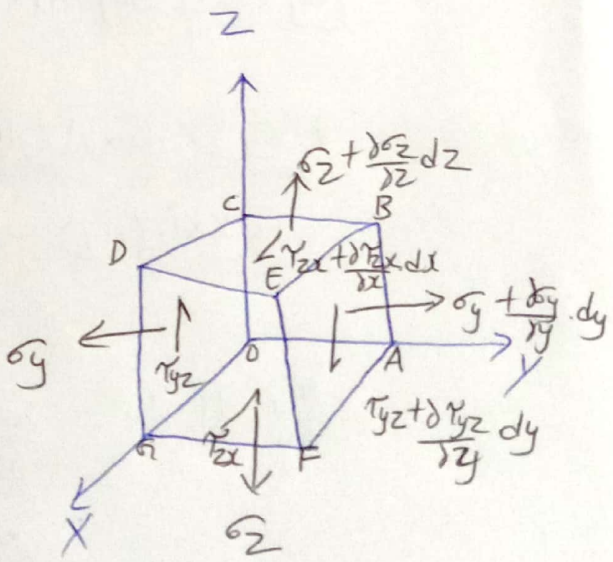
Similarly $\Sigma F_y = 0 \Rightarrow$ $\quad \frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + B_y = 0$

Differential Equations for 3 Dimensional Case:

In 3-D case Differential equations $\sigma_x, \sigma_y, \sigma_z, \tau_{xy}, \tau_{yz}, \tau_{zx}$ are the stress acting on the body.

- The components of body forces are B_x, B_y & B_z per unit volume in x, y & z direction.

Plane	Stress acting
OABC	σ_x
CDGO	σ_y
OAGF	σ_z
DEFG	$\sigma_x + \frac{\partial \sigma_x}{\partial x} dx$
ABEF	$\sigma_y + \frac{\partial \sigma_y}{\partial y} dy$
CDEB	$\sigma_z + \frac{\partial \sigma_z}{\partial z} dz$
OABC	τ_{xy}
CDGO	τ_{yz}
OAGF	τ_{zx}
DEFG	$\tau_{xy} + \frac{\partial \tau_{xy}}{\partial x} dx$
ABEF	$\tau_{yz} + \frac{\partial \tau_{yx}}{\partial y} dy$
CDEB	$\tau_{zx} + \frac{\partial \tau_{zx}}{\partial z} dz$



Taking Moment of forces about 'O' we get

$$\tau_{xy} = \tau_{yx}$$
$$\tau_{yz} = \tau_{zy}$$
$$\tau_{zx} = \tau_{xz}$$

For this cube element in equilibrium it has to satisfy 2-conditions

i) Sum of forces in each direction must be zero.

ii) Sum of Moments of forces about reference axis must be zero

From equilibrium of forces $\Sigma F_x = 0$

$$-\sigma_x)(dydz) + \left(\sigma_x + \frac{\partial \sigma_x}{\partial x}dx\right)(dydz) - \tau_{zx}\,dxdy + \left(\tau_{zx} + \frac{\partial \tau_{zx}}{\partial z}dz\right)dxdy$$

$$+\left(\tau_{yx} + \frac{\partial \tau_{yx}}{\partial y}dy\right)dxdz - \tau_{yx}\,dxdz + B_x\,dydxdz = 0$$

$$\frac{\partial \sigma_x}{\partial x}dxdydz + \frac{\partial \tau_{zx}}{\partial z}dxdydz + \frac{\partial \tau_{yx}}{\partial y}dxdydz + B_x\,dydxdz = 0$$

$$\left(\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{zx}}{\partial z} + \frac{\partial \tau_{yx}}{\partial y} + B_x\right)(dxdydz) = 0$$

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{zx}}{\partial z} + \frac{\partial \tau_{yx}}{\partial y} + B_x = 0 \quad -① \quad (\because dxdydz \neq 0)$$

Similarly in y-direction we get

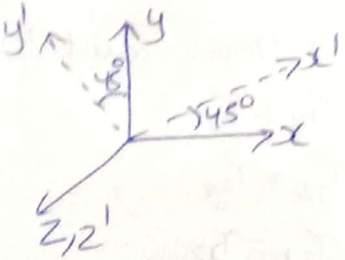
$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{zy}}{\partial z} + B_y = 0 \quad -②$$

$$\frac{\partial \sigma_z}{\partial z} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{xz}}{\partial x} + B_z = 0 \quad -③$$

Note: These equations represent the balance between externally applied body forces & internally developed stress forces.

2) The state of stress at a point w.r.t x,y,z system is $\begin{bmatrix} 10 & 5 & -15 \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{bmatrix}$ KN/m^2. Determine the stresses relative to x', y', z' co-ordinate syst obtained by a rotation through 45° about z-axis.

Note: About the z axis means z coincides with z'



Axis	x	y	z
x'	45°	45°	90
y'	135°	45°	90
z'	90	90	0°

The transformation matrix Q is given by

$$Q = \begin{bmatrix} \cos(x',x) & \cos(x',y) & \cos(x',z) \\ \cos(y',x) & \cos(y',y) & \cos(y',z) \\ \cos(z',x) & \cos(z',y) & \cos(z',z) \end{bmatrix}$$

$$= \begin{bmatrix} \cos 45^\circ & \cos 45^\circ & \cos 90^\circ \\ \cos 135^\circ & \cos 45^\circ & \cos 90^\circ \\ \cos 90^\circ & \cos 90^\circ & \cos 0^\circ \end{bmatrix}$$

$$= \begin{bmatrix} 0.707 & 0.707 & 0 \\ -0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[\sigma'] = [Q]\,[\sigma]\,[Q]^T$$

$$= \begin{bmatrix} 0.707 & 0.707 & 0 \\ -0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 10 & 15 & -15 \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{bmatrix} \begin{bmatrix} 0.707 & -0.707 & 0 \\ 0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 14.995 & 0 & 3.535 \\ 0 & 4.9984 & 24.745 \\ 3.535 & 24.745 & 25 \end{bmatrix}$$

3) The Three stress components at a point are given by $\begin{bmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{bmatrix}$ Kpa. Calculate the principal stresses and their direc and maximum shear stress?

$$[\sigma] = \begin{bmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{bmatrix} \text{Kpa}$$

$\sigma_p^3 - I_1\sigma_p^2 + I_2\sigma_p - I_3 = 0 \rightarrow$ Cubic equation

$I_1 = \sigma_x + \sigma_y + \sigma_z$ (Trace of Matrix)

$= 100 + 80 + 60 = 240$ Kpa

$$I_2 = \text{Cofactor of } \sigma_x + \text{Co}(\sigma_y) + \text{Co}(\sigma_z)$$

$$= \begin{vmatrix} 80 & 100 \\ 100 & 60 \end{vmatrix} + \begin{vmatrix} 100 & 60 \\ 60 & 60 \end{vmatrix} + \begin{vmatrix} 100 & 50 \\ 50 & 80 \end{vmatrix}$$

$$= -5200 + 2400 + 5500$$

$$= 2700$$

$$I_3 = |\sigma| = 100(-5200) - 50(-3000) + 60(200)$$

$$= -5,23,000$$

$$\therefore \sigma_p^3 - 240\sigma_p^2 + 2700\sigma_p + 5,23,000 = 0$$

$$\sigma_1 = 216.35 \text{ Kpa}$$

$$\sigma_2 = 62.396 \text{ Kpa}$$

$$\sigma_3 = -38.74 \text{ Kpa}$$

Direction cosines of σ_1:

$$\begin{bmatrix} (\sigma_x - \sigma_1) & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & (\sigma_y - \sigma_1) & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & (\sigma_z - \sigma_1) \end{bmatrix} \begin{bmatrix} l_1 \\ m_1 \\ n_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} (100-216.35) & 50 & 60 \\ 50 & (80-216.35) & 100 \\ 60 & 100 & (60-216.35) \end{bmatrix} \begin{bmatrix} l_1 \\ m_1 \\ n_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} -116.35 & 50 & 60 \\ 50 & -136.35 & 100 \\ 60 & 100 & -156.35 \end{bmatrix} \begin{bmatrix} l_1 \\ m_1 \\ n_1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Cofactor of the determinants on the elements of first row

$$a = \begin{vmatrix} -136.35 & 100 \\ 100 & -156.35 \end{vmatrix} = 11,318.3225$$

$$b = \begin{vmatrix} 50 & 100 \\ 60 & -156.35 \end{vmatrix} = -13,817.5$$

$$c = \begin{vmatrix} 50 & -136.35 \\ 60 & 100 \end{vmatrix} = 13,181$$

$$K = \frac{1}{\sqrt{a^2+b^2+c^2}} = \frac{1}{\sqrt{(11318.32)^2 + (-13,817.5)^2 + (13,181)^2}} = 4.505 \times 10^{-5}$$

The Direction cosines of principal stress σ_1 are

$$l_1 = ak = 11,318.32 \times 4.505 \times 10^{-5} = 0.509$$
$$m_1 = bk = -13,817.5 \times 4.505 \times 10^{-5} = -0.622$$
$$n_1 = ck = 13,181 \times 4.505 \times 10^{-5} = 0.593$$

Direction cosines of σ_2:

$$\begin{bmatrix} \sigma_x - \sigma_2 & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y - \sigma_2 & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z - \sigma_2 \end{bmatrix} \begin{bmatrix} l_2 \\ m_2 \\ n_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} (180-62.396) & 50 & 60 \\ 50 & (80-62.396) & 100 \\ 60 & 100 & (60-62.396) \end{bmatrix} \begin{bmatrix} l_2 \\ m_2 \\ n_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$a = \begin{vmatrix} 17.604 & 100 \\ 100 & -2.396 \end{vmatrix} = -10,042.18$$

$$b = \begin{vmatrix} 50 & 100 \\ 60 & -2.396 \end{vmatrix} = -6,119.8$$

$$c = \begin{vmatrix} 50 & 17.604 \\ 60 & 100 \end{vmatrix} = 3943.76$$

$$K = \frac{1}{\sqrt{a^2+b^2+c^2}} = 8.062 \times 10^{-5}$$

$$l_2 = ak = -0.8096$$
$$m_2 = bk = -0.493$$
$$n_2 = ck = 0.318$$

Direction cosines of σ_3:

$$\begin{bmatrix} \sigma_x - \sigma_3 & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y - \sigma_3 & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z - \sigma_3 \end{bmatrix} \begin{bmatrix} l_3 \\ m_3 \\ n_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 138.74 & 50 & 60 \\ 50 & 118.74 & 100 \\ 60 & 100 & 98.74 \end{bmatrix} \begin{bmatrix} l_3 \\ m_3 \\ n_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$a = \begin{vmatrix} 118.74 & 100 \\ 100 & 98.74 \end{vmatrix} = 1724.38$$

$$b = \begin{vmatrix} 50 & 100 \\ 60 & 98.74 \end{vmatrix} = -1063$$

$$C = \begin{vmatrix} 50 & 118.74 \\ 60 & 100 \end{vmatrix} = -2124.4$$

$$k = \frac{1}{\sqrt{a^2+b^2+c^2}} = 3.41 \times 10^{-4}$$

$$l_3 = ak = 0.588$$
$$m_3 = bk = -0.362$$
$$n_3 = ck = -0.724$$

Maximum shear stress

$$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2} = \frac{216.35 - (-38.74)}{2}$$

$$= 127.54 \text{ Kpa} //$$

4) Derive the Compatibility equations for a 3-D System?

Differential of ϵ_x w.r.t y & z $\Rightarrow$ $\frac{\partial^2 \epsilon_x}{\partial y \partial z} = \frac{\partial}{\partial y}\left(\frac{\partial}{\partial z}\left(\frac{\partial u}{\partial x}\right)\right)$

$$\frac{\partial^2 \epsilon_x}{\partial y \partial z} = \frac{\partial^3 u}{\partial x \partial y \partial z} \quad -(a)$$

Differential

$$\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \qquad \gamma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}$$

$$\frac{\partial}{\partial z}(\gamma_{xy}) = \frac{\partial^2 u}{\partial y \partial z} + \frac{\partial^2 v}{\partial x \partial z} \quad -(b) \qquad \frac{\partial \gamma_{yz}}{\partial x} = \frac{\partial^2 v}{\partial x \partial z} + \frac{\partial^2 w}{\partial x \partial y} \quad -(c)$$

$$\gamma_{zx} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}$$

$$\frac{\partial}{\partial y}(\gamma_{zx}) = \frac{\partial^2 u}{\partial y \partial z} + \frac{\partial^2 w}{\partial y \partial x} \quad -(d)$$

By doing b+d−c

$$\frac{2\partial^2 u}{\partial y \partial z} = \frac{\partial \gamma_{xy}}{\partial z} + \frac{\partial \gamma_{zx}}{\partial y} - \frac{\partial \gamma_{yz}}{\partial x}$$

we know that

$$\frac{\partial}{\partial x}\left(\frac{2\partial^2 u}{\partial y \partial z}\right) = \frac{2\partial \epsilon_x}{\partial y \partial z}$$

$$\frac{2\partial^2 \epsilon_x}{\partial y \partial z} = \frac{\partial}{\partial x}\left(\frac{\partial \gamma_{xy}}{\partial z} - \frac{\partial \gamma_{yz}}{\partial x} + \frac{\partial \gamma_{xz}}{\partial y}\right)$$

Similarly in y-direction

$$\frac{2\partial^2 \epsilon_y}{\partial x \partial z} = \frac{\partial}{\partial y}\left(\frac{\partial \gamma_{xy}}{\partial z} - \frac{\partial \gamma_{xz}}{\partial y} + \frac{\partial \gamma_{yz}}{\partial x}\right)$$

Similarly in z-direction

$$\frac{2\partial^2 \epsilon_z}{\partial x \partial y} = \frac{\partial}{\partial z}\left(-\frac{\partial \gamma_{xy}}{\partial z} + \frac{\partial \gamma_{yz}}{\partial x} + \frac{\partial \gamma_{zx}}{\partial y}\right)$$

These are the 3D compatibility equations of strain

Note: The above equations are called "Saint-Venant's Equations of compatibility of components of strain".

Assignment - I

Advance Solid Mechanics (ASM).

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1. Differential equations of equilibrium for 2D and 3D problem.

Two Dimensional (2D) differential equations.

If the body is in equilibrium, then the small respresntative parts are also in equilibrium.

ie, $x \longrightarrow dx \longrightarrow \partial x$

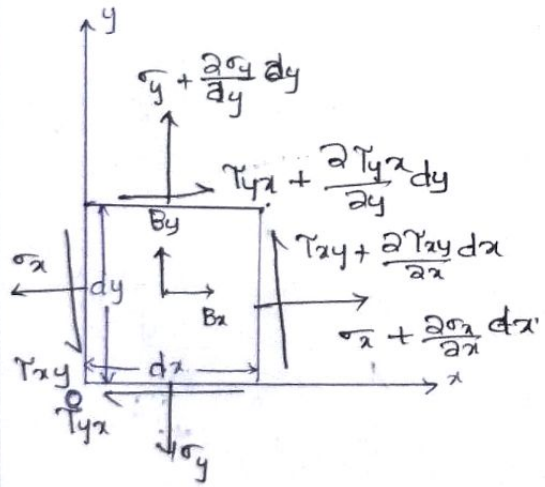
part of x — part of dx.

In a stressed body, stress components vary from point to point.

In 2D, the stresses acting are σ_x, σ_y, σ_z, τ_{xy}, τ_{yz} and τ_{xz}

These stresses doesnot vary from point to point through the thickness, because they are independent of z-axis.

Let us consider an x-y plane.



Bx and By are the components of body forces per unit volume in x and y axis.

($B_z = 0$, 2D).

Take moments about point 'O'.

$$\left[\sigma_y + \frac{\partial \sigma_y}{\partial y}(dy)\right] \times dx \times \frac{dx}{2} - \sigma_y \times dx \times \frac{dx}{2}$$

$$- \left[\sigma_x + \frac{\partial \sigma_x}{\partial x}(dx)\right] dy \cdot \frac{dy}{2} + [\sigma_x \times dy] \frac{dy}{2}$$

$$+ \left[\tau_{xy} + \frac{\partial \tau_{xy}}{\partial x}(dx)\right] \times dy \times dx$$

$$- \left[\tau_{yx} + \frac{\partial \tau_{yx}}{\partial y}(dy)\right] dx \cdot dy$$

$$- B_x\, dx\, dy \frac{dy}{2} + B_y\, dx\, dy \frac{dx}{2} = 0$$

(∵ $dx^2 dy$ or $dy dx^2$ almost equal to zero)

By neglecting triple product ie, ($dx, dy, \frac{dx}{2}$ (or) $\frac{dy}{2}$) we get

$$\tau_{xy}\, dy\, dx - \tau_{yx}\, dx\, dy = 0 \Rightarrow \tau_{xy} = \tau_{yx}$$

11'y, $\tau_{yz} = \tau_{zy}$, $\tau_{xz} = \tau_{zx}$.

For this element in equilibrium, it has to satisfy conditions.

1. Sum of forces in each direction must be zero.
2. Sum of the moments of the force about the reference axis should be zero.

$\Sigma f_x = 0$ → for equilibrium of forces.

$$\left(\sigma_x + \frac{\partial \sigma_x}{\partial x} dx\right) dy \times 1 - \sigma_x \times dy \times 1 + \left(\tau_{yx} + \frac{\partial \tau_{yx}}{\partial y} dy\right) dx - \tau_{yx} \, dx \times 1$$

$$+ B_x \cdot dx \cdot dy = 0 \qquad (dx \cdot dy \neq 0)$$

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + B_x = 0$$

11'y, $\Sigma f_y = 0$

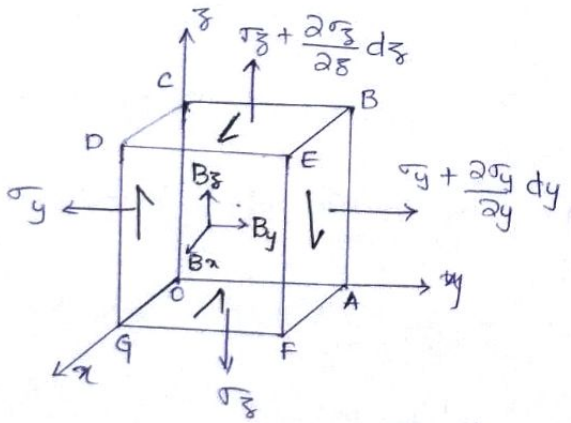
$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + B_y = 0$$

Differential equation for 3D.

In 3D, eq. equations are 6. ($\sigma_x, \sigma_y, \sigma_z, \tau_{xy}, \tau_{yz}, \tau_{zx}$).

Body force components are B_x, B_y, B_z per unit.

Volume in x, y, z - direction.



← $-\tau_{zx} + \frac{\partial \tau_{zx}}{\partial z} dz$

↑ $-\tau_{yz}$

| $-\tau_{yz} + \frac{\partial \tau_{yz}}{\partial y} dy$.

↗ $-\tau_{zx}$.

OCDG → σ_y

ABEF → $\sigma_y + \frac{\partial \sigma_y}{\partial y} dy$

OAGF → σ_z

BCDE → $\sigma_z + \frac{\partial \sigma_z}{\partial z} dz$.

OABC → τ_{xy}

OCDG → τ_{yz}

OAGF → τ_{zx}

DEFG $\longrightarrow \tau_{xy} + \frac{\partial \tau_{xy}}{\partial x} dx$

ABEF $\longrightarrow \tau_{yz} + \frac{\partial \tau_{yz}}{\partial y} dy.$

BCDE $\longrightarrow \tau_{zx} + \frac{\partial \tau_{zx}}{\partial z} dz.$

By taking moment of force about point O, we get

$$\tau_{xy} = \tau_{yx}$$

$$\tau_{yz} = \tau_{zy}$$

$$\tau_{xz} = \tau_{zx}$$

For this cube element in equilibrium, it has to satisfy two conditions.

1. Sum of forces in each direction must be zero.
2. Sum of moment of force about reference axis must be zero.

equilibrium eq. $\Sigma f_x = 0.$

$$-\sigma_x dydz + (\sigma_x + \frac{\partial \sigma_x}{\partial x} dx) dydz - \tau_{zx} dxdy + (\tau_{zx} + \frac{\partial \tau_{zx}}{\partial z} dz) dxdy$$

$$+ B_x (dxdydz) + (\tau_{yx} + \frac{\partial \tau_{yx}}{\partial y} dy) dxdz - \tau_{yx} dxdz = 0.$$

$$-\left(\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{zx}}{\partial z} + \frac{\partial \tau_{yx}}{\partial y} + B_x\right) dxdydz = 0$$

$\because dxdydz \neq 0.$

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{zx}}{\partial z} + \frac{\partial \tau_{yx}}{\partial y} + B_x = 0 \longrightarrow 1$$

11'y

$$\Sigma f_y = 0$$

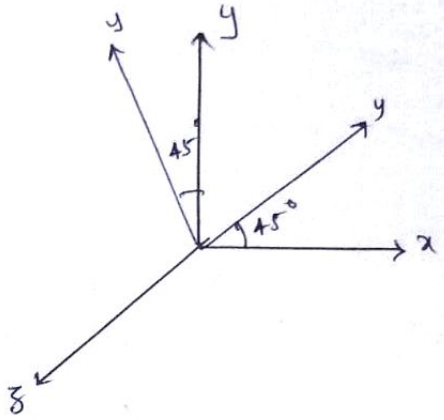
$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \frac{\partial \tau_{xy}}{\partial x} + B_y = 0 \longrightarrow 2$$

$$\Sigma f_z = 0$$

$$\frac{\partial \sigma_z}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + B_z = 0 \longrightarrow 3.$$

The equations 1, 2, 3 represents the balance between externally applied body forces and internally developed stress forces.

2. $$\begin{bmatrix} 10 & 15 & -15 \\ 5 & 10 & 20 \\ -15 & 20 & 25 \end{bmatrix} KN/m^2$$



Axis	x	y	z
x'	45°	45°	90°
y'	135°	45°	90°
z'	90°	90°	0°

$$Q = \begin{bmatrix} \cos 45 & \cos 45 & \cos 90 \\ \cos 135 & \cos 45 & \cos 90 \\ \cos 90 & \cos 90 & \cos 0 \end{bmatrix} = \begin{bmatrix} 0.707 & 0.707 & 0 \\ -0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\sigma' = [Q][\sigma][Q]^T$$

$$[\sigma'] = \begin{bmatrix} 19.99 & 4.99 & 3.54 \\ -4.99 & 0 & 24.745 \\ 3.535 & 24.745 & 25 \end{bmatrix}$$

3. $\sigma = \begin{bmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{bmatrix}$ Calculate the principal stresses and their directions, Max. shear stress.

$$\sigma = \begin{bmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{bmatrix} \text{ KPa}$$

$\sigma_p^3 - I_1\sigma_p^2 + I_2\sigma_p - I_3 = 0$ → Quadratic equation.

$I_1 = \sigma_x + \sigma_y + \sigma_z$.

$= 100 + 80 + 60$

$= 240$ KPa.

$I_2 =$ co-factor $(\sigma_x) + (\sigma_y)$ cofactor + co factor σ_z.

$$= \begin{vmatrix} 80 & 100 \\ 100 & 60 \end{vmatrix} + \begin{vmatrix} 100 & 60 \\ 60 & 60 \end{vmatrix} + \begin{vmatrix} 100 & 50 \\ 50 & 80 \end{vmatrix}$$

$= -5200 + 2400 + 5500$

$= 2700$ KPa

$$I_3 = |\sigma| = \begin{vmatrix} 100 & 50 & 60 \\ 50 & 80 & 100 \\ 60 & 100 & 60 \end{vmatrix}$$

$= -358000$ KPa.

$\sigma_p^3 - 240\sigma_p^2 + 2700\sigma_p + 358000 = 0$

$\sigma_{p_1} = 220.38$ KPa

$\sigma_{p_2} = 51.30$ KPa

$\sigma_{p_3} = -31.67$ KPa

Direction cosines of σ_1

$$\begin{vmatrix} (\sigma_x - \sigma_1) & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & (\sigma_y - \sigma_1) & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & (\sigma_z - \sigma_1) \end{vmatrix} \begin{Bmatrix} l_1 \\ m_1 \\ n_1 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}$$

$$\begin{vmatrix} (100 - 220.38) & 50 & 60 \\ 50 & (80 - 220.38) & 100 \\ 60 & 100 & (60 - 220.38) \end{vmatrix} \begin{Bmatrix} l_1 \\ m_1 \\ n_1 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}$$

→ Co-factor of the determinants on the elements of first row.

$$a = \begin{vmatrix} -110.38 & 50 & 60 \\ 50 & -140.38 & 100 \\ 60 & 100 & -160.38 \end{vmatrix}$$

$$a = \begin{vmatrix} -140.38 & 100 \\ 100 & -160.38 \end{vmatrix}, \quad b = \begin{vmatrix} 50 & 100 \\ 60 & -160.38 \end{vmatrix}, \quad c = \begin{vmatrix} 50 & -140.38 \\ 60 & 100 \end{vmatrix}$$

$= 12514.14 \text{ KPa}$ $= -14019 \text{ KPa}$ $= 13422.8 \text{ KPa}$

$$K = \frac{1}{\sqrt{a^2 + b^2 + c^2}} = \frac{1}{\sqrt{12514.14^2 + (-14019)^2 + (13422.8)^2}}$$

$$= 5.307 \times 10^{-5}.$$

The direction cosines of the principal stress σ_1 are.

$l_1 = ak = 12514.14 \times 5.307 \times 10^{-5}.$

$l_1 = 0.664$

$m_1 = bk = (-14019 \times 5.307 \times 10^{-5})$

$= -0.743.$

$n_1 = ck = 13422.8 \times 5.307 \times 10^{-5}.$

$= 0.712.$

Direction cosine of σ_2.

$$\begin{vmatrix} \sigma_x-\sigma_2 & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y-\sigma_2 & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z-\sigma_2 \end{vmatrix} \begin{Bmatrix} l_2 \\ m_2 \\ n_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}$$

$$\begin{vmatrix} 100-51.30 & 50 & 60 \\ 50 & 80-51.30 & 100 \\ 60 & 100 & 60-51.30 \end{vmatrix} \begin{Bmatrix} l_2 \\ m_2 \\ n_2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}$$

$$\begin{vmatrix} 48.7 & 50 & 60 \\ 50 & 28.7 & 100 \\ 60 & 100 & 8.7 \end{vmatrix}$$

$$a = \begin{vmatrix} 28.7 & 100 \\ 100 & 8.7 \end{vmatrix} \quad b = \begin{vmatrix} 50 & 100 \\ 60 & 8.7 \end{vmatrix} \quad c = \begin{vmatrix} 50 & 28.7 \\ 60 & 100 \end{vmatrix}$$

$$= -9750.31 \qquad = -5565 \qquad = 3278.$$

$$K = \frac{1}{\sqrt{a^2+b^2+c^2}} = 8.55 \times 10^{-5}$$

$$l_2 = ak = -0.833$$

$$m_2 = bk = -0.475$$

$$n_2 = ck = 0.280$$

Direction cosines of σ_3

$$\begin{vmatrix} (100+31.67) & 50 & 60 \\ 50 & 80+31.67 & 100 \\ 60 & 100 & (60+31.67 \end{vmatrix} \begin{Bmatrix} l_3 \\ m_3 \\ n_3 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \end{Bmatrix}$$

$$\begin{vmatrix} 131.67 & 50 & 60 \\ 50 & 111.67 & 100 \\ 60 & 100 & 91.67 \end{vmatrix}$$

$$\begin{vmatrix} 111.67 & 100 \\ 100 & 91.67 \end{vmatrix} \quad b = \begin{vmatrix} 50 & 100 \\ 60 & 91.67 \end{vmatrix} \quad c = \begin{vmatrix} 50 & 111.67 \\ 60 & 100 \end{vmatrix}$$

$= 236.789 \qquad = -1416.5 \qquad = -1700.2$

$$K = \frac{1}{\sqrt{a^2+b^2+c^2}} = 4.493 \times 10^{-4}$$

$l_3 = aK = 0.106.$

$m_3 = bK = -0.636$

$n_3 = cK = -0.763$

Max. shear stress.

$$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2}$$

$$= \frac{220.38 - (-31.67)}{2}$$

$$= 126.025 \text{ kPa.}$$

4. Compatability equations of 3D strain case

u, v, w are displacement components.

wkt,

$$\epsilon_x = \frac{\partial u}{\partial x}, \quad \epsilon_y = \frac{\partial v}{\partial y}, \quad \epsilon_z = \frac{\partial w}{\partial z}.$$

$$\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}, \quad \gamma_{yz} = \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}, \quad \gamma_{xz} = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}.$$

Differentiation of ϵ_x wrt y, z, γ_{xy} wrt z, γ_{yz} wrt x, γ_{xz} wrt y.

$$\epsilon_x = \frac{\partial u}{\partial x} \Rightarrow \frac{\partial \epsilon_x}{\partial y} = \frac{\partial^2 u}{\partial x^2}$$

$$\Rightarrow \frac{\partial^2 \epsilon_x}{\partial y \partial z} = \frac{\partial^3 u}{\partial x \partial y \partial z} \longrightarrow a$$

$$\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

$$\frac{\partial \gamma_{xy}}{\partial z} = \frac{\partial^2 u}{\partial y \partial z} + \frac{\partial^2 v}{\partial x \partial z} \longrightarrow b.$$

$$\frac{\partial \gamma_{yz}}{\partial x} = \frac{\partial^2 v}{\partial x \partial z} + \frac{\partial^2 w}{\partial y \partial x} \longrightarrow c \quad ; \quad \frac{\partial \gamma_{xz}}{\partial y} = \frac{\partial^2 u}{\partial z \partial y} + \frac{\partial^2 w}{\partial x \partial y} \longrightarrow d.$$

By solving eq. b + d − c, we get

$$\frac{\partial \gamma_{xy}}{\partial z} + \frac{\partial \gamma_{xz}}{\partial y} - \frac{\partial \gamma_{yz}}{\partial x} = \frac{\partial^2 u}{\partial y \partial z} + \frac{\partial^2 u}{\partial y \partial z} = \frac{2\partial^2 u}{\partial y \partial z}$$

From eq-a, we get

$$2 \cdot \frac{\partial^2 \epsilon_x}{\partial y \partial z} = \frac{\partial}{\partial x}\left[2 \cdot \frac{\partial^2 u}{\partial y \partial z}\right]$$

$$= \frac{\partial}{\partial x}\left[\frac{\partial \gamma_{xy}}{\partial z} + \frac{\partial \gamma_{xz}}{\partial y} - \frac{\partial \gamma_{yz}}{\partial x}\right] \longrightarrow 1$$

11'y

$$\frac{2\partial^2 \epsilon_y}{\partial x \partial z} = \frac{\partial}{\partial y}\left[\frac{\partial \gamma_{xy}}{\partial z} + \frac{\partial \gamma_{yz}}{\partial x} - \frac{\partial \gamma_{xz}}{\partial y}\right] \longrightarrow 2$$

$$\frac{2\partial^2 \epsilon_z}{\partial x \partial y} = \frac{\partial}{\partial z}\left[\frac{\partial \gamma_{xz}}{\partial y} + \frac{\partial \gamma_{yz}}{\partial x} - \frac{\partial \gamma_{xy}}{\partial z}\right]. \longrightarrow 3$$

The above three equations are the 3D compatability equations. and are also called "Saint - Venant's" eq. of compatability.

ASSIGNMENT-III

ADVANCED SOLID MECHANICS

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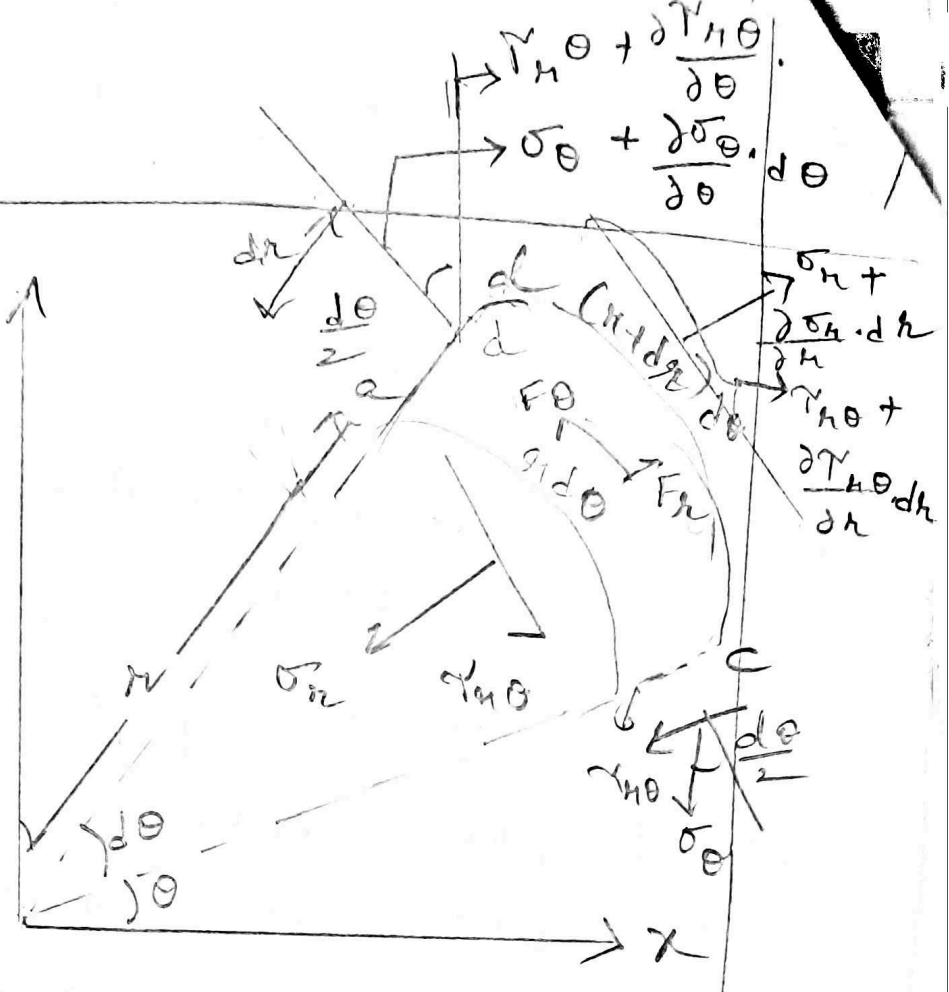
(1) Develop the differential Equations of equilibrium for the case of 2-D problem in elasticity using polar coordinate system

A:- The polar coordinates of a point describes its position interms of distance from a fixed point (origin) of an angle measured from a fixed direction which is normally the horizontal axis.

- Many Engineering components have a degree of axial symetry that is they are either rotationally symetric about a central axis as in a case of circular ring (or) contain circular holes (or) made up of parts of hallow discs (or) like a curved bar.

Equilibrium Equations in polar coordinate



Normal stress component in radial direction $\rightarrow \sigma_r$

Normal stress components in circumferencial direction $\rightarrow \sigma_\theta$.

Shearing stress components $\rightarrow \tau_{r\theta}$.

* On account of variation of stress the values of at the sides are not same

$\Rightarrow$ In polar coordinate system (r, θ) if the cartesian system (x, y) are related by the following.

$x = r\cos\theta$. $\quad r^2 = x^2 + y^2$

$y = r\sin\theta$ $\quad \theta = \tan^{-1}(y/x)$

$r = \sqrt{x^2 + y^2}$

⇒ Consider the state of stress on element abcd of unit thickness described by the polar coordinates as shown in figure.

⇒ 'F_r' & 'F_θ' are the body forces on 'r' & 'θ' directions respectively.

⇒ Resolving forces in r-direction

For Equilibrium $\Sigma F_r = 0$.

$$\left(\sigma_r + \frac{\partial \sigma_r}{\partial r} dr\right)(r+dr)\,d\theta - \sigma_r \cdot r\,d\theta$$

$$-\left(\sigma_\theta + \frac{\partial \sigma_\theta}{\partial \theta} d\theta\right) dr \sin\frac{d\theta}{2} - \sigma_\theta\, dr \sin\frac{d\theta}{2}$$

$$+\left(\tau_{r\theta} + \frac{\partial \tau_{r\theta}}{\partial \theta} \cdot d\theta\right) \cdot dr \cos\frac{d\theta}{2} - \tau_{r\theta}\, dr \cos\frac{d\theta}{2}$$

$$+ F_r\, r\, dr\, d\theta = 0.$$

Since '$d\theta$' is very small

$$\sin\frac{d\theta}{2} = \frac{d\theta}{2} \qquad \cos\frac{d\theta}{2} = 1$$

Neglecting higher order terms & simplifying, we get

$\rightarrow -\sigma_r r d\theta + \sigma_r r d\theta + \sigma_r dr d\theta + \frac{\partial \sigma_r}{\partial r} \cdot r\, dr\, d\theta$

$+ \frac{\partial \sigma_r}{\partial r} \cdot dr\, d\theta - \sigma_\theta \left(\frac{d\theta}{2}\right) \cdot dr - \sigma_\theta \frac{d\theta}{2} dr$

$- \frac{\partial \sigma_\theta}{\partial \theta} \cdot d\theta \cdot \frac{d\theta}{2} \cdot dr - \tau_{r\theta}\, dr + \tau_{r\theta}\, dr +$

$\frac{\partial \tau_{r\theta}}{\partial \theta} \cdot d\theta\, dr + F_r \cdot r\, dr\, d\theta = 0.$

$\Rightarrow r \frac{\partial \sigma_r}{\partial r} dr\, d\theta + \sigma_r\, dr\, d\theta - \sigma_\theta\, dr\, d\theta + \frac{\partial \tau_{r\theta}}{\partial \theta} d\theta\, dr$

$+ F_r\, r\, d\theta\, dr = 0.$

divide ~~throughout~~ by $r\, d\theta\, dr$

$$\rightarrow \boxed{\frac{\partial \sigma_r}{\partial r} + \frac{1}{r} \frac{\partial \tau_{r\theta}}{\partial \theta} + \left(\frac{\sigma_r - \sigma_\theta}{r}\right) + F_r = 0} \quad \hookrightarrow (1)$$

||ly Resolving all forces in θ-direction.

In Equilibrium $\Sigma F_\theta = 0.$

$\left(-\sigma_\theta \cos\frac{d\theta}{2}\right)(dr \cdot 1) + \left(\sigma_\theta + \frac{\partial \sigma_\theta}{\partial \theta} d\theta\right) \cos$

$\frac{d\theta}{2}(dr \times 1) + \left(\tau_{r\theta} \sin\frac{d\theta}{2}\right) \cdot (dr \times 1)$

$+ \left(\tau_{r\theta} + \frac{\partial \tau_{r\theta}}{\partial \theta} d\theta\right)(dr \times 1) \sin\frac{d\theta}{2} -$

$\tau_{r\theta}(r\, d\theta \times 1) + \left(\tau_{r\theta} + \frac{\partial \tau_{r\theta}}{\partial r} \cdot dr\right)$

$(r\, dr\, d \times)\, d\theta + F_\theta\,(r \cdot d\theta \cdot dr) = 0.$

By solving we get

$$\frac{1}{r}\cdot\frac{\partial \sigma_\theta}{\partial \theta} + \frac{\partial \tau_{r\theta}}{\partial r} + \frac{2\tau_{r\theta}}{r} + F_\theta = 0 \quad \rightarrow (2)$$

In absence of body forces the equilibrium eq'ns

$$\frac{\partial \sigma_r}{\partial r} + \frac{1}{r}\frac{\partial \tau_{r\theta}}{\partial \theta} + \left(\frac{\sigma_r - \sigma_\theta}{r}\right) = 0$$

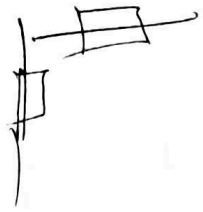
$$\frac{1}{r}\cdot\frac{\partial \sigma_\theta}{\partial \theta} + \frac{\partial \tau_{r\theta}}{\partial r} + \frac{2\tau_{r\theta}}{r} = 0 \quad \rightarrow (2)$$

2. Write short note on strain rosette

- Strain gauge is a device used to measure the strain on the free surface of a structure.
- strain gauges are employed to measure the linear deformation over a strain gauge length to measure the change in length
- Since a single gauge can measure the strain only a single direction.
- Strain rosettes consists of two or more co-located strain gauges oriented at a fixed angle wrt each other.
- Rosettes typically involve 2, 3, (or) 4 strain gauges relative orientation of 30°, 45°, 60° (or) 70°.

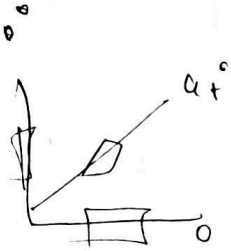
Types of Roselles are:-

1. Tee rosette $(0^\circ, 90^\circ)$



- used only when a principle strain directions are known in advance

2. Rectangular rosette $(0^\circ, 45^\circ, 90^\circ)$



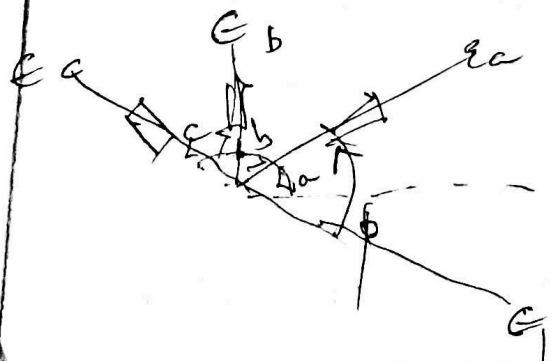
- they are mostly 3 gauge rosettes bcz of their single geometry

3. Delta rosette $(0^\circ, 60^\circ, 120^\circ)$

Consider a strain rosette with 3 gauges oriented at a, $a+b$, $a+b+c$ with horizontal axis.

Let the strains measure using the results be ε_a, ε_b, ε_c

ε_1 is the major principle strain which is measured at ϕ wrt ε_a



orientation of strains.

ing transformation matrix we can write

$\epsilon_a = \epsilon_x \cos^2 a + \epsilon_y \sin^2 a + \gamma_{xy} \sin a \cos a$

$\epsilon_b = \epsilon_x \cos^2(a+b) + \epsilon_y \sin^2(a+b) + \gamma_{xy} \cdot \sin(a+b) \cdot \cos(a+b)$

$\epsilon_c = \epsilon_x \cos^2(a+b+c) + \epsilon_y \sin^2(a+b+c) + \gamma_{xy} \sin(a+b+c) \cos(a+b+c)$

Solve

$\epsilon_a, \epsilon_b, \epsilon_c$ to get ϵ_x ; ϵ_y & γ_{xy}.

principle strain

$$\epsilon_1 = \left(\frac{\epsilon_x + \epsilon_y}{2}\right) + \sqrt{\left(\frac{\epsilon_x - \epsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

$$\epsilon_2 = \left(\frac{\epsilon_x + \epsilon_y}{2}\right) - \sqrt{\left(\frac{\epsilon_x - \epsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2}$$

principle stress ϕ w.r.t the given strain axis

ϵ_a given by $\tan 2\phi = \frac{\gamma_{xy}}{\epsilon_x - \epsilon_y}$.

principle stresses can be calculated by

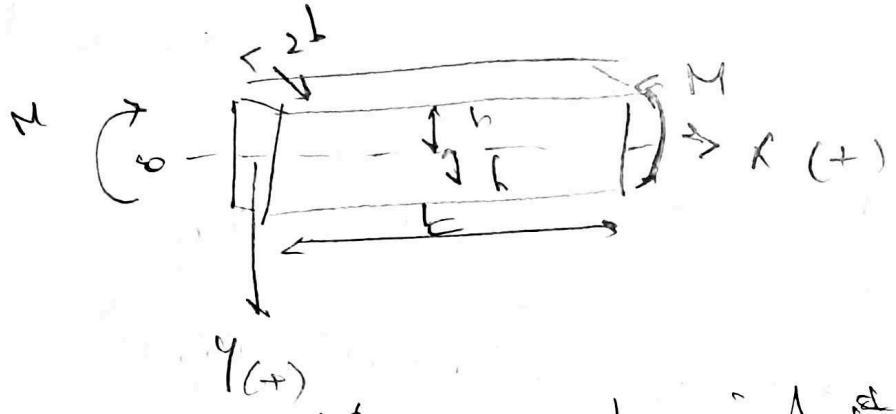
$$\sigma_1 = \frac{E}{(1-\nu^2)} (\epsilon_1 + \mu \epsilon_2)$$

$$\sigma_2 = \frac{E}{(1-\nu^2)} (\epsilon_2 + \mu \epsilon_1)$$

3. Derive the expression of bending moment for pure bending of beam.

4. Pure bending of a beam

Consider a rectangular beam with length L width 2b, depth 2h subjected to pure couple M along its length as shown in fig



Consider a 2nd order polynomial such that if any term gives only a constant state of stress

therefore, $\phi = \frac{a_2 x^2}{2} + b_2 xy + \frac{c_2 y^2}{2}$

by defenition

$\sigma_x = \frac{\partial^2 \phi}{\partial y^2} = c_2$

$\sigma_y = \frac{\partial^2 \phi}{\partial x^2} = a_2$

$\tau_{xy} = \frac{-\partial^2 \phi}{\partial x \partial y} = -b_2$

Consider $a_2 = b_2 = 0$.
Except c_2

Apply boundary conditions

a) $y = \pm h$; $\sigma_y = 0$

b) $y = \pm h$; $\tau_{xy} = 0$

c) at x = any value

moment = force × 1st distance.

M = stress × area × 1st distance.

$$M \equiv \int_{-h}^{+h} \sigma_x x\, b\, dy = 2b \int_{-h}^{+h} c_2 y\, dy = 2b c_2 \left[\frac{y^2}{2}\right]_{-h}^{+h}$$

$$= 2b c_2 \left[\frac{h^2}{2} + \frac{(-h)^2}{2}\right]$$

$$\boxed{M = 0}$$

∴ This clearly does not fit the problem of pure bending.

Now consider a third order q'n.

$$\phi = \frac{a_3 x^3}{6} + \frac{b_3 x^2 y}{2} + \frac{c_3 x y^2}{2} + \frac{d_3 y^3}{6}$$

Now: $\sigma_x = \frac{\partial^2 \phi}{\partial y^2} = c_3 x + d_3 y$

$\sigma_y = \frac{\partial^2 \phi}{\partial x^2} = a_3 x + b_3 y$

$\tau_{xy} = \frac{-\partial^2 \phi}{\partial x \partial y} = -b_3 x - c_3 y$

Next by consider $a_3 = b_3 = 0$, $e_3 = 0$, except c_3.

Apply boundary conditions.

(1) at $y = \pm b$, $\sigma_y = 0$,

(2) at $x = \pm h$, $\tau_{xy} = 0$,

(3) at $x =$ any value.

hence $\sigma_x = d_3 y$.

obviously biharmonic eq'n also satisfied

i.e., $\frac{\partial^4 \phi}{\partial x^4} + 2\frac{\partial^4 \phi}{\partial x^2 \partial y^2} + \frac{\partial^4 \phi}{\partial y^4} = 0$.

Now bending moment M = force × distance

= stress × area × distance.

$$M = 2b \int_{-h}^{+h} \sigma_x y\, dy = 2b \int_{-h}^{+h} b_3 y^2\, dy.$$

$$M = 2b \cdot d_3 \left[\frac{y^3}{3}\right]_{-h}^{+h} = 2b\, d_3 \left[\frac{h^3}{3} + \frac{h^3}{3}\right]$$

$$m = 4b\, d_3 \frac{h^3}{3} \quad (\text{or}) \quad d_3 = \frac{3m}{4bh^3}$$

$$d_3 = \frac{m}{I}, \text{ where } I = \frac{4h^3 b}{3}$$

$$\therefore \sigma_x = d_3 y$$

$$\boxed{\sigma_x = \frac{m}{I} y} \rightarrow \text{pure bending of beam}$$

This the expression for pure bending of beam

4. State and explain the assumptions of plasticity.

(1) The response is independent of rate effects.

(2) The material is incompressable in the plastic range.

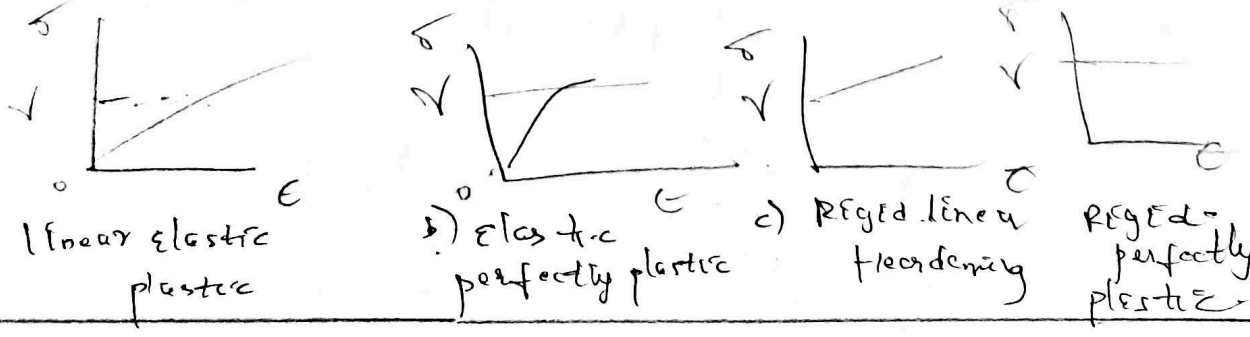
(3) There is no Bauschinger effect.

(4) The yield stress is independent of hydrostatic pressure.

(5) The material is isotropic.

First two of these assumptions will usually be very good

The other three may or may not be depending on the material and circumstances.



a) linear elastic plastic

b) elastic perfectly plastic

c) Rigid linear Hardening

Rigid-perfectly plastic

Theories of failures

The history behind the various failure theories is that whatever is responsible for failure in the standard tensile test will also be responsible for failure under all other conditions of static loading.

Max. principle stress theory - Rankine

Max principle strain theory - St. Venants

Max strain energy - Beltrami

Distortional energy - Von Mises

max shear stress theory - Tresca

octahedral shear stress theory

- Failure occurs when material starts exhibiting inelastic behaviour.
- Brittle & ductile materials are different modes of failures → mode of failure - depends on loading
- Ductile materials - exhibit yielding - plastic deformation before failure
- Brittle materials - no yielding - sudden failure.

6). b) yield criteria

plastic yielding of the material subjected to any external forces is of considerable importance in the field of plasticity.

- For predicting the onset of yielding in elastic material; there are at present two generally accepted criteria

(1) Von mises distortion - energy criterion.

(2) Tresca or max shear stress criterion.

(c) plasticity

The ability of a solid material to undergo permanent deformation.

- A non-reversable change of shape in response to applied forces

(d) strain hardening

- Work hardening also known as strain hardening is the strengthening of a metal (or) polymer by plastic deformation.

(e) Nominal and true stress & strain

True stress is the ratio of force per actual (instantaneous) cross-sectional area taking lateral strain into consideration.

Nominal strain is the ratio of change is length per original length.

Nominal stress is the ratio of force per initial area of cross-section.

$$\text{True strain} = \frac{\text{change is length}}{\text{actual length (instantaneous length)}}$$

f) Resilance and toughness

The ability of a material to withstand elastic deformation without deforming plastically is called resilance.

The ability of material to absorb energy and plastically deform without fracturing.

a) Factor of safety

It expresses how much stronger a system is than its needs to be for an intended load.