Structural Analysis

For

Civil Engineering

By

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Syllabus for Structural Analysis

Statically Determinate and Indeterminate Structures by Force/ Energy Methods; Method of Superposition; Analysis of Trusses, Arches, Beams, Cables and Frames; Displacement Methods: Slope Deflection and Moment Distribution Methods; Influence Lines; Stiffness and Flexibility Methods of Structural Analysis.

Analysis of GATE Papers

Year	Percentage of Marks	Overall Percentage
2015	4.50	2.60 %
2014	11.00	
2013	7.00	
2012	-	
2011	-	
2010	3.00	
2009	2.00	
2008	6.00	
2007	9.00	
2006	6.00	

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"The starting point of all achievement is DESIRE. Keep this constantly in mind. Weak desire brings weak results, just as a small fire makes a small amount of heat."

.... Napoleon Hill

CHAPTER 1

Introduction to Structures

Learning Objectives

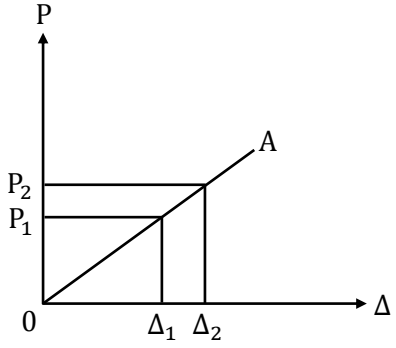
After reading this chapter, you will know:

1. Fundamental Assumptions
2. Classification of Structures
3. Classification of Skeletal Structures
4. Poission's Ratio
5. Bernoulli's Assumption In Structural Analysis

Introduction to Structures

1. **Structure (Def.):** When any elastic body is subjected to a system of loads and deformation take space and the resistance is setup against the deformation, then the elastic body is known as 'structure' if no resistance is set up in the body against the deformation, it is known as a 'Mechanism'.

2. **Fundamental Assumptions:**
   - A body is assumed to be Elastic.
   - A body is assumed to be homogeneous, if a body has identical properties in identical directions at all point of it, it is known as 'Homogeneous'.
   - A body is assumed to be isotropic. If a body has identical properties in all directions at a point, it is known as isotropic.
   - A body is assumed to be solid continuous structure.
   - Principle of super position is valid.
     According to this principle, the response of a structure on account of the combined action of any two systems of external forces 'P_1' and 'P_2' is equal to the sum of the responses due to the two systems of forces acting separately.



i. e. , $\Delta_{(1+2)} = \Delta_1 + \Delta_2$

Where,

$\Delta_{(1+2)}$ = Total displacement due to the combined action of P_1 and P_2 applied in sequence of P_1 and P_2

Δ_1 = Displacement due to the action of P_1 alone

Δ_2 = Displacement due to the action of P_2 alone

Validity of Superposition Principle:

It is valid when

- The structure is in a condition of static equilibrium.
- The material of the structure behaves linearly (i.e., load versus deformation variation is a straight line)
- The supports are unyielding.
- Not valid for the slender columns.

3. **Classification of Structures:**
   - Skeletal Structures: Structures which can be idealized to a series of straight or curved lines. **E.g.,**: Roof trusses, building frames
   - Surface Structures: Structures which can be idealized to plane or curved surfaces. **E.g.,**: Slabs and shells
   - Solid Structures: Structures which can neither be idealized to a skeleton nor to a plane or curved surface. **E.g.,**: Massive foundation

4. **Classification of Skeletal Structures:**
   i. (a) **Pin Jointed Frames** (b) **Rigid Jointed Frames**
      (a) **Pin Jointed Frames:** Members are connected by means of pin joints. These frames support the loads by developing only axial forces, if the external loads act at the joints and members are straight.
      (b) **Rigid Jointed Frames:** Assumptions: The joints of rigid jointed frames are assumed to be rigid so that the angles between the members meeting a joint remain unchanged.
      These frames resist external forces by developing bending moments, shear forces, axial forces and twisting moments in the members of the frame.

   ii. (a) **Plane Frames** (b) **Space Frames**
      (a) **Plane Frames:** All members of the plane frames as well as the external loads are assumed to be in one frame.

Further Classifications:

Pin jointed plane frame: Members carry only axial forces.

Rigid jointed plane frame: Members are subjected to axial forces, shear forces and bending moments.

Important Note:

- If loaded in its own plane, any cross-section of member is subjected to three internal forces (one axial force, one shear force and one bending moment).
- If loading is away from the plane torsional moments also.

(b) **Space Frames:** All members do not lie in one plane. Very often, it is also a combination of series of frames.

Further Classifications

Pin jointed space frame: Members are subjected to axial forces only.
Rigid jointed space frame: Members are subjected to axial forces, shear forces, bending moments and twisting moments.

Important Note: Any cross section of a member of a skeletal space structure, there are six internal force components Viz., one axial force, biaxial shear force components Q_x and Q_y twisting moments 'T' and biaxial bending moments 'M_x' and 'M_y'.

5. **Poission's Ratio (μ or $1/m$):**
Defined as the ratio of lateral strain to linear strain
General values: Concrete = 0.15, Steel: 0.33, Cork = 0, Isotropic materials = 0.25
Note: For ideal elastic in-compressible materials Poission's ration is maximum of 0.5 (E.g., Rubber)

6. **Bernoulli's Assumption in Structural Analysis:**
"Plane sections which are normal to the neutral axis before bending remain plane and normal to the neutral axis after bending".
It leads to linearly varying strain over the cross-section.
Validity:
- Valid for elastic (working stress), limit state and ultimate (plastic) theories.
- Valid for prismatic or non-prismatic members.
- Valid for shallow beams only.
- Not valid for deep beams and locations of high shears.

7. **Equations of Static Equilibrium:**
Using the Cartesian system of coordinates as the reference frame, the equations of static equilibrium may be written as
$\Sigma F_x = \Sigma F_y = \Sigma F_z = 0$
$\Sigma M_x = \Sigma M_y = \Sigma M_z = 0$
Where, $\Sigma F_x, \Sigma F_y$ and ΣF_z are algebraic sums of the components of all external forces including reactive forces, along $x-, y-$ and $z-$ axis respectively and $\Sigma M_x, \Sigma M_y$ and ΣM_z are the algebraic sums of the moments of all external forces, including reactive forces, about $x-, y-$ and $z-$ axis respectively.

Assignment

1. A simply supported beam having an internal hinge is a
   (A) Structure (C) Elastic body
   (B) Mechanism (D) None of these

2. Elastic structural analysis makes use of
   (A) Linear stress-strain relation only
   (B) Elasticity only
   (C) Elastic and linear stress-strain relation
   (D) Elastic but either linear or non-linear stress strain relation.

3. The material that exhibits the same elastic properties in all the directions at a point is said to be
   (A) Homogeneous (C) Visco-Elastic
   (B) Orthotropic (D) Isotropic

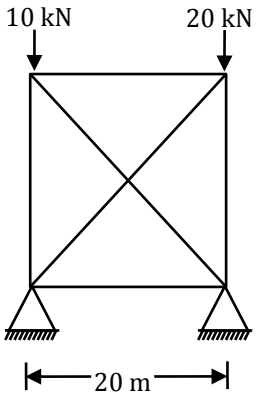
4. Consider the following statements, the principle of super position is applied to
   (i) Linear elastic bodies
   (ii) Bodies subjected to small deformations of these statements
   (A) 1 alone is correct
   (B) 1 & 2 are correct
   (C) 2 alone is correct
   (D) Neither 1 nor 2 is correct

5. The principle of superposition is made use of in structural computations when
   (A) The geometry of the structure changes by a finite amount during the application of the loads
   (B) The changes in the geometry of the structure during the application of the loads is too small and the strain in the structure the directly proportional to the corresponding stresses
   (C) The strains in the structure are not directly proportional to the corresponding stress, even though the effect of changes in geometry can be neglected
   (D) None of the above conditions are met

6. **Assertion (A):** The principle of superposition for deflection of beams subjected to a number of loads can be applied in the case of large deformation
   Reason (R): In the principle of superposition, the resultant deflection's due to each load acting separately.
   (A) Both A and R are true and R is the correct explanation of A
   (B) Both A and R are true but R is NOT the correct explanation of A
   (C) A is True but R is False
   (D) A is False but R is True

7. Consider the following statements:
   The principle of superposition is not applicable when
   (i) The material does not obey Hooke's law
   (ii) The effect of temperature changes are taken into consideration
   (iii) The structure is being analyzed for the effect of support settlement
   Which of the above statements is/are Correct?
   (A) 1 only (C) 2 and 3
   (B) 1 and 2 (D) 1, 2 and 3

8. Given figure (1) shows square plane truss it is



   (A) Internally indeterminate

(B) Internally determinate
(C) Externally determinate
(D) None of the above

9. For a plane truss with the degree of internal redundancy, force x due to the effect of redundant compressive force is given by

(A) $X = -\dfrac{\sum_{i=1}^{m-2}\frac{w_i k_i l_i}{2}}{\sum_{iz1}^{m-2} k_i l_i + \left(\frac{lx}{A_x E}\right)}$

with usual notaitons

(B) $X = -\dfrac{\sum_{i=1}^{m-1}\frac{w_i k_i l_i}{2}}{\sum_{iz1}^{m-1}\frac{k^2 i l_i}{A_i E} + \frac{l_x}{A_x E}}$

(C) $X = -\dfrac{\sum_{i=1}^{m-2}\frac{w_i k_i l_i}{2}}{\sum_{iz1}^{m-1}\frac{k_i l_i}{A_i E} + \frac{l_x}{A_x E}}$

(D) None of the above

10. An alternate method for evaluating x is given by

(A) $X = \dfrac{\sum_{1z1}^{m-1}\frac{p\,k\,p}{A}}{\sum_{1z1}^{m}\frac{k^2 l}{A}}$

with usual notations.

(B) $X = \dfrac{\sum_{1}^{m-1}\frac{(fkl)^2}{A}}{\sum_{iz1.1}^{m}\frac{k^2 l}{A}}$

(C) $X = \dfrac{\sum_{1z1}^{m-1}\left(\frac{pkl}{A}\right)^3}{\sum_{iz1}^{m}\frac{k^2 l}{A}}$

(D) None of the above

11. For analyzing the plane rigid frame we apply some amount of forces in the redundant member and then determine the member force k, their
(A) The amount of forces applied is unit forces
(B) The amount of forces applied in twice unit forces
(C) The amount of force applied in thrice unit forces
(D) None of the above

12. A portal frame with column of same height and fixed base and having symmetrical load in the column, then it is a
(A) Non sway frame
(B) Sway frame
(C) Redundant frame
(D) None of the above

13. Which of the following material is likely to behave as isotopic material
(A) Coarse grained
(B) Fine grained material
(C) single crystal
(D) None of the above

14. A compression member is subjected to axial force. The stress is uniform basically near
(A) Ends
(B) At mind span only
(C) At distances beyond depth of the beam from ends
(D) None of the above

15. A tie member of a truss has a rivet hole. It is subjected to axial force. Pick up the correct statement of the following
(A) It is subjected to uniform direct stress
(B) It is subjected to uniform bending stress
(C) It is subjected to maximum stress near the rivet hole
(D) It is subjected to minimum stress near the rivet hole

Answer Keys & Explanations

Assignment

1. [Ans. B]
2. [Ans. C]
3. [Ans. D]
4. [Ans. B]
5. [Ans. B]
6. [Ans. D]
7. [Ans. D]
8. [Ans. A]
9. [Ans. B]
10. [Ans. A]
11. [Ans. A]
12. [Ans. A,B]
13. [Ans. B]
14. [Ans. C]
15. [Ans. C]