Degree of static and kinematic indeterminacies for plane frames - analysis of indeterminate pin-jointed frames – rigid frames (Degree of statical indeterminacy up to two) - Energy and consistent deformation methods.

Knowledge Level: Apply

1. Why it is necessary to compute deflections in structures?

Computation of deflection of structures is necessary for the following reasons:

(i) If the deflection of a structure is more than the permissible, the structure will not look aesthetic and will cause psychological upsetting of thje occupants.

(ii) Excessive deflection may cause cracking in the materials attached to the structure. For example, if the deflection of a floor beam is excessive, the floor finishes and partition walls supported on the beam may get cracked and unserviceable.

2. What is meant by 'cambering technique, in structures?

Cambering is a technique applied on site, in which a slight upward curve is made in the structure / beams during construction, so that it will straighten out and attain the straight shape during loading. This will considerably reduce the downward deflection that may occur at later stages.

3. Name any four methods used for the computation of deflections instructures.

(i) Virtual work method – Dummy unit load method   (ii) Strain energy method

(iii) Willot Mohr diagram method   (iv) Method of elastic weights

4. State the difference between strain energy method and unit load method in the determination of deflection of structures.

In strain energy method, an imaginary load P is applied at the point where the deflection is desired to be determined. P is equated to Zero in the final step and the deflection is obtained. In unit load method, an unit load (instead of P) is applied at the point where the deflection is desired.

5. What are the assumptions made in the unit load method?

Assumptions made in unit load method are

1. The external and internal forces are in equilibrium

2. Supports are rigid and no movement is possible.

3. The material is strained well within elastic limit.

6. Give the equation that is used for the determination of deflection at a givenpoint i in beams and frames.

Deflection at a point i is given by,

$$\delta_i = \int_0^l \frac{M_x m_x \, dx}{EI}$$

Where Mx = moment at a section X due

Mx = moment at a section X due to unit load applied at the point i and in the direction of the desired displacement

EI = flexural rigidity

7. State the Principle of Virtual work.

It states that the work done on a structure by external loads is equal to the internal energy stored in a structure (Ue = Ui)

Work of external loads = work of internal loads

8. What is the strain energy stored in a rod of length l and axial rigidity AE to an axial force P?

Strain energy stored

$$U = \frac{P^2 L}{2AE}$$

9. Define Virtual work.

The term virtual work means the work done by a real force actingthrough a virtual displacement or a virtual force acting through a real displacement.The virtual work is not a real quantity but an imaginary one.

10. Explain the procedure involved in the deflection of pin jointed planeframes.

1. Virtual forces k: Remove all the real loads from the truss. Place aunit load on the truss at the joint and in the direction of the desired displacement. Usethe method of joints or the method of sections and calculate the internal forces k ineach member of the truss.

2. Real forces F: These forces arre caused only by the real loads actingon the truss. Use the method of sections or the method of joints to determine the forcesF in each member.

3. Virtual work equation: Apply the equation of virtual work, todetermine the desired displacement.

11. **Distinguish between pin jointed and rigidly jointed structure.**

Sl.no	Pin jointed structure	Rigidly jointed structure
1.	The joints permit change of angle Between connected members.	The members connected at a rigid joint will maintain the angle between them even under deformation due to loads.
2.	The joints are incapable of transferring any moment to the connected members and vice-versa.	Members can transmit both forces and moments between themselves through the joint.
3.	The pins transmit forces between Connected member by developing shear.	Provision of rigid joints normally increase the redundancy of the structures.

12. What is meant by thermal stresses?

Thermal stresses are stresses developed in a structure/member due to change in temperature. Normally, determine structures do not develop thermal stresses. They can absorb changes in lengths and consequent displacements without developing stresses.

13. What is meant by lack of fit in a truss?

One or more members in a pin jointed statically indeterminate frame may be a little shorter or longer than what is required. Such members will have to be forced in place during the assembling. These are called members having Lack of fit. Internal forces can develop in a redundant frame (without external loads) due to lack of fit.

14. Write down the two methods of determining displacements in pin jointed plane frames by the unit load concept.

The methods of using unit loads to compute displacements are,

i) dummy unit load method   ii)Using the principle of virtual work.

15. What is the effect of temperature on the members of a statically determinate plane truss.

In determinate structures temperature changes do not create any internal stresses. The changes in lengths of members may result in displacement of joints. But these would not result in internal stresses or changes in external reactions.

16. Distinguish between „deck type" and „through type" trusses.

A deck type is truss is one in which the road is at the top chord level of the trusses. We would not see the trusses when we ride on the road way.

A through type truss is one in which the road is at the bottom chord level of the trusses. When we travel on the road way, we would see the web members of the trusses on our left and right. That gives us the impression that we are going` through" the bridge.

17. Define static indeterminacy of a structure.

If the conditions of statics i.e., $\Sigma H=0$, $\Sigma V=0$ and $\Sigma M=0$ alone are not sufficient to find either external reactions or internal forces in a structure, the structure is called a statically indeterminate structure.

18. Differentiate the statically determinate structures and statically indeterminate structures?

Sl.No	statically determinate structures	statically indeterminate structures
1.	Bending moment and shear force is dependent on member properties	Bending moment and shear force is independent of member properties
2.	No stresses are caused due to temperature change	Stresses are caused due to temperature change
3.	Conditions of equilibrium are sufficient	Conditions of equilibrium are insufficient

19. Define : Trussed Beam.

A beam strengthened by providing ties and struts is known as Trussed Beams.

20. Define: Unit load method.

The external load is removed and the unit load is applied at th e point, where the deflection or rotation is to found.

21. Give the procedure for unit load method.

1. Find the forces P1, P2, ……. in all the members due to external loads.

2. Remove the ex ternal loads and apply the unit vertical point load at the joint if the vertical deflection is required and find the stress.

3. Apply the equation for vertical and horizontal deflection.

22. Write the general steps of the consistent deformation method.

☐ By removing the restraint in the direction of redundant forces, released structure (which is a determinate structure) is obtained.

☐ In this released structure, displacements are obtained in the direction of the redundant forces.

☐ Then the displacement due to each redundant force is obtained and the conditions of displacement compatibility are imposed to get additional equations.

☐ Solution for these equations gives the values of redundant forces.

☐ Then the released structure subjected to these known forces gives the forces and moments in the structure.

23. Give example of beams of one degree static indeterminacy.
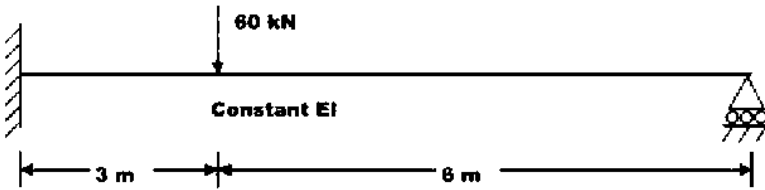
For this case, $r=4 \ and \ e=3$

$\therefore E = 4 - 3 = 1$

24. Define degree of kinematic indeterminacy (or) Degree Of Freedom.

It is defined as the least no of independent displacements required to define the deformed shape of a structure. There are two types of DOF

☐ Joint type DOF

☐ Nodal type DOF

25. Differentiate external redundancy and internal redundancy.

In pin jointed frames, redundancy caused by too many members is called internal redundancy. Then there is external redundancy caused by too many supports. When we introduce additional supports/members, we generally ensure more safety and more work (in analysis).

26. Why to provide redundant members?

☐ To maintain alignment of two members during construction

☐ To increase stability during construction

☐ Tomaintain stability during loading (Ex: to prevent buckling of compression members)

☐ To provide support if the applied loading is changed

☐ To act as backup members in case some members fail or require strengthening

☐ Analysis is difficult but possible

27. What are the different methods used to analyze indeterminate structures?

☐ Finite element method   ☐ Flexibility matrix method   ☐ Stiffness matrix method

28. Define consistent deformation method.

This method is used for the analysis of indeterminate structure. This method is suitable when the number of unknown is one or two. When the number of unknown becomes more, it is a lengthy method.

29. Define primary structure.

A structure formed by the removing the excess or redundant restraints from an Indeterminate structure making it statically determinate is called primary structure. This is required for solving indeterminate structures by flexibility matrix method.

30. Write the formulae for degree of indeterminancy.

☐ Two dimensional in jointed truss (2D truss):$i=(m+r)- 2j$

☐ Two dimensional rigid frames/plane rigid frames (2D frame):$i=(3m+r)- 3j$

☐ Three dimensional space truss (3D truss):$i=(m+r)- 3j$

☐ Three dimensional space frame (3D frame):$i=(6m+r)- 6j$

Where,m = number of members   r = number of reactions   j = number of joints

31. What is the effect of temperature on the members of a statically determinate plane truss?

In determinate structures temperature changes do not create any internal stresses. The changes in lengths of members may result in displacement of joints. But these would not result in internal stresses or changes in external reactions.

32. Define internal and external indeterminancy.

Internal indeterminacy (I.I) is the excess no of internal forces present in a member that make a structure indeterminate.

External indeterminacy (E.I) is the excess no of external reactions in the member that make a structure indeterminate.

Indeterminacy (i) = I.I + E.I.   E.I = r − e;   I.I = i − EI

Where,   r = no of support reactions ande = equilibrium conditions

e = 3 (plane frames) and e = 6 (space frames)

33. What are the requirements to be satisfied while analyzing a structure?

☐ Equilibrium condition   ☐ Compatibility condition   ☐ Force displacement condition

34. Define degree of indeterminacy.

The excess number of reactions take make a structure indeterminate is called degree of indeterminacy. Indeterminacy is also called degree of redundancy.

Indeterminacy consists of internal and external indeterminacies. It is denoted by the symbol 'i'.

Degree of redundancy (i) = I.I + E.I

Where, I.I = Internal indeterminacy   E.I = External indeterminacy

35. Write the difference between deficient and redundant frames?

If the number of members in a frame are less than $(2j-3)$, then the frame is known as deficient frame.

If the number of members in a frame are more than $(2j-3)$, then the frame is known as redundant frame.

36. Differentiate perfect and imperfect trusses?

The frame which is composed of such members, which are just sufficient to keep the frame in equilibrium, when the frame is supporting an external load, is known as perfect frame. Hence for a perfect frame, the number of joints and number of members are given by, $n=2j-3$

A frame in which number of members and number of joints are not given by $n=2j-3$ is known as imperfect frame. This means that number of members in an imperfect frame will be either more or less than $2j-3$