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### IES MASTER Civil Engineering Toppers Handwritten Notes STRUCTURAL ANALYSIS

- Theory BY-KANCHAN SIR
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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# Structural Analysis

(1) Introduction

obj (2) Deflection of beams & Frames

obj (3) Determinacy and Indeterminacy

obj + conv\* (4) Force method of analysis

obj + conv\*

(5) Displacement method of analysis

(a) slope deflection method

(b) Moment distribution method

obj + conv\*

obj + conv\* (6) Trusses

obj (7) Influence line diagram

obj (8) Matrix method of Analysis

obj (9) Cable & Arches.

## ① Introduction

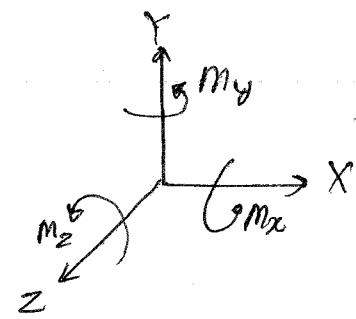
- In structural analysis our aim is to
  - Find out internal member forces
  - Find out slopes and deflections

Equilibrium Equations: ⇒

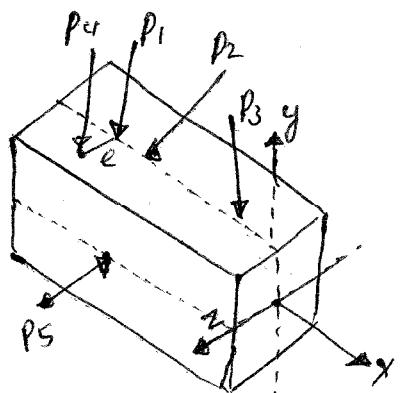
$$\begin{array}{l|l} \sum F_x = 0 & \sum M_{x1} = 0 \\ \sum F_y = 0 & \sum M_y = 0 \\ \sum F_z = 0 & \sum M_z = 0 \end{array}$$

↓

General case (3D)



External and internal forces: ⇒



Internal forces

$F_x$  → axial forces

$F_y$  → shear forces

$F_z$  → twisting moment

$M_x$  → bending moment.

$M_y$  → bending moment.

$M_z$  → bending moment.

$P_1, P_2, P_3, P_4, P_5 \rightarrow$  external forces

- under general loading (3D): maximum no. of internal force = 6

In 2D cases:  $P_4$  &  $P_5$  will not exist

⇒  $M_x, M_y, F_z$  will not exist

Hence in 2D case, max no of internal forces are (3).

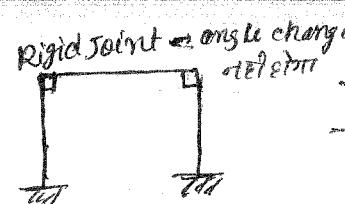
$F_x$  → axial force

$F_y$  → shear force

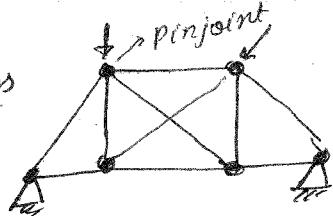
$M_z$  → bending moment.



Frame



Truss

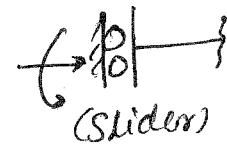
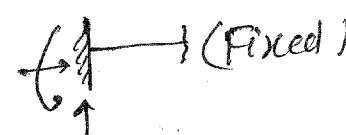
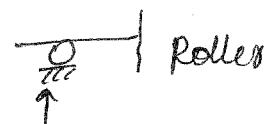
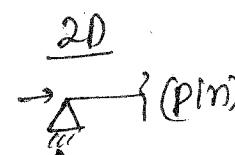
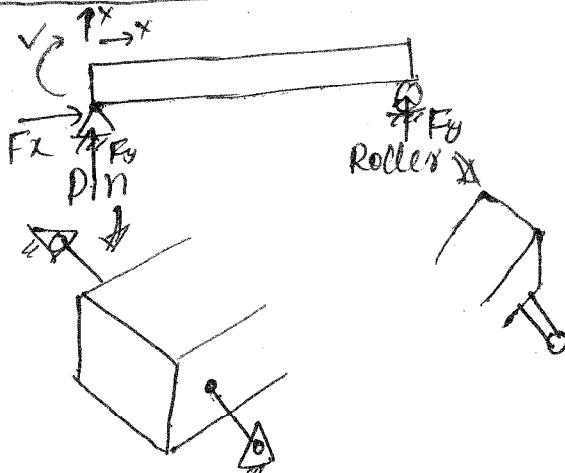


- For Normal Proportion beam & Frame, major deformation is due to B.M.

- Unless given otherwise, we will treat members in beam & frames to be axially rigid.

In Truss → to design against Torsion force, axial force & convert into

Support Reactions ⇒ Reactions develops on account of restraining of deformations.



Note In case of beams if supports are at same level & load is purely vertical then horizontal reaction will not develop. However if supports are not at same level in the beams & in even if load is vertical horizontal reaction does level. The above statement is true for beams only not for trusses & frames.

$$\textcircled{1} \quad \begin{array}{c} P \\ \downarrow \\ a \quad b \\ \uparrow R_1 = \frac{Pb}{a+b} \end{array}$$

$$\textcircled{2} \quad \begin{array}{c} P \\ \downarrow \\ a \quad b \\ \uparrow R_2 = \frac{Pa}{a+b} \end{array}$$

$$\textcircled{3} \quad \begin{array}{c} Mo \\ \downarrow \\ a \quad b \\ \uparrow \frac{Mo}{a+b} = \frac{Mo}{l} \end{array}$$

③

$$\begin{array}{c} Mo \\ \downarrow \\ a \quad b \\ \uparrow \frac{Mo}{a} = \frac{Mo}{l} \end{array}$$

$$\textcircled{4} \quad \begin{array}{c} P \\ \downarrow \\ l \quad a \\ \uparrow \frac{Pa}{l} = \frac{P(l+a)}{l} \end{array}$$

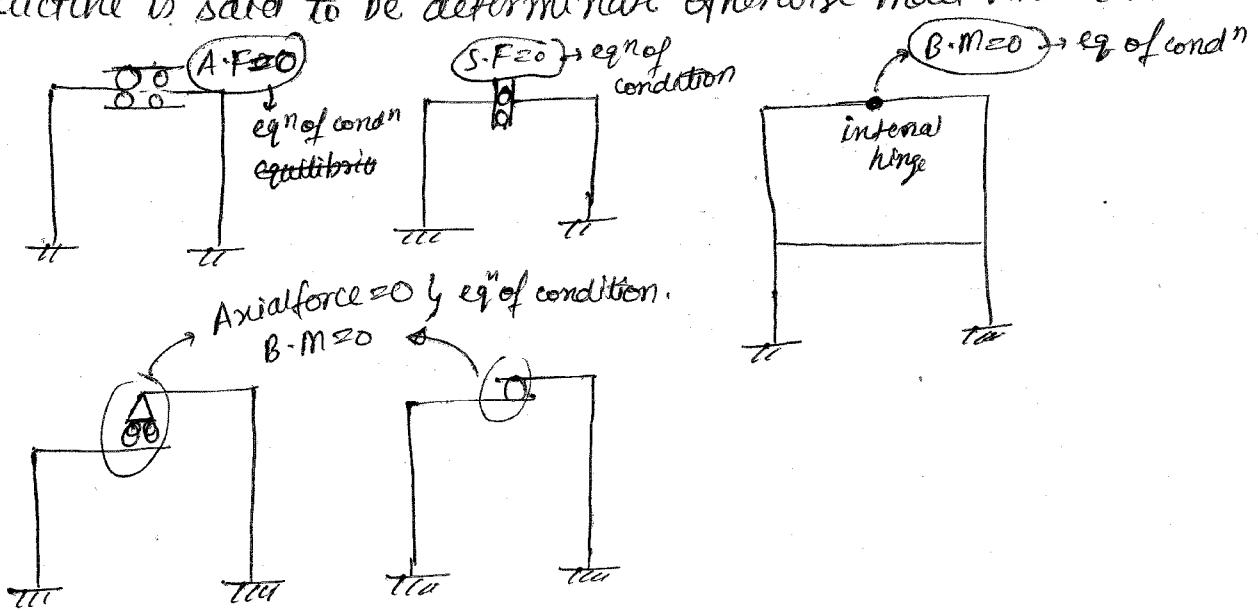
$$\textcircled{5} \quad \begin{array}{c} Mo \\ \downarrow \\ l \quad a \\ \uparrow \end{array}$$

C.G. of load  
w₀ = equivalent point load.

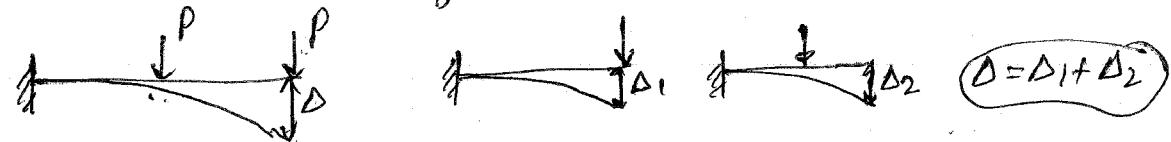
- Distributed loading like UDL, UVL etc can be treated as a point load having magnitude equal to area of the load distributed diagram & passing through the C.G of load distributed diagram (only for reactions calculation).

### Determinate & Indeterminate Structure

- If all of the support reactions & member forces can be calculated only by using equilibrium equations and equation of conditions then the structure is said to be determinate otherwise indeterminate.



Principle of Superposition: As per principle of superposition, each of the loading produces its effect independent of others and total effect is the summation of effects due to individual loading.



For the validity of principle of superposition

- Material should behave as linearly elastic (stress  $\propto$  strain i.e. Hook's law valid)
- deformations are small.

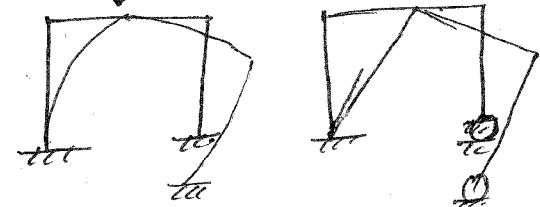
$\Rightarrow BM = R \cdot x \rightarrow$  1st order analysis  $\rightarrow$  deformations are small.



Note: If deformations are large, action of loading will be affected by deformation of structure.

### Advantage and disadvantages of Indeterminate structures

- Indeterminate structure needs to smaller B-M development & hence small cis requirement. Thus there is saving in material and DL.
- Indeterminate structures are more rigid & hence deformed less.
- There are multiple paths of load transfer available in indeterminate structure & hence localized failure may not lead to complete collapse of the structure.



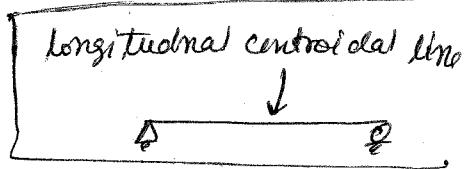
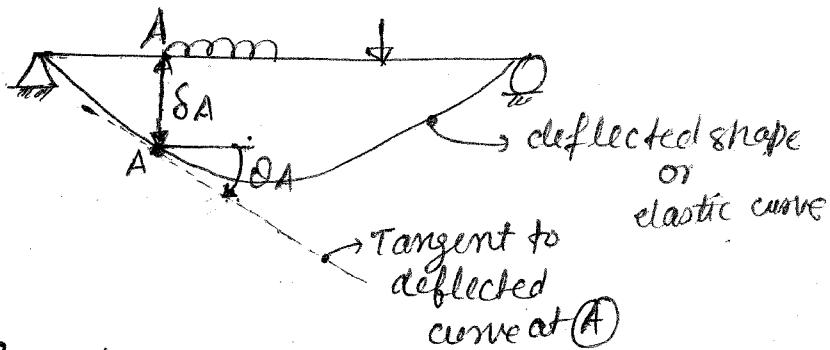
- Indeterminate structures require rigid support & hence part of saving in material is compensated.
  - Settlement of supports & temperature changes will lead to additional stress development
- $\Rightarrow$  Overall is economical to adopt indeterminate structures.

$$\Delta = \frac{5}{384} \frac{wL^4}{EI}$$

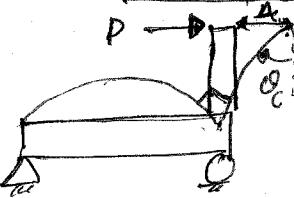


$$\Delta = \frac{1}{384} \frac{wL^4}{EI}$$

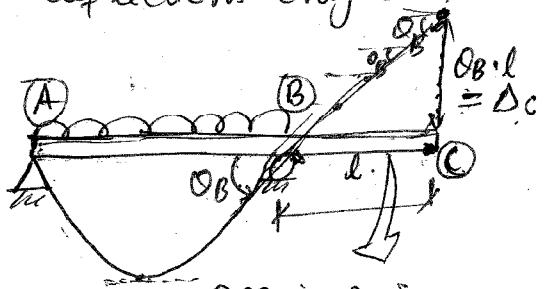
## chap (2) Deflection of Beams & Frames



• deformation leads to deflection & slope.

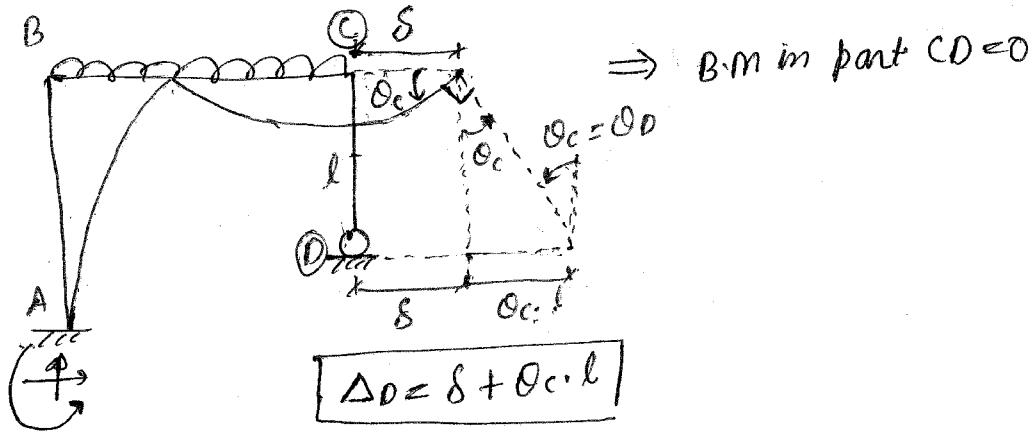


- Internal forces in the Beams & frames produce deformations which lead to slope and deflection. However majority of slope & deflection is only due to B.M. hence in our course we will calculate slopes and deflections only due to B.M unless specified otherwise.



• Hence if B.M in any part of the structure is zero, the beam will not deform in that part and hence will remains straight.

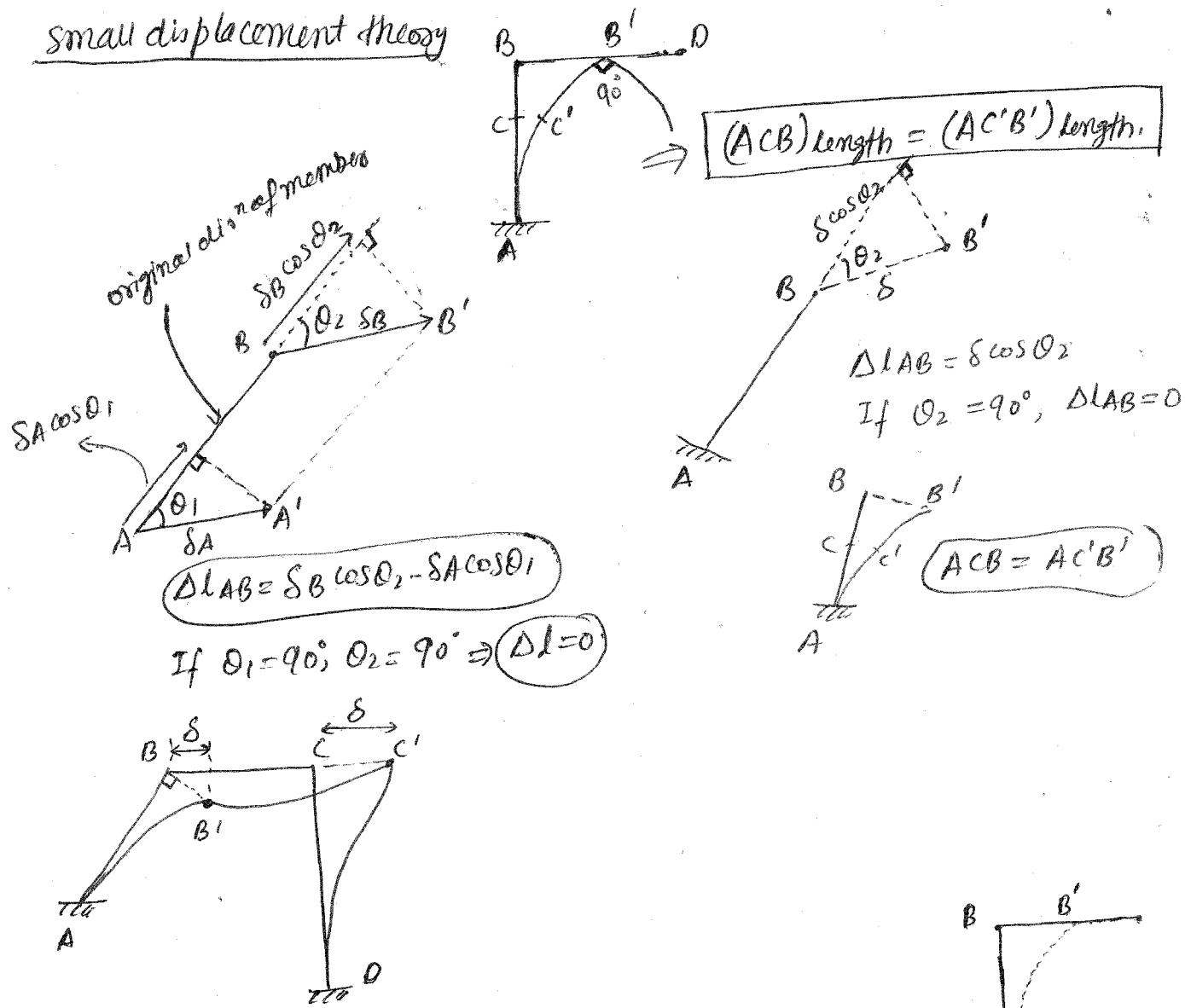
BM in BC is zero.  
⇒ BC will remains straight.  
 $\theta_C = \theta_B$ ,  $\delta_C = \theta_B \cdot l$



## Assumption Assumptions and Important Points:

- (1) Principle of superposition is valid i.e. linearly elastic condition & small displacement theory is valid.

### small displacement theory



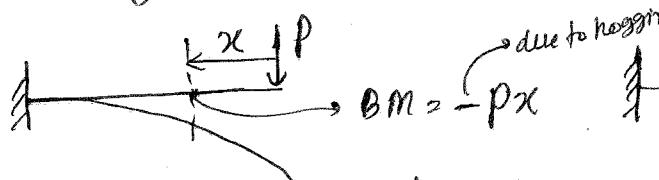
- (2) Rigid joints, will remain rigid after deformation.  
 (3) Curvature of beam will be as per the nature of B.M.

$$\text{curvature} = \frac{1}{R}$$

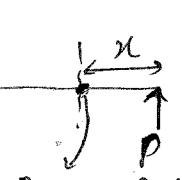
$R = \text{Radius of curvature}$

$$\frac{1}{R} = \frac{M}{EI} \quad M = \text{Bending moment}$$

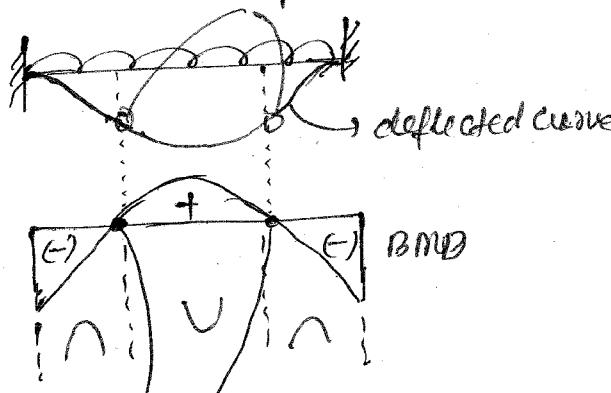
- Sagging BM causes  $\rightarrow$  concave ↑ curvature  sagging BM
- Hogging BM causes  $\rightarrow$  concave ↓ curvature  hogging BM



Point of inflection



Not a Point of contraflexure



Point of contraflexure [At this point  
 $BM=0$ ]   
BM changes sign

① On the symmetry condition, deflected shape and BMD may be symmetrical but SFD will be antisymmetrical.

- symmetry
- material
  - loading
  - C/S
  - support

② On the antisymmetric condition, deflected shape & BM will be antisymmetric but SFD will be symmetrical.

