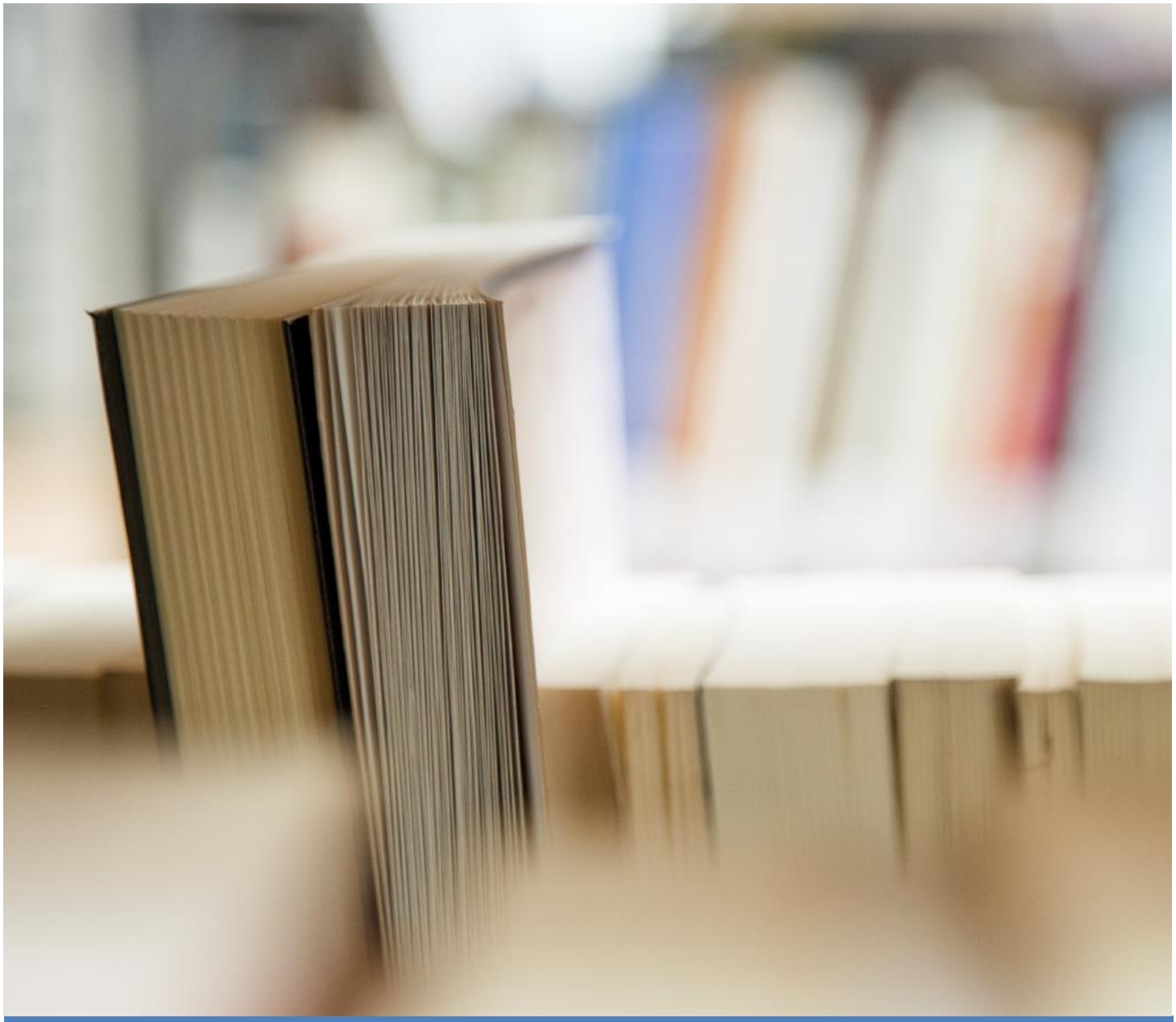


CIVIL LATEST MADEEASY HAND NOTES

15.STRUCTURE ANALYSIS-2020

ADMIN GATEIESMENTOR

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Structural Analysis

Recommended Literature:

1. R.C. Hibbeler - 9th Edition - 14000/-
   6th Edition - 700/- (Pdf is available).
2. Class Notes
3. Work book
4. Previous Year Question Papers of Gate and IES.

1. Basic Concepts

1.1 Introduction:

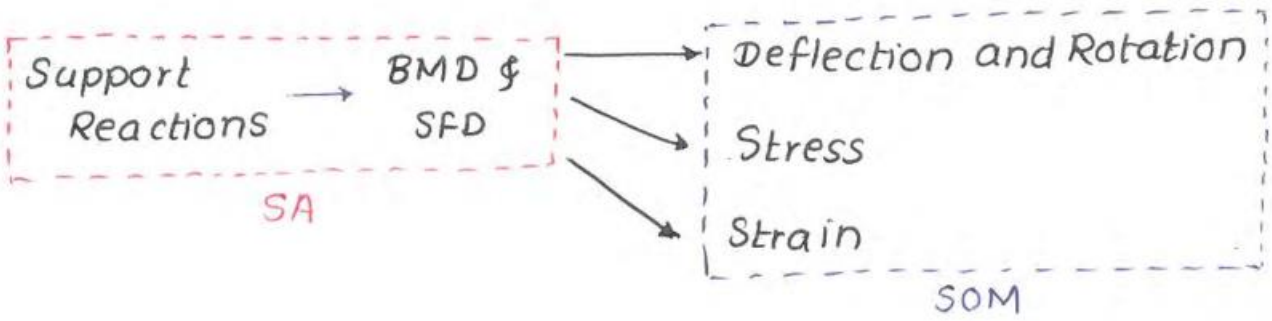
Structural Engineering.

- Analysis (SOM, SA)
  - Equilibrium
  - Compatibility
  - Energy
- Design (RCC, PSC, STEEL)
  - Safety
  - Serviceability
  - Durability
  - Economy
  - Aesthetic

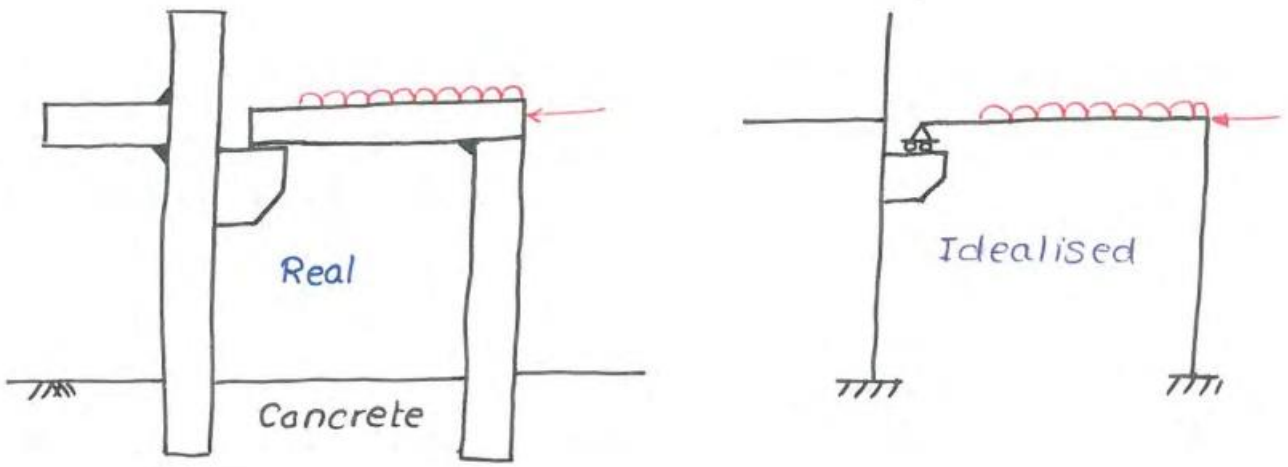
1.2 What is a Structure ?

Any arrangement of members that can transfer load acting upon it to the supports safely can be termed as Structure.

1.3 Meaning of Structural Analysis:



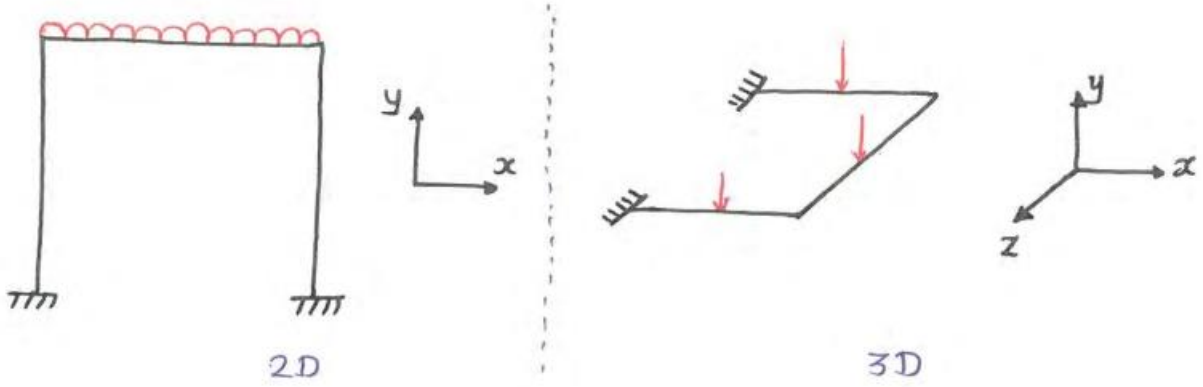
1.4 Idealisation of Structure:



1.5 Planar and 3D Structure:

If 2-axes are sufficient to define geometry and loading of a structure then that structure is called 2D structure/ planar structure.

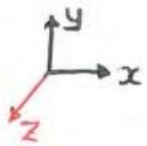
If 3-axes are required to define geometry and loading of a structure then that structure is called 3D structure.



2D 3D

1.6 Sign Convention:

	Positive
x-axis	→
y-axis	↑
z axis	$\vec{x} \times \vec{y}$



Rotation	Clockwise
Forces	Along axis
Moment	Clockwise
SF	



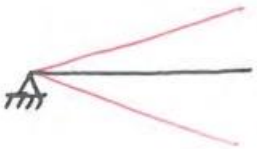
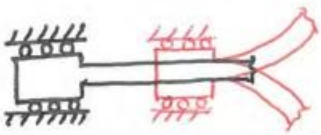
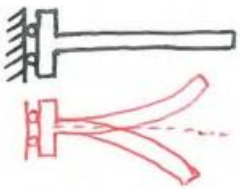
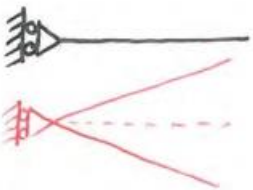
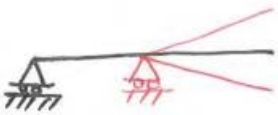
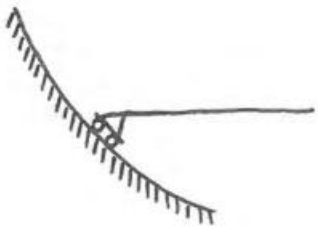
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1.7 Types of Support :

Any arrangement that can restrict movement of any point of a structure is called as support.

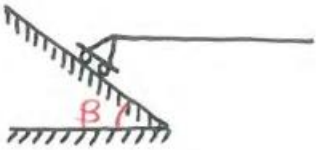
Reaction at support is always due to restriction of movement so direction of reaction is always in opposite direction to expected movement.

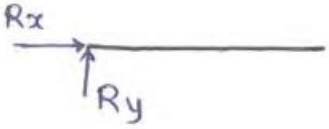
Movement Restricted	Representation	Reaction	Remarks.
x, y. rotation			Fixed
x, y			Pin / Hinge
y. rotation			Guided Roller
x, rotation			Guided Roller
x			Roller
y			Roller
			Inclined Roller.

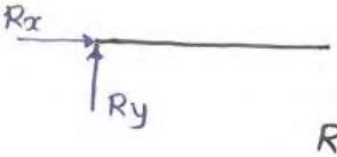
* Note:

Inclined roller support and hinge support both don't provide any movement in x and y direction but we get one reaction for inclined roller and two reactions for hinge support.





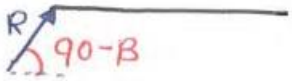




$R_x = R \sin\beta$

$R_y = R \cos\beta$





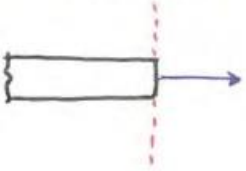
Two unknowns are either (R_x and R_y)

or (R and θ)

Unknown is only R because β is known.

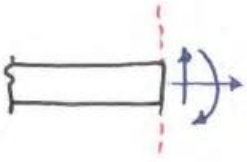
1.8 Types of Structural Member:

1) Axial Member.



Unknown member forces = 1
(Axial Tension or compression)

2) Beam / Frame Member.



Unknown Member forces = 3
(Axial Tension or compression, Shear, Moment)

3) Cable:



Unknown Member Forces = 1
(Axial Tension)

1.9 Equilibrium and Static Equilibrium:

- **Equilibrium:**

If net force (force and moment) acting on a body is zero in all directions then body is in equilibrium.
For e.g. Bodies in space, vehicle moving with constant speed

For 3D :-

$\Sigma F_x = 0$ $\quad \Sigma M_x = 0$

$\Sigma F_y = 0$ $\quad \Sigma M_y = 0$

$\Sigma F_z = 0$ $\quad \Sigma M_z = 0$

For 2D (x-y plane)

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma M_z = 0$

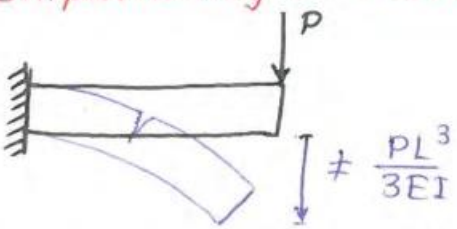
- **Static Equilibrium:**

If net force acting on a body is zero and body is in rest/static state then only body can be classified under static equilibrium condition.
For e.g. Buildings, Bridges etc.

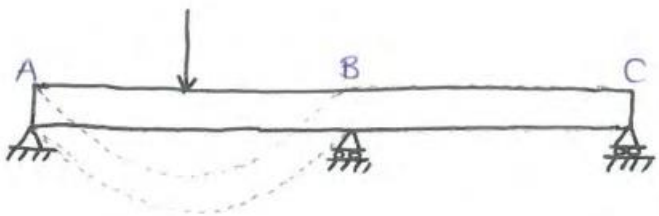
1.10 Compatibility:

The continuity or good-fit of material or member or components while being deformed under loading is called compatibility of structure.

1.10.1 Compatibility of Member:



Compatibility is not maintained due to fracture in member



Compatibility is not maintained because of sudden change in slope at B.

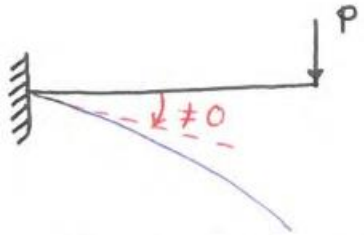


Sudden change in slope at A

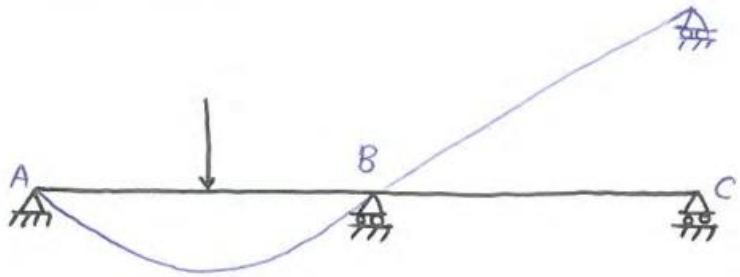


Smooth Curve.

1.10.2 Compatibility of Support:

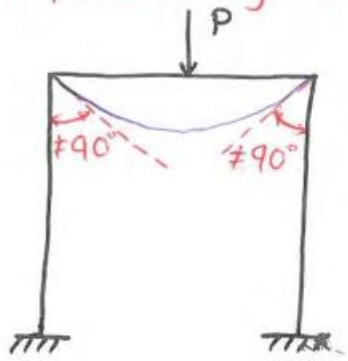


Compatibility is not maintained because of non-zero slope at fixed support.

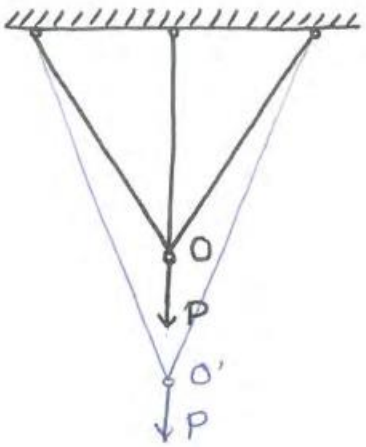


Compatibility is not maintained because of non-zero vertical deflection at C.

1.10.3 Compatibility of Joint:



Compatibility is not maintained because of change in angle between members at rigid joints B & C



Compatibility is not maintained because all 3 members are not intact at O!

1.11 Free Body Diagram:

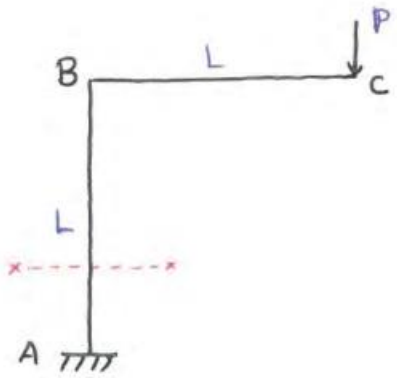
It is a graphical representation of body with all forces (internal and external) acting upon it.

1.11.1 Statically Determinate Structure:

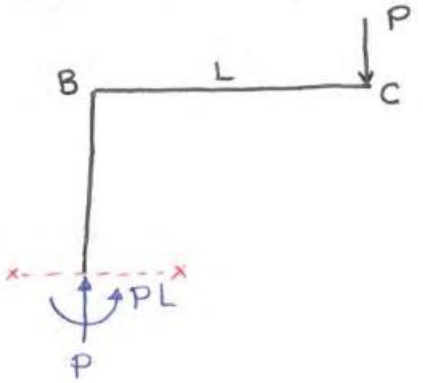
Step I: Make body free from all loads and reactions.

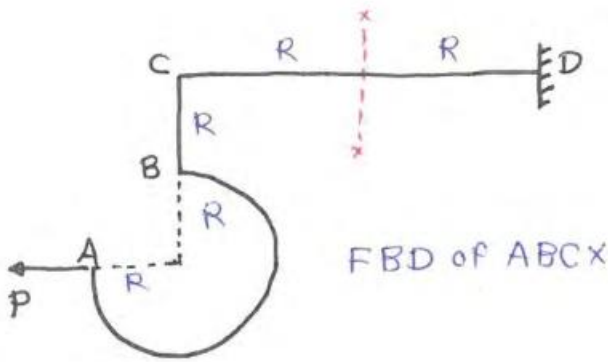
Step II: Apply all loads and support reactions.

Step III: Apply all internal forces at cut section to satisfy conditions of equilibrium.

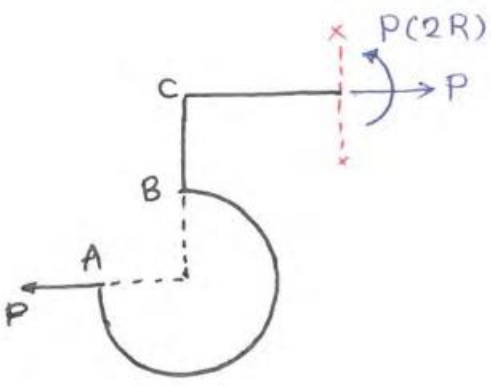


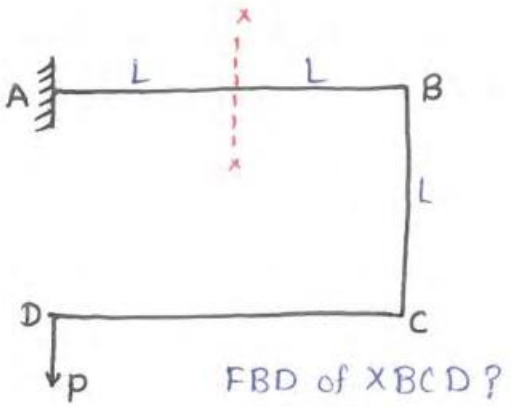
FBD of XBC?



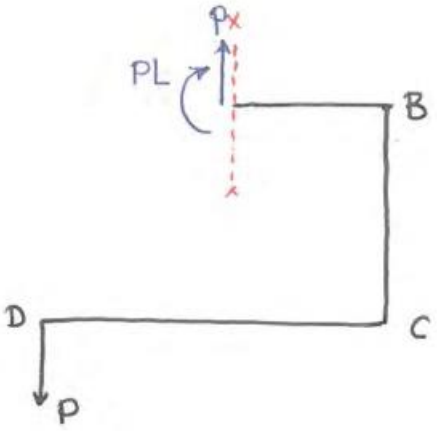


FBD of ABCX?

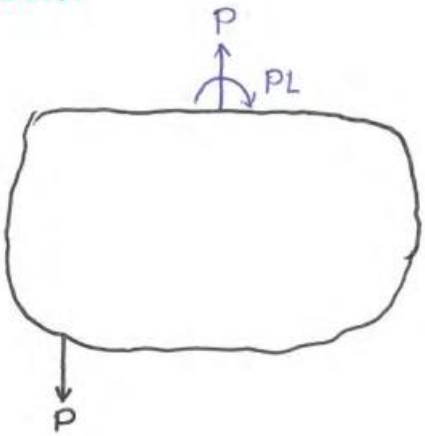




FBD of XBCD?

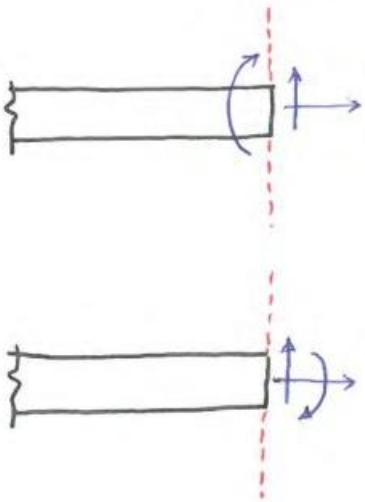


Approach:



*Note:

Preferable way of representation of force at cut section.



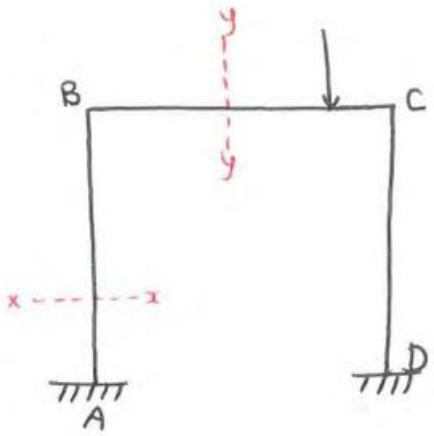
'Preferable'

1.11.2 Statically Indeterminate Structure:

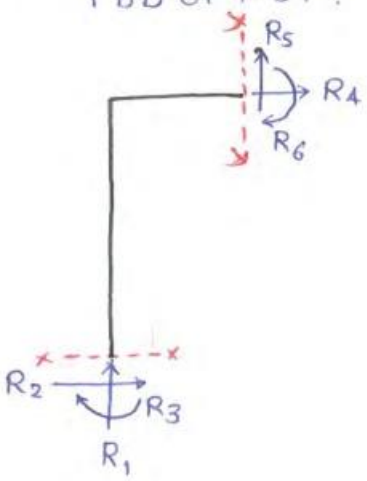
Step I: Make body free from all loads and reactions.

Step II: Apply all external loads and all possible support reactions. (because support reactions are not known).

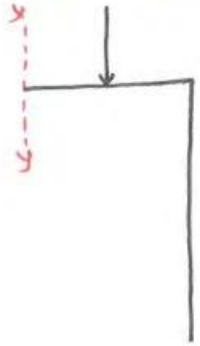
Step III: Apply all possible internal forces at cut section (because member forces are not known)

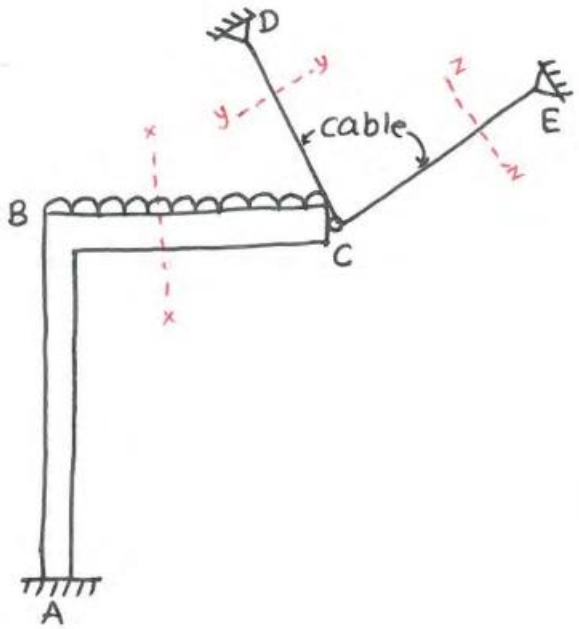


FBD of XBY?

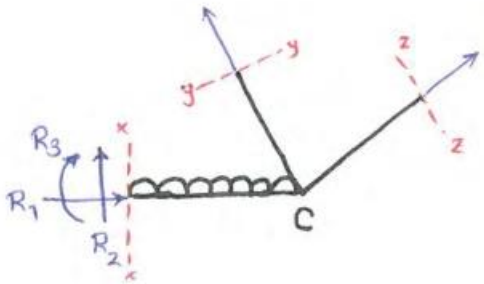


FBD of YCD?





FBD of XCYZ?



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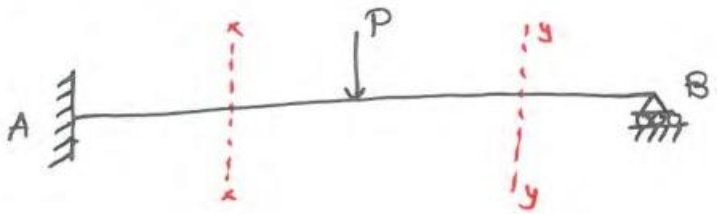
1.12 Static Indeterminacy:

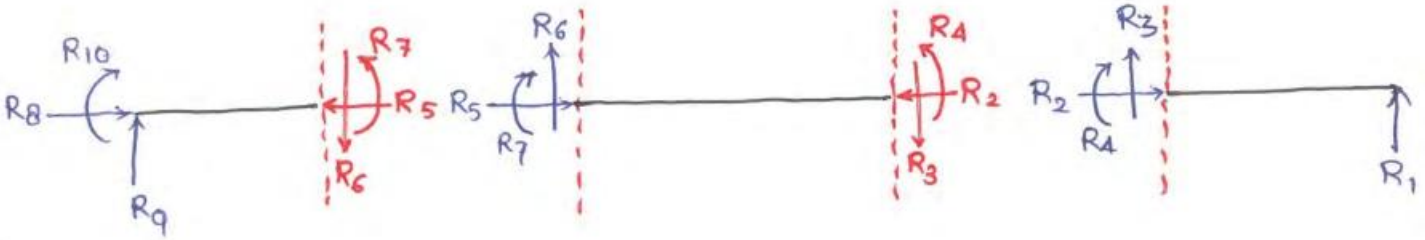
If available equations from conditions of equilibrium are not sufficient to analyse the structure completely then such type of structure is called statically indeterminate structure.

1.12.1 Degree of Static Indeterminacy:

Total number of unknowns (internal forces and support reactions) − Total number of available equations from conditions of equilibrium is called degree of static indeterminacy.

1.12.2 Meaning of DSI





- Observation:

i) In above FBD, total number of unknown are 10 (R_1 to R_{10})

ii) Total number of available equations from conditions of static equilibrium are 9 for 3 portions ($3 \times 3 = 9$)

- Conclusion:

From above FBD, it is clear that only 1 unknown (R_1) is required to be known to calculate all other unknowns (R_2 to R_{10}) so degree of static indetermi-nacy is 1.

In general, minimum number of unknown forces (support reaction or member forces) are required to be known to calculate all other unknown forces (support reactions and member forces) of a

structure is Dsi of that structure.

1.12.3 Procedure:

StepI: Identify start joint.

StepII: Calculate Total number of unknowns (member forces and support reactions) at that joint.

StepIII: Calculate total number of available equations. (including extra equations due to release) at that joint.

StepIV: Calculate StepII - Step III. This is static indetermina at that joint. It may be positive or negative.

StepV: Make mark on each member meeting at that joint.

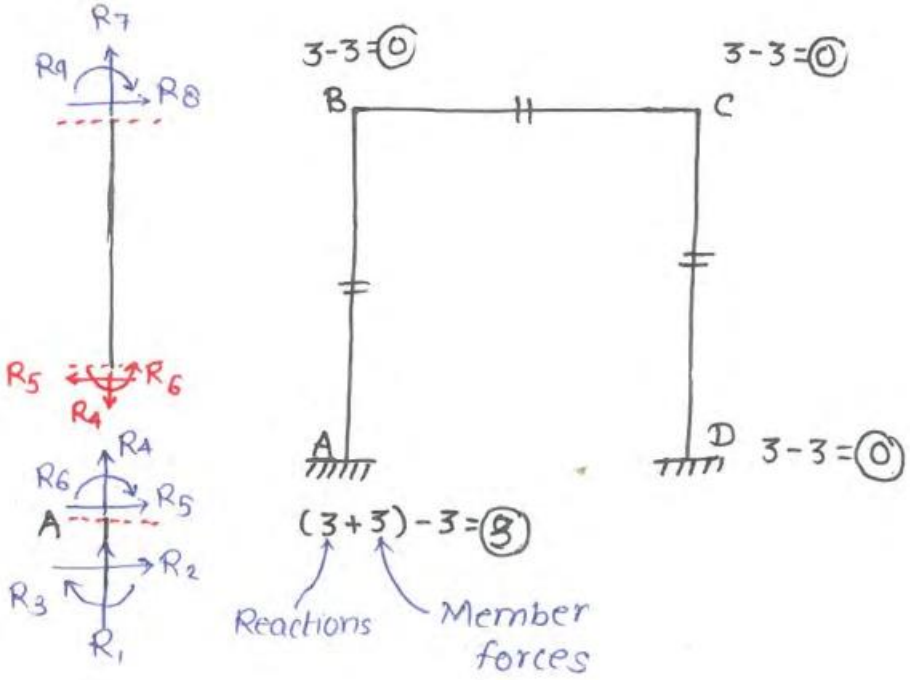
StepVI: Repeat stepII to StepV at all joints.

StepVII: Add up values obtained from stepIV for all joints. This is Dsi of entire structure.

*Note:

Free end of overhang portion should also be considere as joint.

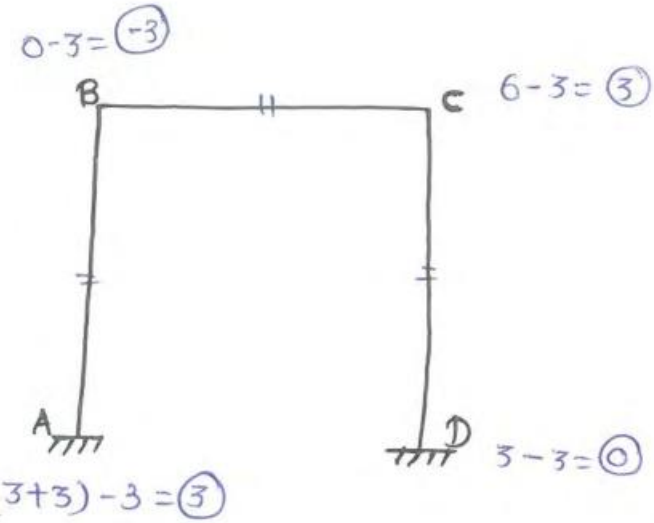
Ex.1.



Seq → ABCD

DSI = 3+0+0+0

= 3

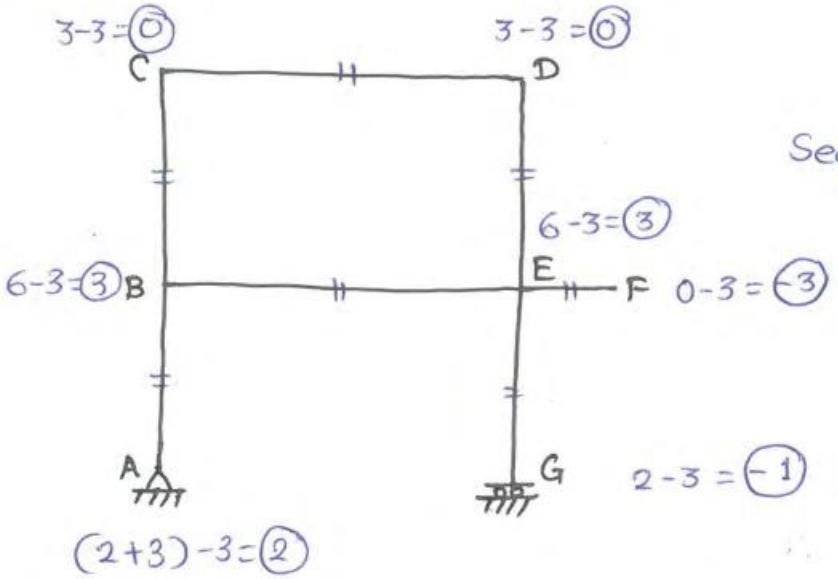


seq - CABD

DSI = 3+3-3+0

= 3

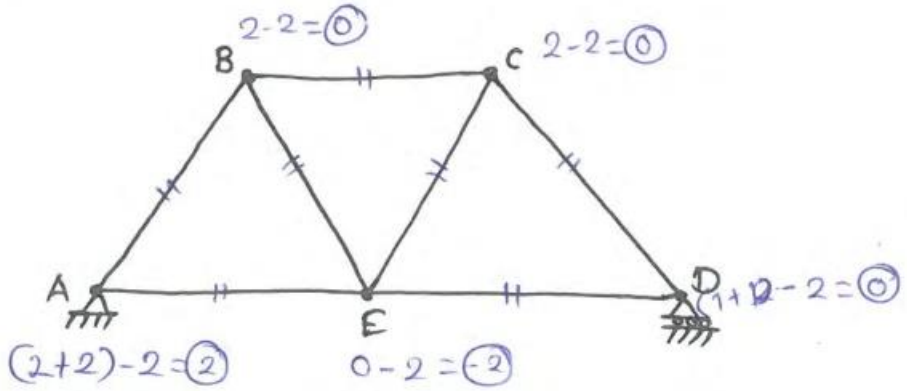
Ex.1



Seq. ABCDEFG

DSI = 2+3+3-3-1 = 4

Ex.3.

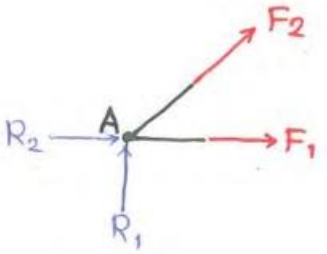


Seq. ABCDE

DSI = 2-2 = 0

*Note:

$\Sigma M_z = 0$ does not provide any equilibrium equation at joint of truss because all forces are concurrent at joint of truss.

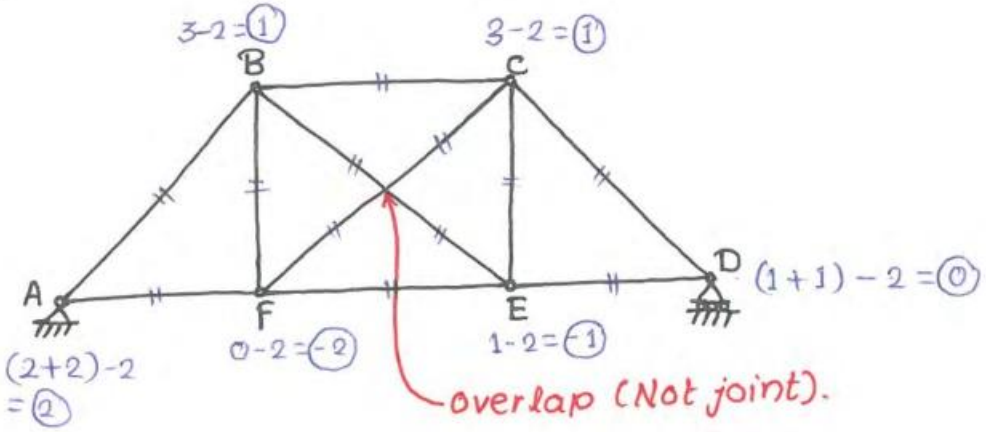


$\Sigma M_z = 0$

$\Rightarrow \Sigma M_A = 0$

$\Rightarrow 0 = 0$ (useless)

Ex.4.



Seq. A to F

DSI = 2+1+1+0-1-2 = 1

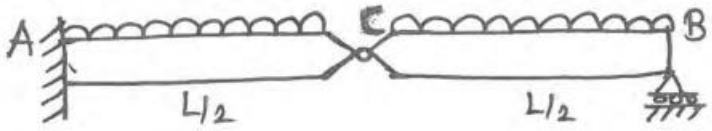
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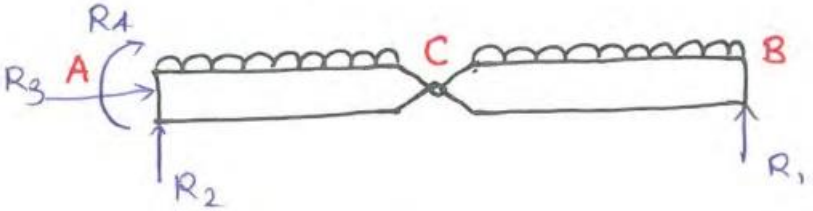
1.12.4 Effect of Internal Hinge:

- Internal Hinge:-

It is a joint in a structure about which part of a structure may rotate.

If structure is in equilibrium then no part of a structure is rotating about hinge. It means, moment about internal hinge from either side must be zero.





$\Sigma F_x = 0$

$\Rightarrow R_3 = 0$ ----- (i)

$\Sigma F_y = 0$

$\Rightarrow R_1 + R_2 - WL = 0$ ----- (ii)

$\Sigma M_z = 0$

$\Rightarrow \Sigma M_A = 0$

$\Rightarrow R_4 + WL \times \frac{L}{2} - R_1 \times L = 0$ ---- (iii)

$M_C = 0$ (Right)

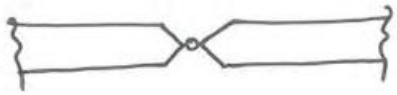
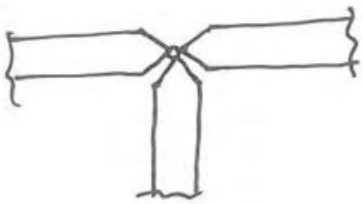
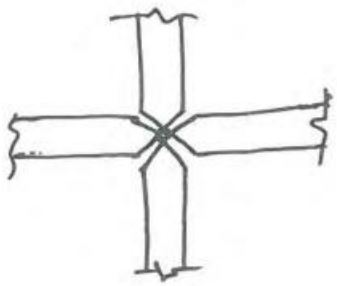
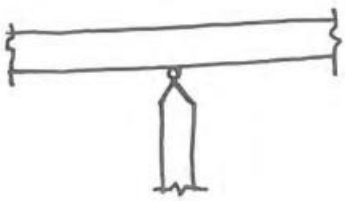
$\Rightarrow W \times \frac{L}{2} \times \frac{L}{4} - R_1 \times \frac{L}{2} = 0$ ---(iv)

$M_C = 0$ (Left)

$\Rightarrow R_2 \times \frac{L}{2} + R_4 - W \times \frac{L}{2} \times \frac{L}{4} = 0$ ---- (v)

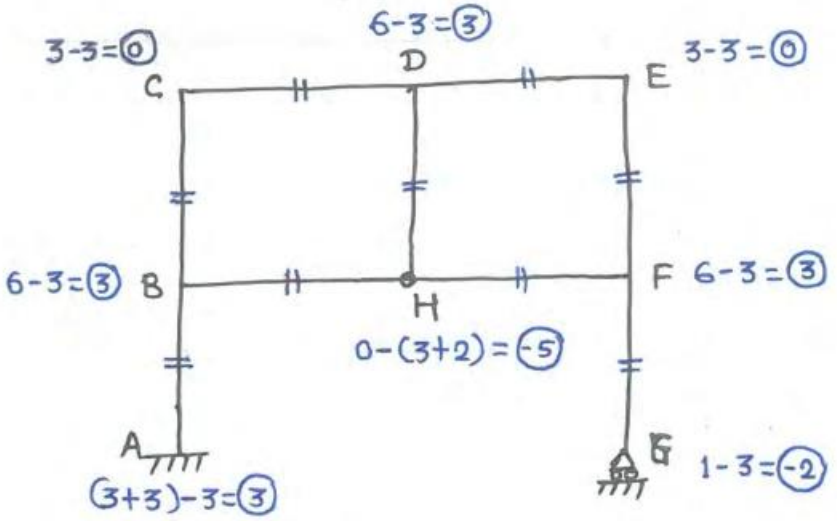
By adding equation (iv) and (v) and replacing R_2 in terms of R_1 from equation (ii), we get equation (iii). It means, moment about hinge equal to zero from both sides does not provide independent equations.

Moment about hinge equal to zero from all sides is equivalent to $\Sigma M_z = 0$.

Arrangement of Hinge	No of extra equation.	
	2D	3D
	1	3
	2	6
	3	9
	1	3

In general for 2D structure.

$$\text{No of extra equations at hinge} = \text{No. of members connected through hinge} - 1$$

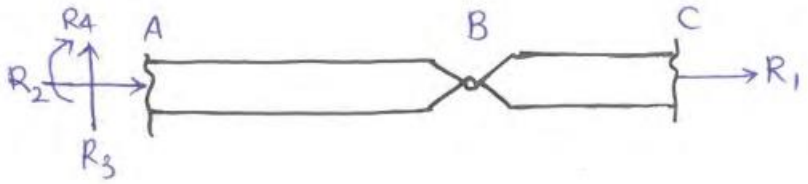


seq. A to H

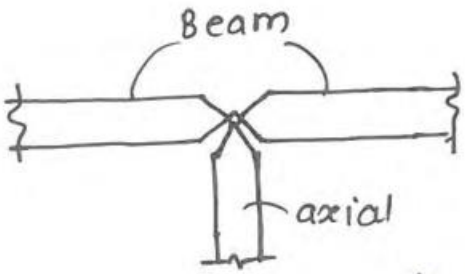
DSI = 12-7 = 5

*Note:

If axially loaded member is connected through hinge then that does not provide any extra equation at hinge.

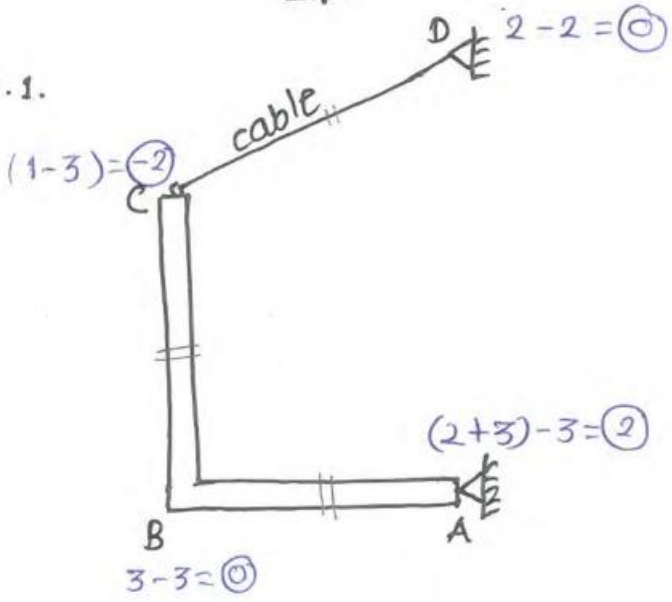


No extra equation



One extra equation.

Ex. 1.



seq. ABCD

DSI = 0