Introduction to Structures & Static and Kinematic Indeterminacy

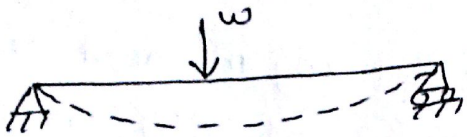
→ **Structure:-**

Any thing is made up of different component which will resist external forces and moment acting is know as structure.

(or)

When any elastic body is subjected to a system of Load and deformation, takes places and the resistance is setup against deformation then elastic body is know as structure.

Eg:-



Outline:-

There are many different type of structure all around us. Each structure has a specific function and purpose. Some structures are complex and another are simple. They are two basic principles of composing structure.

① They must be capable of carring the Loads that they are designed for without collapsing.

② They must support the various parts of the external Load in the correct relative position.

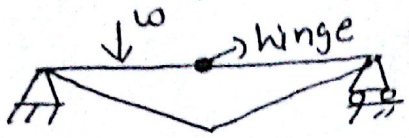
→ **Mechanism:-**

A structure which has not sufficient number of reactions to resist the Load without moving called unstable (or) mechanisms.

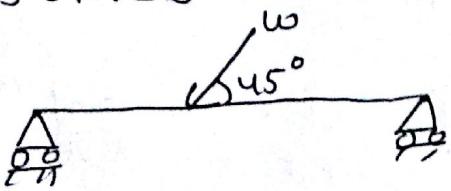
(or)

No Resistance setup in the body against deformation it is know as unstable (or) mechanisms.

Eg:- A simply supported beam subjected to Internal hinge.



A simply supported beam subjected to Inclined Load with two supports rollers.



→ Analysis:-

To find out shear force, Bending moment diagram and worst combination axial forces. by using equilibrium and compability equation.

Outline:-
Deflection due to shear force and axial forces are very small is neglected and deflection due to Bending ismoment is high. so we consider deflection due to Bending moment.

→ Shear force:-

Algebric sumanation of all vertical forces is know as shear force.

→ Bending moment:-

Algebric summation of all moment is know as Bending moment.

outline:-
Shear force is due to Loads and its units are KN
Bending moment due to moment and its unit are KN-mt

→ Classification of structure:-

(i) Skeleton structures (or) one dimensional:-

structure which can be idealized to series of straight (or) curved lines.

Eg:- Roof trusses, beam, frames, girds, arch ribs, cables, etc

(ii) surface structure (or) Two dimensional:-

structure which can be idealized to plane (or) curved surface

Eg:- slabs, shells, folded plates.

outline
plates considered as a speical case of shells but in plates mechanism: axial & shear forces are considerd to be negliable.

(iii) Solid structure (or) Three Dimensional:-

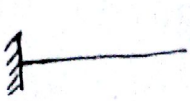
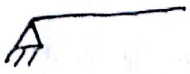
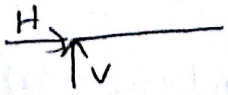
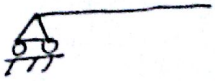
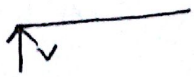
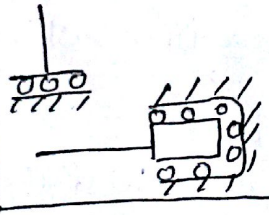
structure which can neither be idealized to a skeleton nor to a plane (or) curved suface.

Eg:- Retaining walls, massive foundation, massive gravity dam, certain arch dam etc.

outline:-
skeleton (or) one dimensional structure are greater than suface (or) Two dimensional structure.

outline:-
practically simply supported slab is lying on a smoth brick wall

→ Types of supports.

S.No	Name of Support	Diagram	Represent Reaction as Free body diagram	No of Reactions
1	Fixed support/Encastre (or) Built-in			3.
2	Pinned/Hinge support			2
3.	Roller/Free/Rocker support			1
4.	Free end		No reaction	0
5.	Vertical shear release support (or) guided roller			2
6.	Horizontal shear release support (or) guided roller			2

Outline:-

① practically Fixed support rotation is zero with finite moment of resistance

* In steel structure multiple riveting / welding behaves as fixed action (may be partial)
* In RCC monolithic concreting and steel having Levelam

② practically pinned support.

* Convential door (Not a sliding one) when you open (or) close the door (or) Leave it partially open. The hinge may make it possible for you to do facilitating rotation about vertical axis.

→ Important points:-

① A pin permits rotational movement about itself
② A pin cannot transmit turning effects or moments.

Outline:-

① practically Roller support might comprise sliding rubber bearing for example steel roller sandwiched b/w steel plates
② practically guided roller is mean bottom is fixed and top is movable.
* A Locomotive railway moving on a rail track
* A car moving with engine on a road truck.

Here road & rail are fixed at bottom Locomotive & car moving on fixidity. It behave as guided roller.

→ Stiffness (K):-

Load per deflection.

$$K = \frac{\text{Load}}{\text{deflection}} = \frac{w}{\delta}$$

Stiffness (K) is inversely proportional to deflection.

↑ stiffness = ↓ deflection.
↓ stiffness = ↑ deflection.

↑ - Increase
↓ - decrease

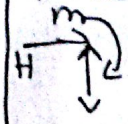
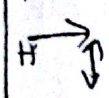
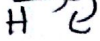
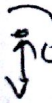
*Reaction exist the displacement at that point doesnot exist.

* Reaction doesnot exist then displacement at that point exist

Outline:-

Slope and deflection are togethea called displacement

→ Stiffness of support:-

S.No	Name of support	K_H	K_V	K_θ
1	Fixed support:- It has three reactions.  So deflection at that point is zero $K = 1/0 = \infty$.	∞	∞	∞
2.	pinned support :- It has two reaction.  So deflection at that point is zero.	∞	∞	0
3:	Roller support:- It has one reaction  So deflection at that point is zero	0	∞	0
4.	Free end:- It has no zero reaction	0	0	0
5.	Vertical shear released (or) guided roller:- It has two reaction  so deflection at that point is zero	∞	0	∞
6.	Horizontal shear released (or) guided roller:- It has two reaction  so deflection at that point is zero	0	∞	∞

K_H = Stiffness in horizontal direction.

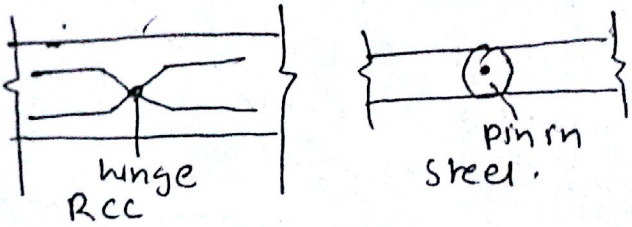
K_V = Stiffness in vertical direction

K_θ = Stiffness in rotational direction.

Outline:-

This is called vertical spring. It subject only one reaction. i.e. vertical reaction.

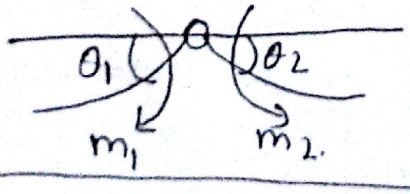
→ Difference between plastic hinge and structural hinge:-

Plastic hinge	Structural hinge
* Moment of plastic hinge is constant (Mp) * Rotation of plastic hinge is infinite. * plastic hinge is not physical device it is the internal response of structure at failure.	* moment of structural hing is zero * Rotation of structural hinge is finite. * Structural hinge is artificially (man-made) (i) In steel structure single rivet (or) bolt will give hinge action. (ii) In Rcc cracking bus with zero lever arm will give negligible mome of resistance. (neglecting the strength of concrete 

→ Types of hinges:-

① Flexural hinge:-

It allow independent rotation.



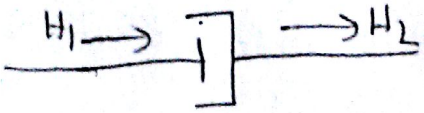
Outline:-

when Reinforcement yields hinge forms.

② axial hinge:-

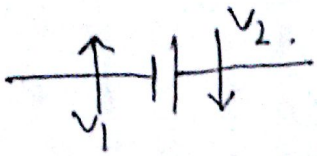
It not transeive axial force. but it transeive Bending moment and shear force

Eg:- piston, clay soil in pile.



③ Shear hinge:-

It not transeive shear it transeive Bending moment and axial force.



Outline:-

① presence of hinge it reduce the value of statical Indeterminacy.

② presence of hinge it increases the value of kinematic Indeterminacy.

→ Equation of static equilibrium.

① In 2D-structure (or) plane structure (which all members and forces are in one plane only) the equation of equilibrium is

$$\Sigma F_x = \Sigma F_y = \Sigma m = 0 .$$

ΣF_x = Algebric sum of component of all external force in horizontal direction.

ΣF_y = Algebric sum of component of all external force in vertical direction.

Σm = Algebric sum of moment of all force about any point in the plane of the structure.

② In 3D-structure.

$$\Sigma F_x = \Sigma F_y = \Sigma F_z = \Sigma m_x = \Sigma m_y = \Sigma m_z = 0 .$$

Outline:-
If however member forces cannot be founded by equation of equilibrium alone the structure is called ~~streatly~~ statically Indeterminate.

→ Compatibility equations:-
Additional equations needed to obtained by relating the applied Load and reaction to the displacement (or) slope known at different point of the structure. is know as compatibility equation.

→ Statically determinate structure:-
① It can be analyzied by using equation of equilibrium.
② It undergoes finite deformation before the condition of equillbrium are satisfied.
Eg:- cantilever beam, simply supported Beam, suspension cable. three hinged arch.

→ Statically Indeterminate structure:-
① It cannot be analyzied by using simple equilibrium equation alone additional equation are required i.e compability equation (or) consistent displacement.
② The number of unknow forces is greater than the number of equilibrium equation.

By continuity equation $\frac{M}{I} = f/y = E/R$.

$$m = EI \times \frac{1}{R}$$

$$\boxed{m = EI \frac{d^2y}{dx^2}}$$ → This compability equation.

$\frac{1}{R} = \frac{d^2y}{dx^2}$ = Rate of change of slope along the length of Beam is curvature.

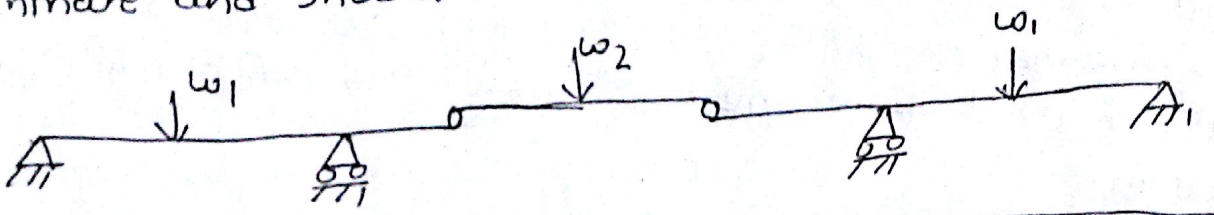
→ Important point:-

① If Beam is continous we say compatibility.

② If Beam is not continous we say incompability.

Outline:-

Balanced cantilever beam. It behave both statically determinate and indeterminate. and its statical determinate is one.



→ Degree of static indeterminacy or redundancy:-

$$D_S = \begin{bmatrix} \text{No of unknow forces in member} \\ \text{(or) at support reaction} \end{bmatrix} - \begin{bmatrix} \text{Equation of static} \\ \text{equilibrium available} \end{bmatrix}$$

$D_S = D_{Si} + D_{Se}$.

D_S = Total static indeterminacy.

D_{Si} = Degree of Internal static indeterminy.

D_{Se} = Degree of External static indeterminacy.

→ Internal Link:-

A link (consisting of a short bar with a pin at each end) provided any where in the structure. It is incapable of transmitting moment as well as horizontal force from one part to the other part. And it provide two additional condition equation.

$$\Sigma m = 0$$

$$\Sigma H = 0.$$

→ open tree Like structure;-

The structure is cut in such a way that each individual cut part Looks like a tree.

① The Tree should have only one root

② Tree cannot have a closed Looped branch.

→ whether static Indeterminate (or) determinate structure is prefeasable;-

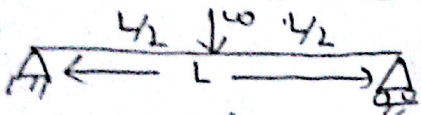
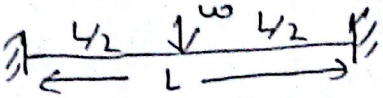
Static Indeterminate structure is more preferable than determinate structure. because.

① Rigidity of static Indeterminate is more when compare to determinate.

② If any failure of one component of structure (ie especially beam) occurs, load distribution (from slab to foundation) will takes another part.

→ Difference b/w statically determinate and Indeterminate structures

Determinate structures	Indeterminate structures.
→ It is analysied by only equilibrium equation.	→ It is analytied both equilibno and compability equation
→ It is uneconomical	→ It is economical.
→ B.m at a section or forces in any member is independent of material/sectional properties	→ B.m at a section or forces in any member is dependent of material/sectional properties.
→ stresse are not caused due to temperature change and Lack of fit	→ stresses are caused due to temperature change and Lack of fit

Statical determinate	Statical Indeterminate.
→ Deflection are more too.	→ Deflection are Less.
Eg:- simple support beam with centre loaded  $\delta = \frac{PL^3}{48EI}$	Eg:- Fixed Sup Beam with centre Loaded.  $\delta = \frac{PL^3}{192EI}$

→ Stability of structure:-

If a body is sufficiently constraint by external reaction such that rigid body movement of structure does not occur then structure is stable. externally.

condition:-

① There should be three reaction that are neither concurrent nor parallel (In plane structure)

② Reaction should be non-parallel, non-concurrent and non-coplanar for space structure.

outline:-

① Concurrent means meeting at single point

② non-concurrent means not meeting at single point

→ unstable (or) deficient structures:-

If a system doesnot have a sufficient number of Internal or external constraints It will under go a rigid body movement upon the application of a small forces.

outline:-

① static determinant structure prefered for bridges constructed across the weak soil

② static Indeterminate structure prefered for long span bridges.