MOHAMED SATHAK A.J. COLLEGE OF ENGINEERING

(Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai)

DEPARTMENT OF CIVIL ENGINEERING

CE8501-DESIGN OF REINFORCED CEMENT CONCRETE ELEMENT

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The objectives of structural design

- The objectives of structural design is to design the structure for stability, strength and serviceability. It must also be economical and aesthetic. **The design of a structure must satisfy three basic requirements:**

  1) **Stability** to prevent overturning, sliding or buckling of the structure, or parts of it, under the action of loads,

  2) **Strength** to resist safely the stresses induced by the loads in the various structural members; and

  3) **Serviceability** to ensure satisfactory performance under service load conditions - which implies providing adequate stiffness and reinforcements to contain deflections, crack-widths and vibrations within acceptable limits, and also providing impermeability and durability (including corrosion-resistance), etc.

Steps in RCC Structural Design Process

❖ The process of structural design involves the following stages.

1. Structural planning
2. Action of forces and computation of loads
3. Methods of analysis
4. Member design
5. Detailing, Drawing and Preparation of schedules

Types of loads on structure

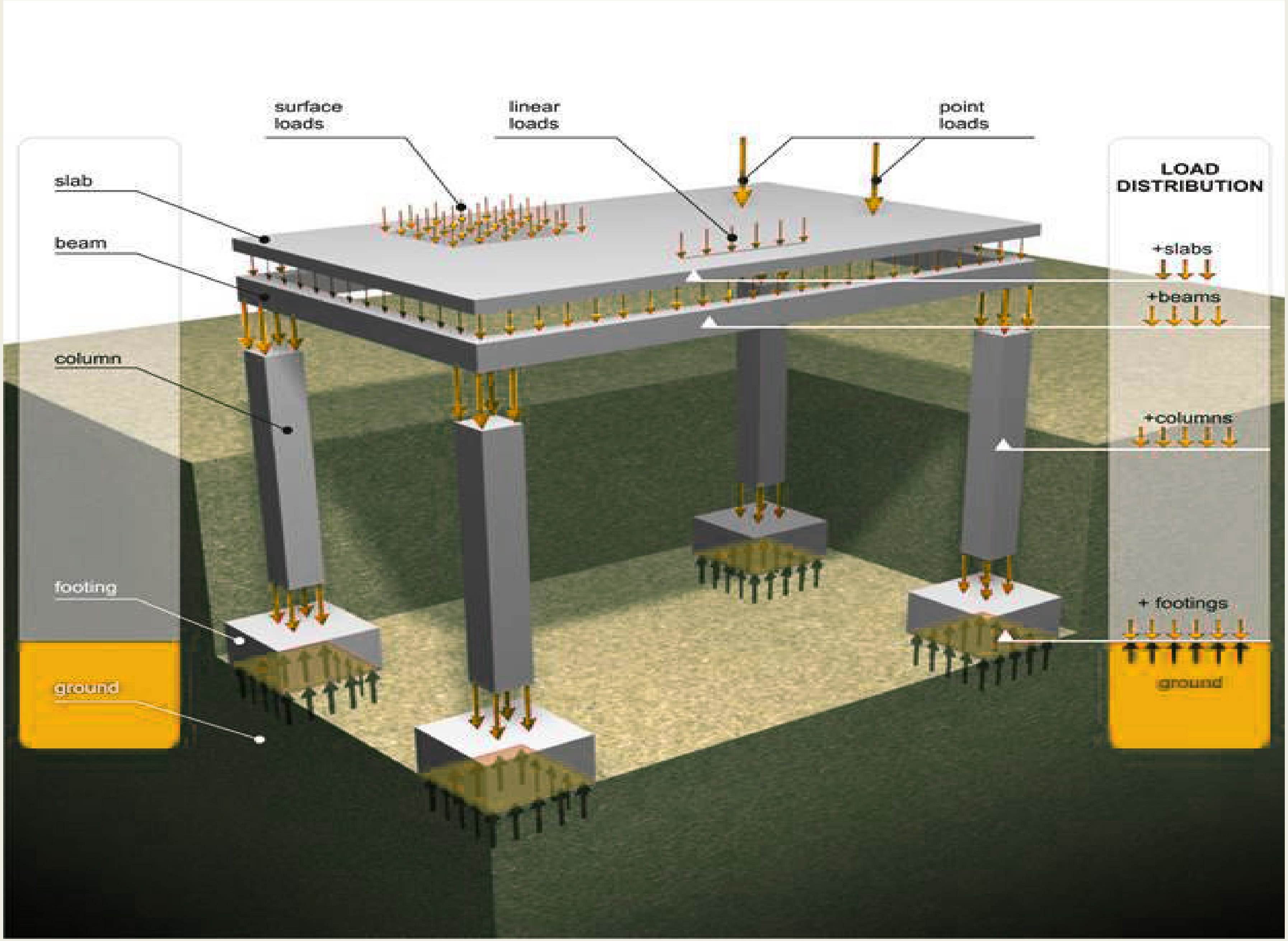
The loads in buildings and structures can be classified as vertical loads, horizontal loads and longitudinal loads.

❖ The vertical loads consist of

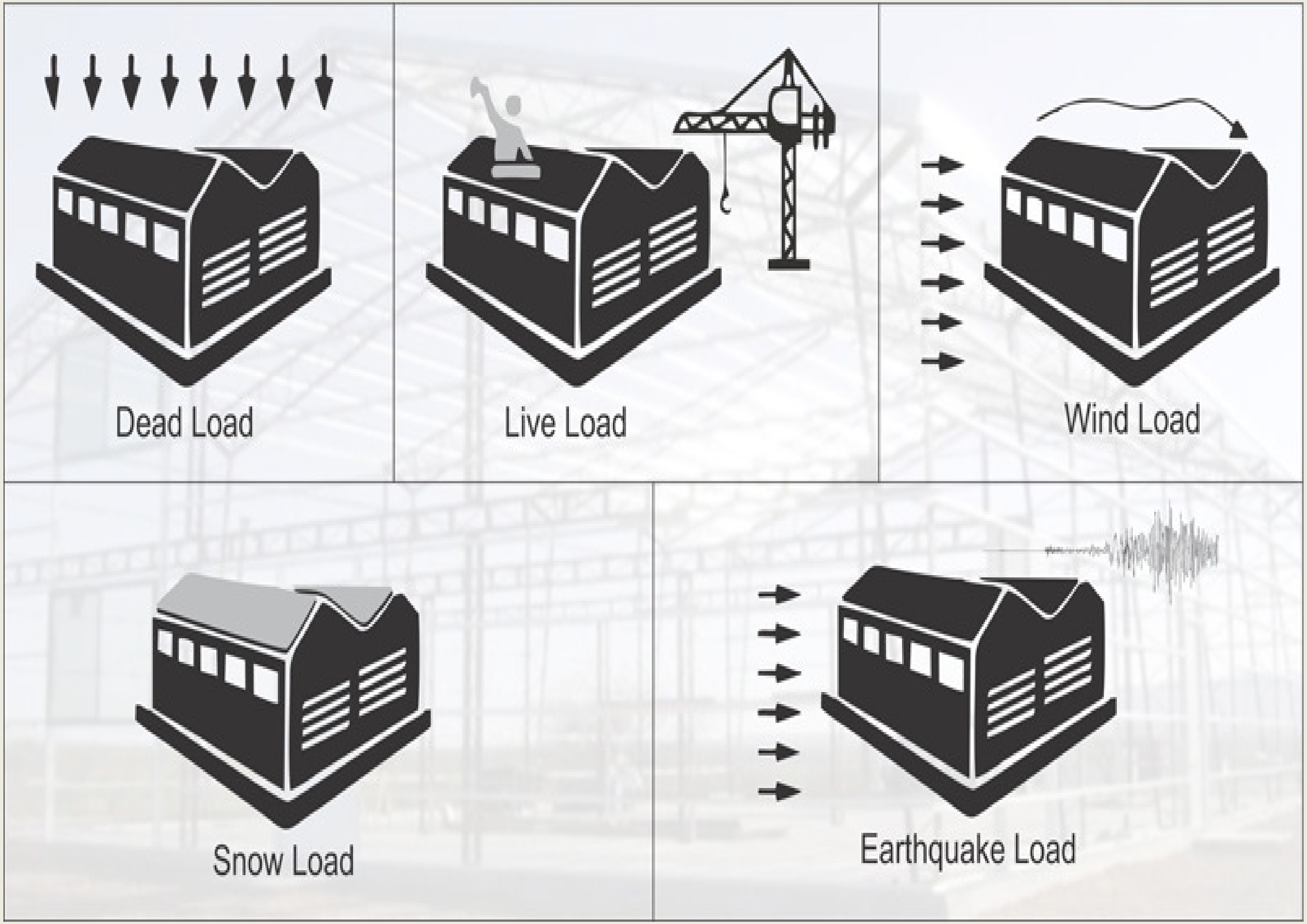
1. dead load,
2. live load
3. impact load.

❖ The horizontal loads consist of

1. wind load
2. earthquake load.



surface loads
linear loads
point loads
slab
beam
column
footing
ground
LOAD DISTRIBUTION
+slabs
+beams
+columns
+ footings
ground


Dead Load
Live Load
Wind Load
Snow Load
Earthquake Load

Load combination

A load combination results when more than one load type acts on the structure. Building codes usually specify a variety of load combinations together with load factors (weightings) for each load type to ensure the safety of the structure under different maximum expected loading scenarios.

Code of practices and Specifications

- **IS Codes for Reinforced Concrete Design of Structures**

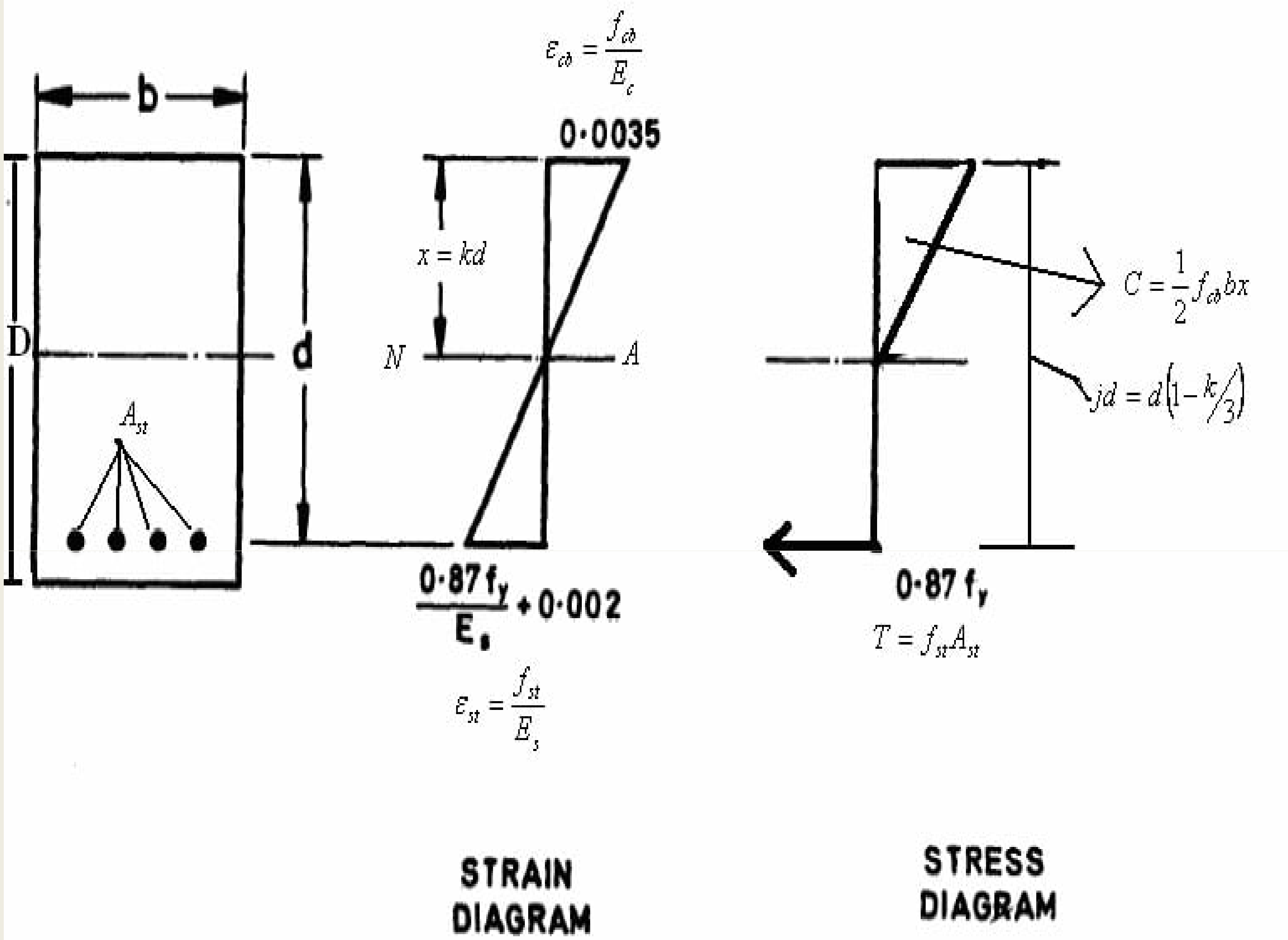
  Following are the design codes in India: (i) IS 456: 2000 – plain and reinforced concrete – code of practice (fourth revision) (ii) Loading standard codes The loads to be considered for structural design are specified in the following loading standards: IS 875 (Part 1 to 5) : 1987 – code of practice for design loads (other than earthquake) for buildings and structures (second revision). Part – 1: Dead loads Part – 2: Imposed (Live) loads Part – 3: Wind loads Part – 4: Snow loads Part – 5: Special loads and load combinations IS 1893: 2002 – criteria for earthquake resistant design of structure (fourth revision). IS 13920: 1993 – ductile detailing of reinforced concrete structures subject to seismic forces.

- **Design Handbooks:**

  The bureau of Indian Standards have also published the following handbooks which serve as useful supplement to the 1978 version of the codes. Although the handbooks need to be updated to bring them in line with the recently revised (2000 version) of the code, many of the provisions continue to be valid (especially with regard to structural design provisions). SP 16 – 1980 – Design Aids (for Reinforced Concrete) to IS456: 1978 SP 24: 1983 – Explanatory handbook on IS 456: 1978 SP34: 1987 – Handbook on Concrete Reinforced and Detailing.

Working Stress Design Method

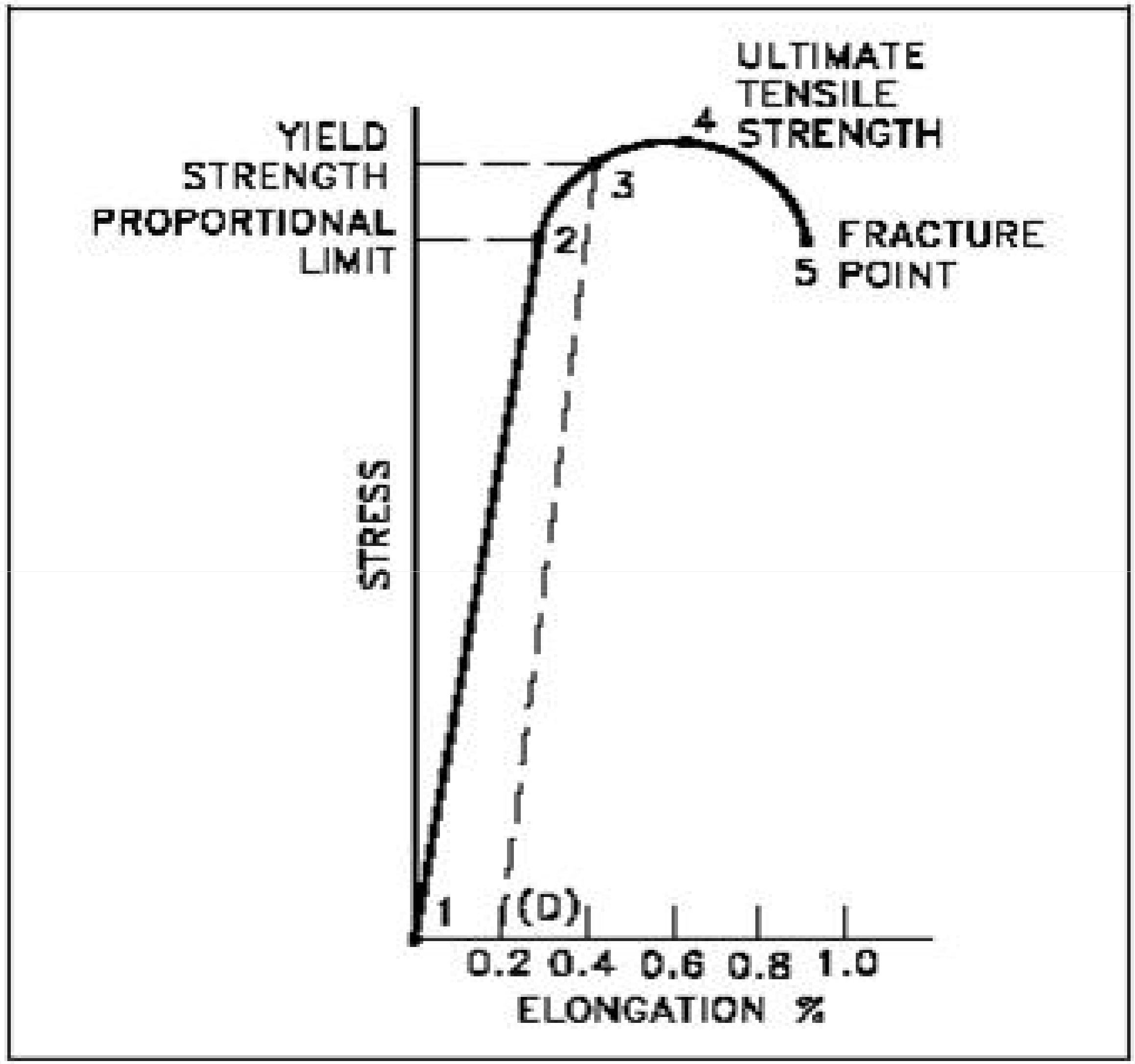
- **Working Stress Design Method** is a method used for the **reinforced concrete design** where **concrete** is assumed as elastic, steel and concrete act together elastically where the relation ship **between loads and stresses is** linear .



b
D
d
A_{st}
$\varepsilon_{cb} = \frac{f_{cb}}{E_c}$
0·0035
$x = kd$
N
A
$\frac{0{\cdot}87 f_y}{E_s} + 0{\cdot}002$
$\varepsilon_{st} = \frac{f_{st}}{E_s}$
$C = \frac{1}{2} f_{cb} bx$
$jd = d(1 - k/3)$
0·87 f_y
$T = f_{st} A_{st}$
STRAIN DIAGRAM
STRESS DIAGRAM

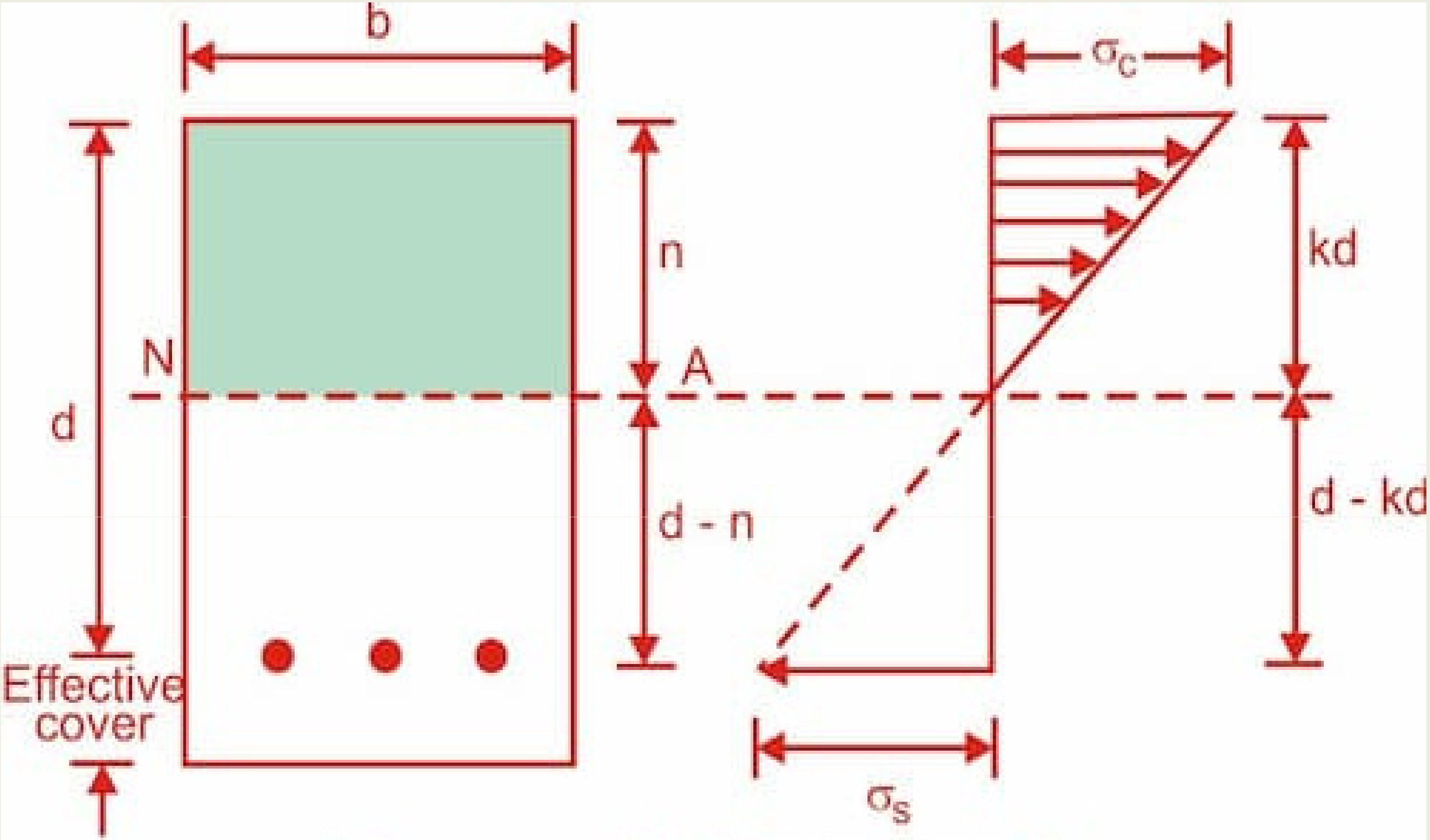
Ultimate Load Design

- This method is sometimes also referred to as the Load factor method.
- In this method, the stress condition at the site of the impending collapse of the structure is analyzed, and the nonlinear stress-strain curves of concrete and steel are made use of.


ULTIMATE
TENSILE
STRENGTH
4
YIELD
STRENGTH
3
PROPORTIONAL
LIMIT
2
FRACTURE
5 POINT
STRESS
1
(D)
0.2 0.4 0.6 0.8 1.0
ELONGATION %

Limit state design load method

- Limit state design approach **considers that the structure should sustain all loads and deformations liable to occur during its construction, perform adequately in normal use, and have adequate durability**.



(a) (b) Stress diagram for given loads

CONCRETE PROPERTIES

- The four main properties of concrete are:

WORKABILITY

COHESIVENESS

STRENGTH

DURABILITY

- Concrete has three different states:

PLASTIC

SETTING

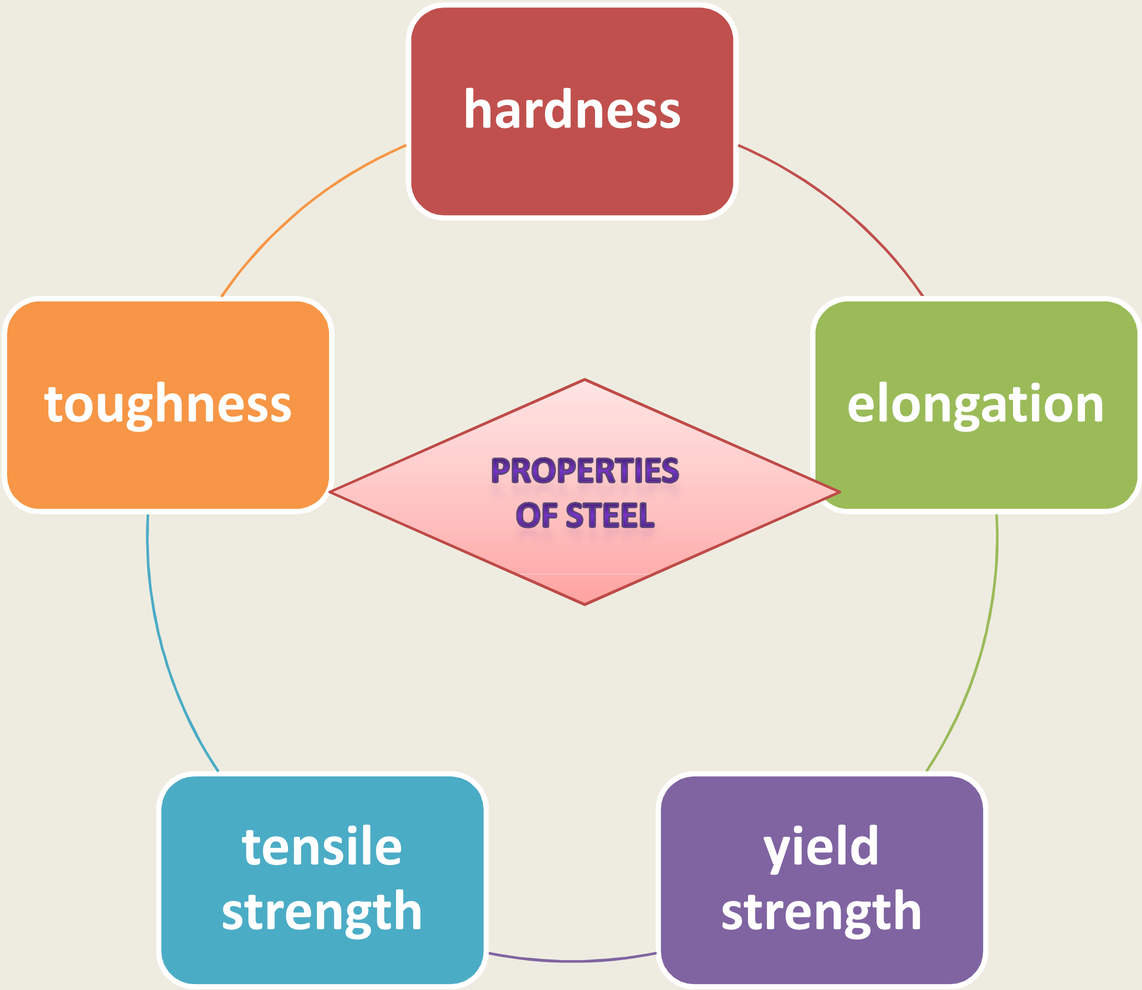
HARDENING

In each state it has different properties.

Properties of steel

❖Steel has a number of properties, including:

- **hardness**
- **toughness**
- **tensile strength**
- **yield strength**
- **elongation**
- **fatigue strength**
- **corrosion**
- **plasticity**
- **malleability**
- **creep**.


hardness
toughness
PROPERTIES
OF STEEL
elongation
tensile
strength
yield
strength

ANALYSIS STEPS for Calculating MOR:

Step 1: Calculate the permissible stresses values for

(a) Concrete σ_{cbc} (From Table 21, Pg.81)

(b) Steel σ_{st} (From Table 22, Pg.82)

Step 2: Calculate the Modular ratio (m) = $\frac{280}{3\sigma_{cbc}}$ (as per IS:456:2000, Pg.80)

Step 3: Determine critical neutral axis (n_c)

$$\frac{\sigma_{st}/m}{d-n_c} = \frac{\sigma_{cbc}}{n_c} \quad » \frac{d}{n_c} = \frac{\sigma_{st}}{m*\sigma_{cbc}} + 1 \quad » n_c = \left(\frac{m*\sigma_{cbc}}{\sigma_{st} + m*\sigma_{cbc}}\right)*d$$

Step 4: Determine actual neutral axis (x_{na})

$$B*x_{na}*\frac{x_{na}}{2} = m*A_{st}*(d-x_{na})$$

Step 5: Compare the value of x_{na} & n_c

(i) If $x_{na} = n_c$, the section is balanced. & $MOR = \frac{1}{2}\sigma_{cbc} . B x_{na} . (d - \frac{x_{na}}{3})$

or $MOR = \sigma_{st} . A_{st} . (d - \frac{x_{na}}{3})$

(ii) If $x_{na} < n_c$, the section is under reinforced.

$$MOR = \sigma_{st} . A_{st} . (d - \frac{x_{na}}{3}) \quad \& \quad C = \frac{\sigma_{st} * x_{na}}{m*(d - x_{na})}$$

(ii) If $x_{na} > n_c$, the section is over reinforced.

$$MOR = \frac{1}{2}\sigma_{cbc} . B x_{na} (d - \frac{x_{na}}{3}) \quad \& \quad T = \frac{\sigma_{cbc}*m*(d - x_{na})}{x_{na}}$$

Note: Safe load (w) is calculated by equating the maximum bending moment to moment of resistance.

Step procedure:

STEP 1: Given data:

STEP 2: Stresses.
f_{ck} & f_y

STEP 3: Cross sectional dimensions.

1) Eff depth IS 456 pg. 37
   Cantilever $\left(\frac{span}{7}\right) = d$.
   S.S $\left(\frac{span}{20}\right) = d$
   Continuous $\left(\frac{span}{26}\right) = d$.

2) Eff span. = clear span + Eff depth.

3) c/c = L + suppor/2.

Step 4: load calculation.
front page.

~~Step 4:~~
1) self weight $= \gamma \times b \times d$ ($\gamma = 24 kN/m$)
2) Live load $= q$.
3) Total load $(w) = (S.W + L.L)$
4) ultimate load $w_u = (1.5 \times T.L)$

STEP 5: Moment and S.F.
front page.

STEP 6: Tension Rft
$M_u = 0.138 f_{ck} bd^2$

$M_u < M.lim$.

Ast calculation.
provide No of bars and diameter.

No of bar $= \frac{Ast}{Area\ of\ one\ bar}$.

STEP 6 SP-16

$M_u/bd^2 = \frac{(20.67 \times 10^6)}{200 \times 200^2}$

(2.58.)

Table(2) sp.16. $P_t = 0.874$.

$Ast = \frac{P_t bd}{100}$. (sp.16).

Hence provide the sam.

STEP 7: check for shear.

$\tau_v = \frac{V_u}{bd}$ (IS456. pg.72).

$P_t = \frac{100 Ast}{bd}$. (Table 19).

$\tau_c > \tau_v$ (ok)

$\tau_c < \tau_v$ Shear Reinforcement Required.

$V_{us} = [V_u - \tau_c bd]$ (IS456 - 73).

Spacing

$S_v = \frac{0.87 f_y S_v d}{V_{us}}$ (IS 456 - 73).

$S_v > 0.75d$.

Step 8: check for deflection.

$(L/d)_{actual} \leq (L/d)_{max}$ (ok)

$(L/d)_{max} = (L/d)_{basic} \times K_t \times K_c \times K_f$

(Note) (L/d)

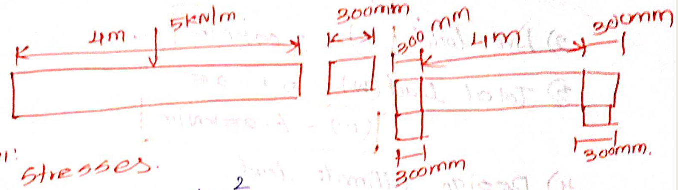
1) Design a singly reinforced concrete beam, to suit the following data.

clear span = 4m.

width of supports = 300mm.

Service load = 5kN/m.

Materials => M-20, Fe415.



STEP1: Stresses.

$f_{ck} = 20\ N/mm^2$

$F_y = 415\ N/mm^2$

Load factor = 1.5 for dead and live load.

STEP2: Cross sectional dimension,

Effective depth = $\left(\frac{span}{20}\right)$

$= \frac{4000}{20}$ $\left(\frac{W}{D} > 0.4 \text{ to } 0.45\right)$

d = 200mm.

adopt d = 200mm.

C.C = 50mm.

Effective span = clear span + effective depth.

l = 4 + 0.2

L = 4.2m.

Centre of centre of supports.

= 0.15 + 4 + 0.15

L = 4.3m

Take Less value L = 4.2m

STEP4: Loads Calculation:

1) Self weight $g = \gamma bd$

$\gamma = 24\ kN/m^2$

$g = 24 \times 0.2 \times 0.25$

g = 1.25 kN/m.

2) Live load. (q) = 5.00 kN/m.

3) Total load (W) = 5 + 1.25

(W) = 6.25 kN/m.

4) Design ultimate load.

$W_u = (1.5 \times 6.25)$

$W_u = 9.375\ kN/m$

STEP5: Ultimate moment and shear force.

S.S (UDL)

$M_u = \frac{wl^2}{8} = \frac{9.375 \times 4.2^2}{8} = 20.67\ kN.m.$

$V_u = \frac{W_u L}{2} = \frac{9.375 \times 4.2}{2} = 19.68\ kN.$

STEP6: Tension Reinforcement:

$M_{u\,lim} = 0.138 f_{ck} bd^2$ [SP16]

$M_{u.lim} = 0.138 \times 20 \times 200 \times 200^2$

$M_{u.lim} = 22.08\ kN.m$

$M_u < M_{u.lim}$ Section is under Rft

$$Mu = (0.87 f_y A_{st} d)\left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$$

$$20.67 \times 10^6 = 0.87 \times 415 \times A_{st} \times 200\left[1 - \frac{A_{st} \times 415}{200 \times 200 \times 20}\right]$$

$A_{st} = 350\,mm^2$.

$$\text{No of bars} = \frac{A_{st}}{\text{Area of one bars}}$$

Provide 16mm dia.

$$= \frac{350}{\frac{\pi}{4} \times 16^2} = \frac{350}{201} = 1.7 \simeq 2$$

Hence

2 bars of $\left(2 \times \frac{\pi}{4} \times 16^2\right) = 402\,mm^2$ 16mm ϕ main bar, 2 hanger bars of 10mm diameter.

STEP7: check for shear stress:

$\tau_v = \frac{V_u}{bd}$ [IS 456: 72) 40.1]

$$\tau_v = \frac{19.68 \times 10^3}{200 \times 200} = 0.49\,N/mm^2.$$

$$P_t = \frac{100 A_{st}}{bd} = \frac{100 \times 402}{200 \times 200} = 1.005$$

$\tau_c = 0.62\,N/mm^2$ (Table 19).

$\tau_v = 0.49$

$\tau_c > \tau_v$

Provide 6mm dia two legged stirrups.

$$S_v = \frac{A_{st} \cdot 0.87 f_y}{0.4 b}$$

$$= \frac{2 \times 28 \times 0.87 \times 250}{0.4 \times 200}$$

$= 152\,mm$.

But

$s_v > 0.75d = (0.75 \times 200) = 150\,mm$.

adopt spacing 150mm. c/c.

Step8:

check for deflection:

$$P_t = \frac{100 \times A_{st}}{bd} = \frac{100 \times 402}{200 \times 200} = 1.01$$

Neglecting hanger bar.

$$= \frac{100 \times A_{sc}}{bd} = \frac{100 \times 157}{200 \times 200} = 0.3925$$

(IS 456).

$f_s = 0.58 \times 415 = 240$

$K_t = 1.05$, $K_c = 1$, $K_f = 1$.

$$\left(\frac{L}{d}\right)_{max} = \left(\frac{L}{d}\right)_{basic}$$

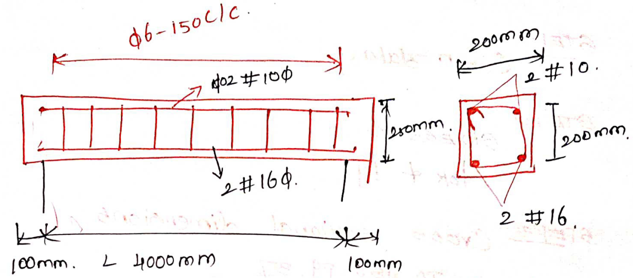
$= 20 \times 1.05 \times 1 \times 1$

$= 21$

$$\left(\frac{L}{d}\right)_{actual} = \frac{4200}{200} = 21.$$

$\left(\frac{L}{d}\right)_{actual} = (L/d)_{max}$. in control.

Reinforcement details:



Load calculation:

i) SS- UDL

$BM = \frac{wl^2}{8} = M$

$SF = \frac{wl}{2} = V$.

ii) SS - PL

$BM = \frac{wl}{4}$

$V = \frac{w}{2}$

iii) Cantilever beam:

$M = wl$

$V = w$

iv) Cantilever beam:

$BM = \frac{wl^2}{2}$

$V = w \times L$.