STEEL STRUCTURES (5 ± 1 marks)

1. MATERIALS & SPECIFICATIONS OF STEEL

→ Advantages of Structural Steel vs. Concrete

(i) Higher strength.

For M20 concrete, $f_{ck} = 20$ MPa.
For mild steel, $f_y = 250$ MPa. $\Rightarrow \frac{f_y}{f_{ck}} \approx 10$ to 12

Compressive & tensile strength of steel are equally good.
But for concrete, tensile strength is approx. $\frac{1}{10}$th compressive stren.

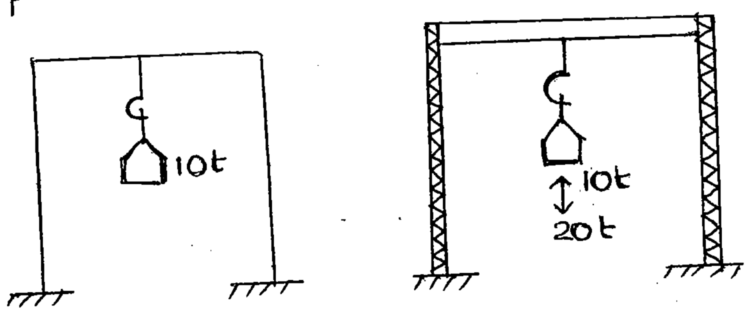
(ii) More economical.

Higher strength to weight ratio for steel compared to concrete. Tall buildings, large span buildings, bridges etc are therefore constructed with structural steel.

(iii) Rapid Construction.

Erection of structure can be completed quickly.

(iv) Easy repair or modification



(v) Ductile material.

$$\% \text{ elongation} = \frac{\delta l}{l} \times 100$$

% elongation > 15 % → Ductile material.

5% − 15% → Intermediate material.

< 5% → Brittle material.

For steel, % elongation > 20%.; shows signs of failure.

(vi) 100% scrap value (reusage value).

Existing steel members can be dismantled and reused for another application with 100% strength.

(vii) Overall construction cost is lesser.

Cost of material, cost of man power, cost of maintenance, dismantling cost etc are cheaper.

(viii) High quality & reliability.

	Safety norms
Working stress method	FOS (= 3 for concrete = 1.7–1.8 for steel)
Limit state Design	Partial safety factor (= 1.5 for concrete = 1.15 for steel)

Lesser values of FOS, P.S.F for steel are because its a factory product; quality control is proper and uncertainities are less.

* Corrosion and proneness to catch fire are the two disadvantages of steel compared to concrete. To make them corrosive and fire resistant, its an expensive process.

$$\underset{(>98\%)}{\text{Iron}} + \underset{\substack{(0.1-1.1\% \\ \text{By weight})}}{\substack{\text{Small \%} \\ \text{of} \\ \text{Carbon}}} + \left.\begin{array}{l}\text{Sulphur} \\ \text{Phosphorous.} \\ \text{Silicon} \\ \text{Manganese} \\ \text{Nickel} \\ \text{Chromium.}\end{array}\right] \longrightarrow \text{STEEL}$$

(v)

* Nickel & Chromium content is more in Stainless steel giving it anti-corrosive properties

→ Mechanical Properties Imparted by Carbon

(i) Yield strength
(ii) Ultimate tensile strength
(iii) Hardness.
(iv) Ductility.
(v) ~~Str~~ Toughness.

Carbon content : 0.23 % ⟶ $f_y = 250$ MPa.
0.27 % ⟶ $f_y = 350$ MPa.

→ Classification of Steel (based on Carbon Content)

(i) Low Carbon steel. — 0.1 to 0.25 %
(ii) Medium Carbon steel. — 0.25 to 0.6 %
(iii) High Carbon steel. — 0.6 to 1.1 %

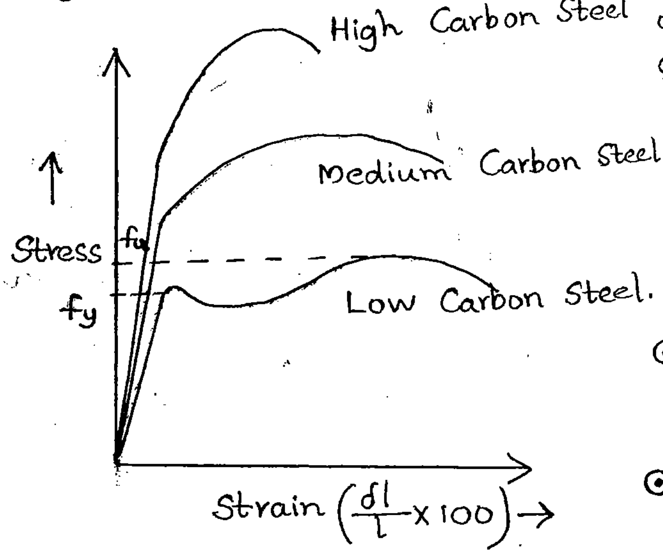
Mild steel used in RCC constructions as reinforcements (Fe 250, 0.25%)
Structural steel section used in steel building construction } Low Carbon

Rails, tyres, high tensile steels (Fe 415, 0.27%), hammers etc. → Medium Carbon

Stone masonry tools, drills, punches etc. → High Carbon

As carbon content ↑, yield strength (f_y)
ultimate tensile strength (f_u)
Hardness of steel. } ↑

Ductility
Toughness } ↓



⊙ Hardness must be lesser to improve weldability.

⊙ Ductility & toughness are very important for structural steel subj to dynamic & impact loads.

→ General Classification:

(i) Reinforcing Steels. :– used as reinforcement in RCC constructions.

Fe 250, Fe 415, Fe 500 etc

Steel. ↗ ↖ Yield strength (MPa)

(ii) Structural Steels. :– used in steel building and bridge constructions.

Fe 410, Fe 540, Fe 570 etc.

Steel. ↗ ↖ Ultimate tensile strength (MPa).

For mild steel, $f_y = 250$ MPa.

$f_u = 415$ MPa.

→ Codes & Standards.

Failures of old constructions.
Performance of existing buildings.
Researches in various publications

} basis for CODE formulation.

⊙ IS 800 —
- 1956 – 1962 (1st)
- 1984 (2nd) WSM
- 2007 (3rd) LSD

} code of practise for use of structural steel. in general building construct

⊙ IS 875 : 1987 (Five parts) : code of practise for design loads for buildings & structur

⊙ IS Hand Book No. 1 (Steel tables) : a) weight /running meter.

b) c/s area.

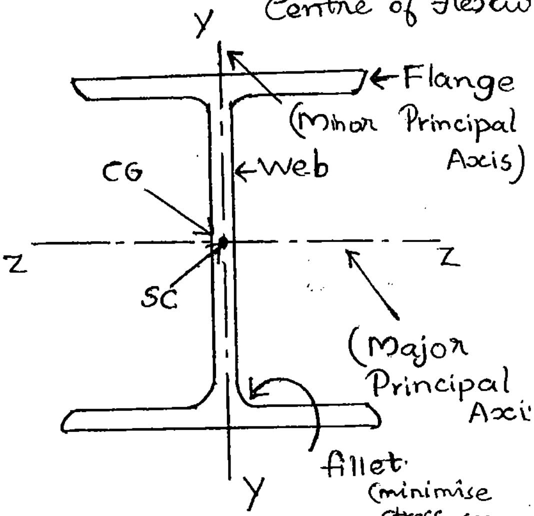
c) radius of gyration.

d) Section modulus.

→ Rolled Steel Sections

(i) Rolled steel I-sections or I beams.
(ii) Rolled steel channel sections.
(iii) Rolled steel Tee sections or T-bars.
(iv) Rolled steel angle sections.
(v) Indian Standard tube sections.
(vi) Rolled Steel bars.
(vii) Rolled steel plates.
(viii) Rolled steel Sheets.
(ix) Rolled steel flats.
(x) Rolled steel strips etc

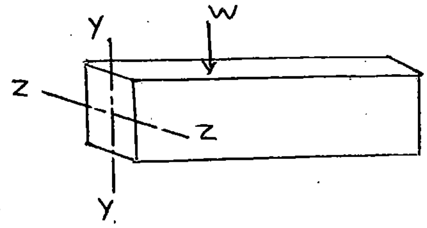
CG: Centre of Gravity.
SC: Shear centre (Centre of Flexu



I-section or I-beams

* Z-Z axis → Major Principal Axis.
Moment of inertia wrt Z-Z axis is more. (bending axis).

$$I_{zz} = y^2\, dA$$



* When only tranverse loads acts on a rectangular beam, bending will be about Z-Z axis. ∴ I_{zz} should be more. For this, depth of beam is increased.

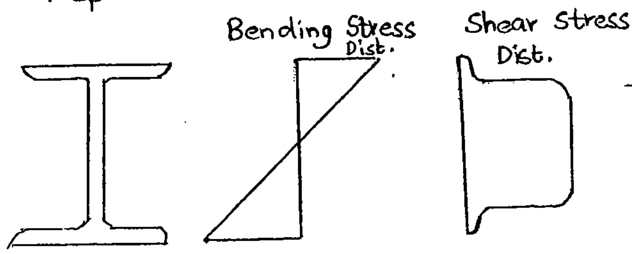
If lateral loads also act on the beam, there will be bending about y-y axis as well. In that case, width of beam is also increased.

* An I-section may be designated as:

ISLB 500 @ 735.6 N/m (≈ 75 kg/m)

Depth of I-section = 500 mm

Weight per running metre =



* 90-92% Bending stress will be taken by Flanges
* Illy, shear by web.

→ Five Types of I-sections:

(i) ISJB — Indian Standard Junior Beams
(ii) ISLB — Indian Standard Light Weight Beams
(iii) ISMB — Indian Standard Medium Weight Beams
(iv) ISWB — Indian Standard Wide Flange Beams
(v) ISHB — Indian Standard Heavy beams Beams.

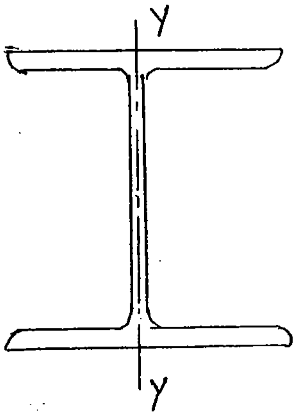
(Max. depth :- 600 mm)

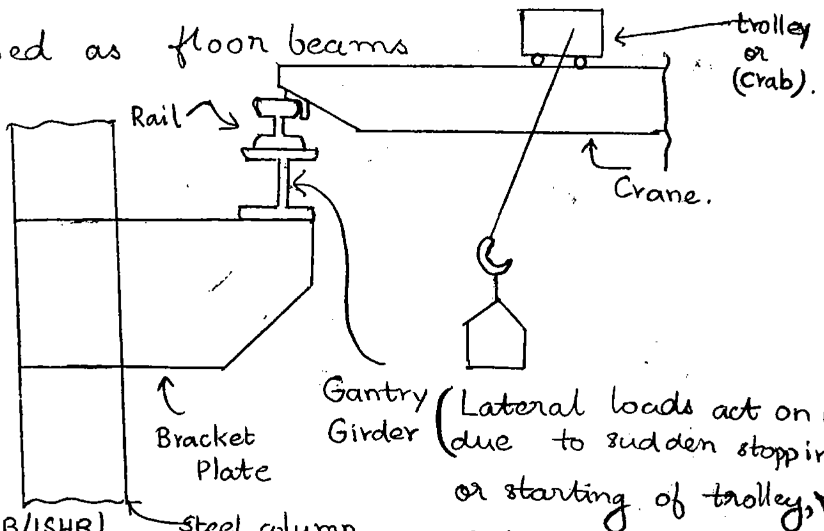
* Special I-section:

ISSC : Indian Standard Column Section

(Max. depth :- 250 mm)

* ISLB & ISMB are used as floor beams

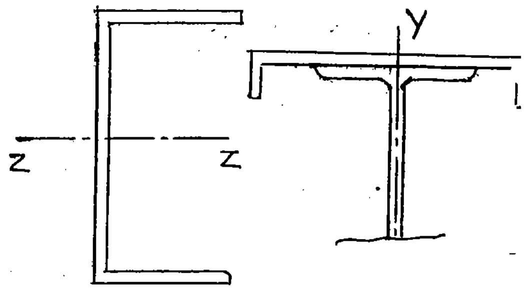




(Lateral loads act on it due to sudden stopping or starting of trolley, ∴ ISWB is used)

$I_{YY}(ISWB) > I_{YY}(ISLB/ISMB/ISHB)$

To increase I_{yy}, sometimes channel sections are also added to the flanges. ∴ I_{zz} of channel section will add to the I_{yy} of I section.



* ISHB is used for columns.

Sectional area & radius of gyration for ISHB are more compared to its counterparts

Critical load carrying capacity, $P_{cr} = \frac{\pi^2 EI}{l^2} = \frac{\pi^2 E A r^2}{l^2}$

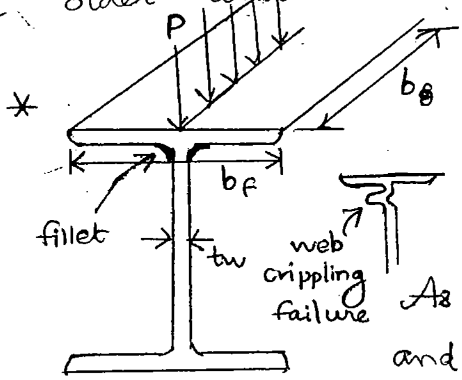
$$P_{cr} = \frac{\pi^2 EA}{(l/r)^2} = \frac{\pi^2 EA}{\lambda^2} \qquad \lambda = \frac{L}{r}$$

$$(P_{cr})_{zz} = \frac{\pi^2 EA}{(l/r_{zz})^2} \; ; \; (P_{cr})_{yy} = \frac{\pi^2 EA}{(l/r_{yy})^2}$$

$$r_{zz} = \sqrt{\frac{I_{zz}}{A}} \; ; \; r_{yy} = \sqrt{\frac{I_{yy}}{A}} \Rightarrow r_{zz} > r_{yy}.$$

$$(P_{cr})_{zz} > (P_{cr})_{yy}.$$

Columns are designed for $(P_{cr})_{yy}$ and failure will be along y-y axis. However, solid circular sections or hollow circular sections are most efficient column sections. So ISHB used in older constructions.



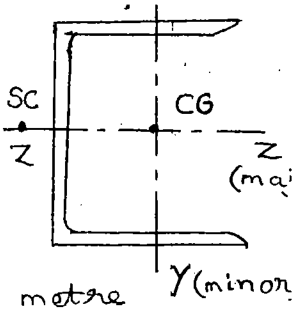
* For the flange, stress $= \dfrac{P}{b \times b_f}$.

For the web, stress $= \dfrac{P}{b \times t_w}$

As $b_f > t_w$, stress conc. occurs in web. and $\therefore$ web crippling failure may occur.

$\therefore$ area is increased in fillets to avoid stress concentration.

→ Channel or C – Sections



⊙ A channel section may be designated as

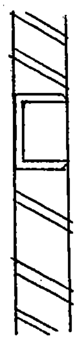
ISLC 350 @ 380.6 N/m

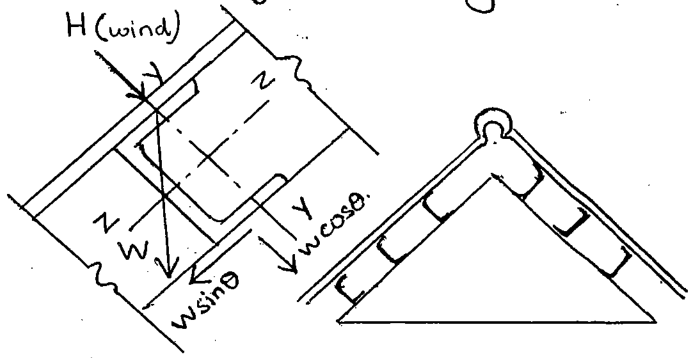
Depth of channel = 350 mm

Weight per running metre = 380.6 N/m (≈ 39.5 k

* $(I_{zz})_{channel} < (I_{zz})_{I\text{-}section}$

∴ channel sections are used for light loadings like lintels, roof purlins.



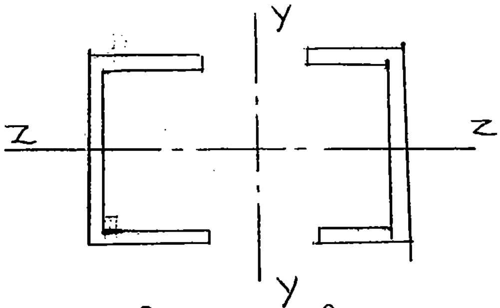


$(H + W\cos\theta)$ cause moment about major axis (Z-

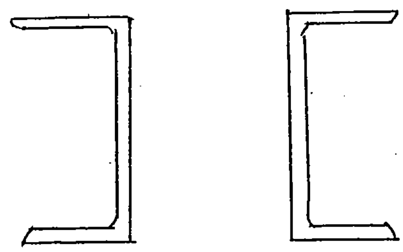
$W\sin\theta$ cause moment about minor axis (y–y)

∴ channel sections are used for light loads as its more economical than I-sections

* Channel sections are also used as Built-up Column sectio



face – to – face



back – to – back

* Types of Channel Sections.

(i) ISJC – Indian Standard Junior Channels.

(ii) ISLC – Indian Standard Light Channels.

(iii) ISMC Medium wt. channel with sloping fl

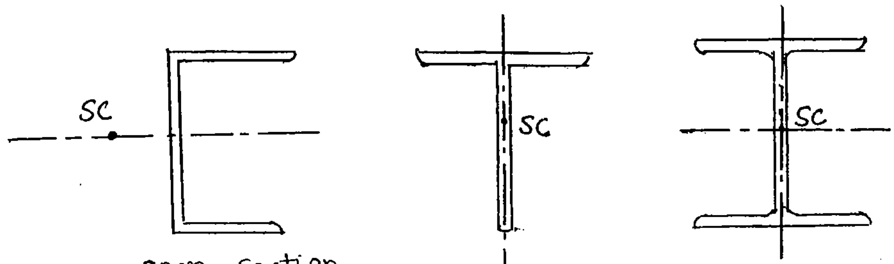
(iv) ISMCP Medium wt. channel with parallel fla

(v) ISGC. Gate Channels.

* SC is a point through which resultant transfer shear load must act. if there is to be no twisting or torsion (section is subjected to BM only).

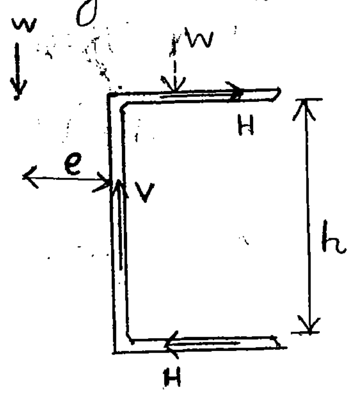
* If given member or section has axis of symmetry about both the principal axes, SC is coincident with CG of a section or member.

* If given section is symmetric about one axis, SC will be lying on axis of symmetry.



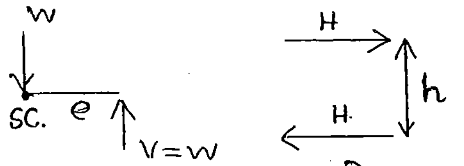
open section | open sections

If load acts at a point different from SC, twisting moment occurs.



Shear stress, $q = \frac{VA\bar{y}}{I.b}$

Shear flow, $Q = q.b = \frac{VA\bar{y}}{I}$

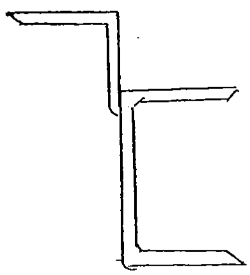


$M = We - Hh$

We (anti clockwise) Hh (clockwise)

* If w acts through SC, the net moment will reduced.

* If w acts at a different point from SC, 'We' will be clockwise and Hh will also be. This will increase the net moment.



The purpose of angle section:

a) I_{zz} increases

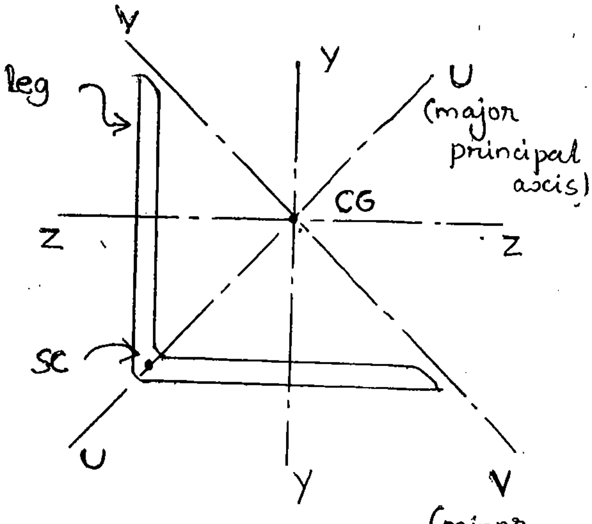
b) I_{yy} increases. $\Delta \propto \frac{1}{I}$

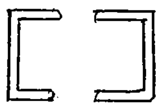
c). Deflection decreases

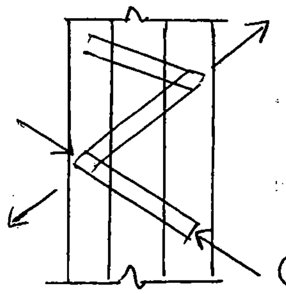
d) makes load pass through SC.

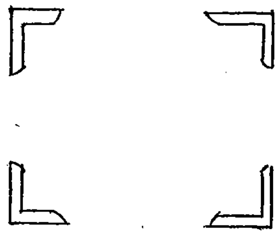
→ Angle Sections (or) L Section

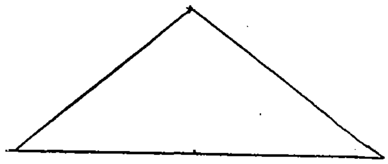
* Angle sections are used as strut (compression) members or tie (tension) members in roof truss, built up colums, bracings etc.











* Three types of Angles.

(i) Equal Angles.

> Designated as ISEA or ISA.

> Eg: ISEA 100×100×10.

> excellent strut members

ISEA 100×100×10

$A = 1902 \text{ mm}^2$

$r_{vv} = 19.4$ mm.

ISA 125×75×10.

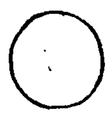
$A = 1903 \text{ mm}^2$

$r_{vv} =$

rd Aug, TURDAY → Indian Standard Bars

(i) Indian Standard Round Bars.

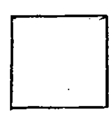
Designated as ISRO 20



> rivets, bolts, welding rods.

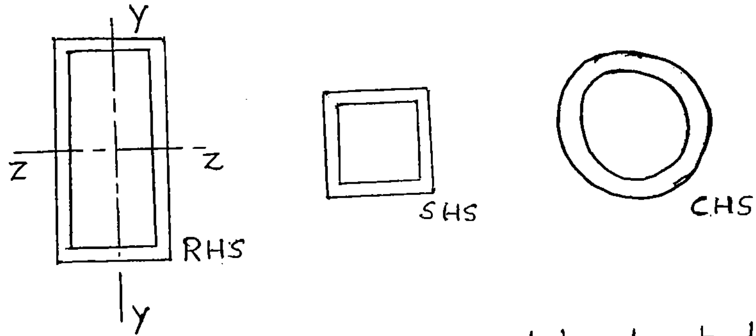
(ii) Indian Standard Square Bars.

Designated as ISSQ 50



→ Indian Standard Tube Section

(i) Rectangular Hollow Sections. (RHS)
(ii) Square Hollow Sections (SHS)
(iii) Circular Hollow Sections (CHS)



To withstand torsional loads, tubular sections are most efficient.

Polar moment of inertia, $I_P = I_{xx} = I_{zz} + I_{yy}$.

$$\frac{T}{J} = \frac{f_s}{r}$$

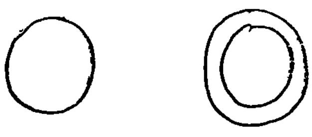
(Izz & Iyy are very large for tubular section)

$$T = \frac{f_s}{r} \times J \qquad (J = I_P).$$

NOTE:

(i) The best section or economical section for column is Solid Circular section or hollow circular section.

(ii) For same weight (c/s area), hollow circular section will provide higher radius of gyration than solid circular section Hence H.C.S will provide higher compressive strength than S.C.S.

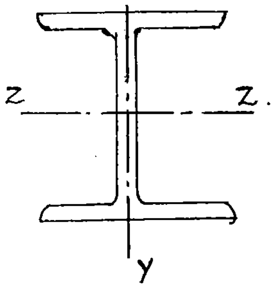


$r_{SCS} < r_{HCS}$.

$$P_{cr} = \frac{\pi^2 EI}{l^2} = \frac{\pi^2 E A r^2}{l^2}$$

$$\Rightarrow \underline{P_{cr} \propto r^2}$$

- For sections having symmetry about both the axes, bending will be about the axis of symmetry.
- For sections which are symmetric about only one axis, bending will be about the axis of symmetry or an axis normal to the axis of symmetry.



→ Indian Standard Plates (when $t \geq 5$ mm).

Designated as ISPL

Eg:- ISPL 2000×1000×10 mm.

Length $L = 2000$

Breadth $B = 1000$

Thickness $t = 10$

→ Indian Standard Sheets (when $t < 5$ mm)

Designated as ISSH

Eg: ISSH 1000×600×2 mm.

$L = 1000$

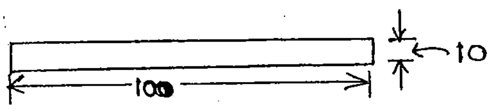
$B = 600$

$t = 2$

→ Indian Standard Flats. (when $t \geq 5$ mm).

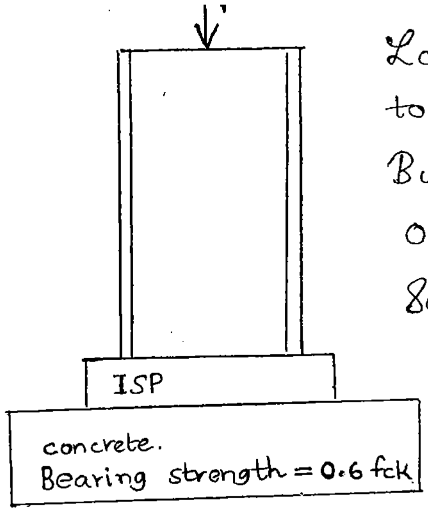
Designated as. ISF.

Eg: 100 ISF 10



$B = 100$ mm

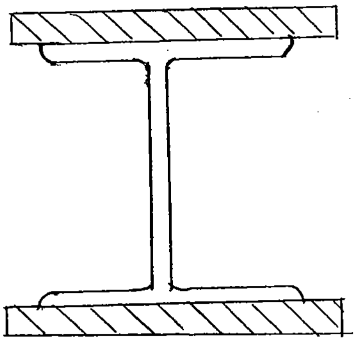
$t = 10$ mm



Load transferred by steel sections to the concrete foundation will be high. But bearing strength of concrete is only 0.6 fck.

So plates are used.

Bearing strength on plates $= \frac{P}{L \times B} < 0.6\ f_c$



$M \leqslant M_d$

$M_d = f(z)$.

Design moment should be greater than the ultimate bending moment acting on th the beams. To increase the M_d, I_{zz} value is increased making use of built up I-sections with flanged plates.

- Sheets are used as coverings.
- Flats are used as lacings and battens for built-up colum

→ Structural Steel vs. Aluminium.

Physical Properties	Steel	Aluminium
Density. ($\rho_a \approx \frac{1}{3} \rho_s$)	$\rho_s = 7850\ kg/m^3$.	$\rho_a = 2700\ kg/m^3$.
Youngs modulus. ($E_a \approx \frac{1}{3} E_s$)	$E_s = 2 \times 10^5$ MPa	$E_a = 0.7 \times 10^5$ MPa.
Coeffecient of Thermal expansion. ($\alpha_a \approx 2\alpha_s$)	$\alpha_s = 12 \times 10^{-6}/°c$.	$\alpha_a = 23 \times 10^{-6}/°c$.

(i) $\left(\frac{\text{Strength}}{\text{weight}}\right)_{\text{Al. sections}} > \left(\frac{\text{Strength}}{\text{weight}}\right)_{\text{structural steel sections}}$

But $E_a \approx \frac{1}{3} E_s$.

$P_{cr} = \frac{\pi^2 E A}{(l/r)^2}$ ⇒ For lighter compressive loads, Al section have more chances of buckling.

∴ Al is not used in civil construction applications. But for aeroplane constructions, Al is used as weight is more important parameter there. Aerospace constructions like missiles, space structures make use of Al.

(ii) Al sections are more corrosive resistant than structural steel sections. Hence maintenance may be lesser for Al sections

→ Method of Design.

(i) Working Stress Method (WSM) – FOS
(ii) Ultimate Load Design (ULD) – Load Factor
(iii) Limit State Design (LSD) – Partial Safety Factor.

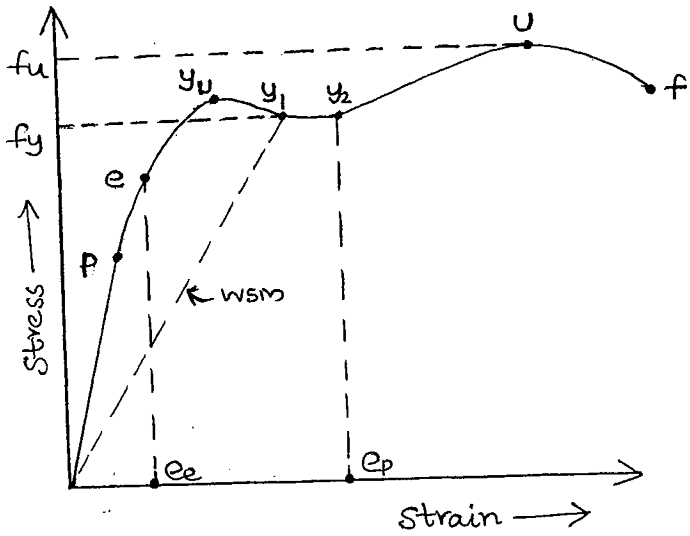
$$\text{FOS} = \frac{\text{yield stress}}{\text{working stress}}$$

$$\text{Load Factor} = \frac{\text{ultimate load}}{\text{working load}}$$

Partial Safety Factor – safety norm for load and material strength

- Design is based on analysis of :-
  - (i) Design Force – shear force & axial force.
  - (ii) Design moments – twisting moments & bending mom[en]ts
- Design is done to obtain :
  - (i) Shape (Eg: I section).
  - (ii) Size (Eg: ISMB 400).
  - (iii) Connection details.
- Design requirements :
  - (i). Anticipated loads.
  - (ii) Deflection to be
  - (iii) Economical sections
  - (iv). Life span.

8th Aug, - RSDAY → Working Stress Method: (WSM)



P: Proportionality limit

e: elastic limit.

Y_U: upper yield point.

y_1: lower yield point.

y_1y_2: plastic yielding

U: ultimate stress point.

f: Breaking stress point.

e_p : Plastic strain ≈ 10 to 15 times e_e

e_e : elastic strain.

NOTES:

⊙ WSM of design is linear elastic method of design. In this method, it is assumed that the stress and strain varies linear upto yield point.

⊙ In WSM of design, the stress in a member due to various working loads ~~are~~ working load combinations are to be evoluted, which are called 'Working Stress'.

⊙ For safety of structural member, stresses due to various working load combinations must be less than or equal to permissible value of stresses. Permissible stress is a fraction of yield strength. ($K \cdot f_y$; $K < 1.0$)

⊙ Design requirement for safety :

(i) Working stress due to DL + LL ≤ Permissible stress.

(ii) Working stress due to DL + WL ≤ Permissible stress.

(iii) Working stress due to DL + LL + WL ≤ 1.33 × Permissible stress

⊙ Safety norm used in WSM of design is FOS.

$$FOS = \frac{\text{yield stress}}{\text{working stress}}$$

WSM results in uneconomic sections as permissible stress is a fraction of yield stress. ∴ present code recommends Limit State Design.

→ Limit State Design.

- Types of Limit State.

  (i) Limit State of strength.

  (ii) Limit State of serviceability.

Limit State of strength	Limit State of serviceabil
– strength (against yielding (tension) or buckling (column) or flexure (beam))	– deflection or deformations
– stability (against sliding or overturning (retaining wall))	– vibrations
– fatigue strength (gantry girder)	– corrosions
– plastic strength.	– fire etc

- Design requirements for safety.

  Design action (Sd) $\leq$ Design strength (Rd)

- Design action (Sd) : design values of internal forces (SF & AF), design moments (BM & TM) due to design loads (Fd).

- Design Load, Fd or Factored load = a partial safety factor or load factor × characteristic loads.

$$F_d = \gamma_L \times \text{characteristic loads.}$$

- Design strength (Rd) $= \dfrac{\text{characteristic strength}}{\text{partial safety factor or Resistance factor } (\gamma_m)}$

Resistance factor (or) partial safety factor against :

- yieldi strength, $\gamma_{m0} = 1.10$
- buckling striength, $\gamma_{m0} = 1.10$
- ultimate tensile strength, $\gamma_{m1} = 1.25$

- A load factor or a partial safety factor (γ_L)

For strength limit state :

Load or load combination	γ_L
DL + LL	1.5
DL + WL	1.5
DL + LL + WL	1.2