SNS COLLEGE OF TECHNOLOGY

AN AUTONOMOUS INSTITUTION

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COIMBATORE

DEPARTMENT OF CIVIL ENGINEERING

19CET304-DESIGN OF STEEL STRUCTURES

III YEAR / VI SEMESTER

Unit 4 :DESIGN OF FLEXURAL MEMBERS

Topic 1- INTRODUCTION TO FLEXURAL MEMBERS

LOCAL BUCKLING

- Steel cross sections consist of an assembly of thin plate elements. When they are subjected to large compressive stresses, if the thin plates are too slender, then it may buckle even before the full strength of the member is attained.

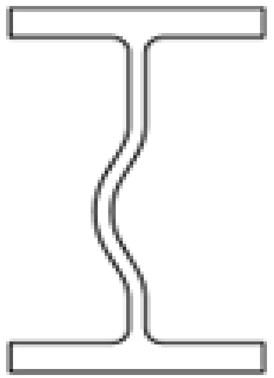
- This phenomenon is called Local buckling and this happens when the width to thickness ratio is too large. Hence, to avoid this, the width to thickness ratio needs to be limited.

Figure 2. Vertical web buckling.

1. Web Buckling:

Web buckling refers to the instability or failure of the web of a steel beam under compressive loads. It occurs when the web of the beam is slender and subjected to high compressive forces, causing it to buckle out of its plane.

- This phenomenon is more likely to occur in beams with thin webs or when the compressive forces are concentrated over a small area. Web buckling can significantly reduce the load-carrying capacity of a beam.



web Buckling

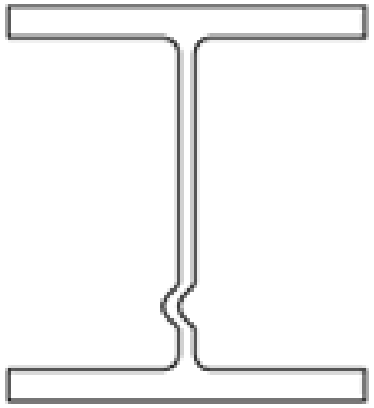
Web Buckling

Web buckling occurs when the intensity of vertical compressive stress near the centre of section becomes greater than the critical buckling stress for the web acting as a column.

web Buckling

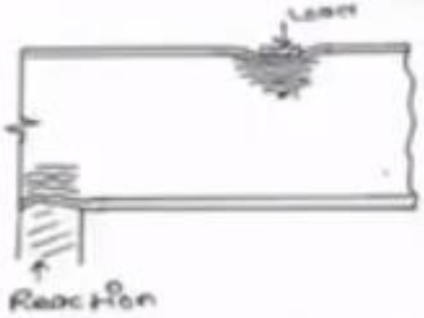
2. Web Crippling:

- Web crippling is the local buckling or failure of the web of a steel beam at points of concentrated load or reaction.
- It occurs when the web is subjected to high bearing stresses near concentrated loads or reactions, leading to the failure of the web in those specific areas.
- This type of failure is common in beams with short spans, high concentrated loads, or when the web is relatively thin.
- Proper design and detailing are necessary to prevent web crippling.


web crippling

Web Crippling

Webs of rolled steel sections are subjected to a large amount of stresses just below the concentrated loads and above the reactions from the support.



Stress concentration occurs at the junction of web and flange. As a result large bearing stresses are developed below the load.

Consequently, the web near the portion of stress concentration tends to fold over the flange. This type of local buckling is known as ***crippling o crimpling*** *of the web.*

3. Deflection of Beam:

- Deflection of a beam refers to the bending or deformation of the beam under the applied loads.
- When a beam is subjected to external loads, it undergoes both bending and deflection. Deflection is the displacement of any point on the beam from its original position.
- The deflection of a beam is influenced by factors such as the magnitude and distribution of the applied loads, the beam's material properties, its length, and the support conditions

  - The IS 800 code provides guidelines and limits on deflection to ensure the structural integrity and serviceability of beams.
  - It's important to note that the specific design considerations, equations, and limitations related to web buckling, web crippling, and deflection of beams can be found in the Indian Standard code IS 800:2007 "General Construction in Steel - Code of Practice."

4. Bending Strength:

- Bending strength, also known as flexural strength, is the maximum moment or bending force that a beam can resist before it starts to deform or fail.
- It is a measure of the beam's ability to resist bending stresses.
- IS 800 provides specifications and formulas for calculating the bending strength of steel beams based on their cross-sectional properties.

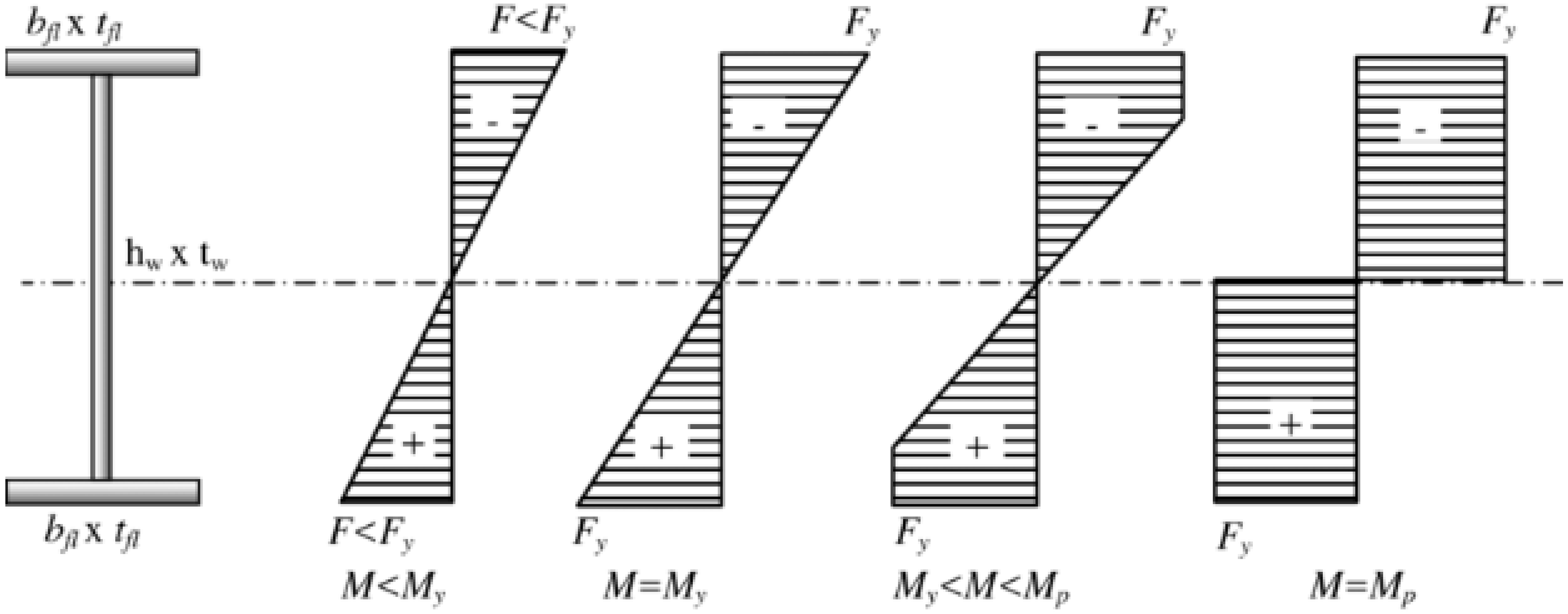
5. Shear Strength:

- Shear strength refers to the maximum shear force that a beam can resist before it fails in shear.
- It is a measure of the beam's resistance to internal forces that cause one part of the beam to slide or shear relative to another part.
- IS 800 provides guidelines for determining the shear strength of steel beams based on their section properties.

Plastic moment

- Plastic moment refers to the moment capacity or resistance of a structural member, such as a beam or a column, beyond which the member enters a plastic or fully yielded state.
- In this state, the material undergoes significant plastic deformation without any increase in load-carrying capacity.
- To understand plastic moment, let's consider a simply supported beam with a rectangular cross-section.
- Initially, when the beam is subjected to increasing loads, it undergoes elastic deformation, meaning it bends but returns to its original shape once the load is removed.

- However, as the load increases, the bending moment in the beam also increases. At a certain point, known as the plastic moment, the extreme fibres of the beam's cross-section reach the yield strength of the material.
- At this moment, the material in the extreme fibres begins to undergo plastic deformation, resulting in permanent changes in shape and size even after the load is removed.



b_{fl} x t_{fl}
h_w x t_w
b_{fl} x t_{fl}
$F<F_y$
-
+
$F<F_y$
$M<M_y$
F_y
-
+
F_y
$M=M_y$
F_y
-
+
F_y
$M_y<M<M_p$
F_y
-
+
F_y
$M=M_p$

- The plastic moment carrying capacity of a section refers to the maximum moment that a structural member or a section can resist before it reaches its fully yielded or plastic state.
- It represents the ultimate capacity of the section to withstand bending forces without any further increase in load-carrying capacity.

The plastic moment carrying capacity depends on the material properties and the geometry of the section.

For a given material, the plastic moment carrying capacity of a section can be determined by considering the plastic stress distribution across the section.

In general, the plastic moment carrying capacity of a section can be calculated using the following formula:

$$Mp = Zp * fy$$

where:

Mp is the plastic moment carrying capacity of the section,

Zp is the plastic section modulus, which represents the distribution of material away from the neutral axis, and

fy is the yield strength of the material.

CLASSIFICATION OF COLUMNS

Columns are of folowing types

1.Short columns

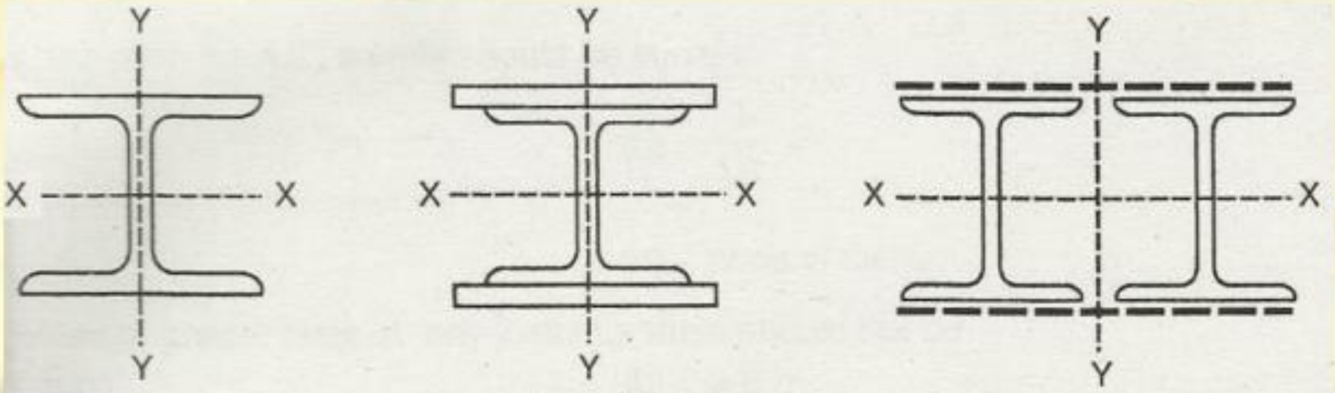
2. Long columns

1) **Short columns:**-When the ratio of effective length of column to the least lateral dimension is less than equal to 12 is known as short column. The failure of such type of columns purely due to direct crushing. The load capacity of the column is equal to the safe compressive stress and x-sectional area of column.

2) Long Columns:- *When the ratio of effective length of column to the least lateral dimension is greater than 12 is known as long column. The failure of such type of columns is mainly due to buckling or bending. The column fails in bending before the compressive stress reaches the crushing value. Direct stress has little importance in its failure.*

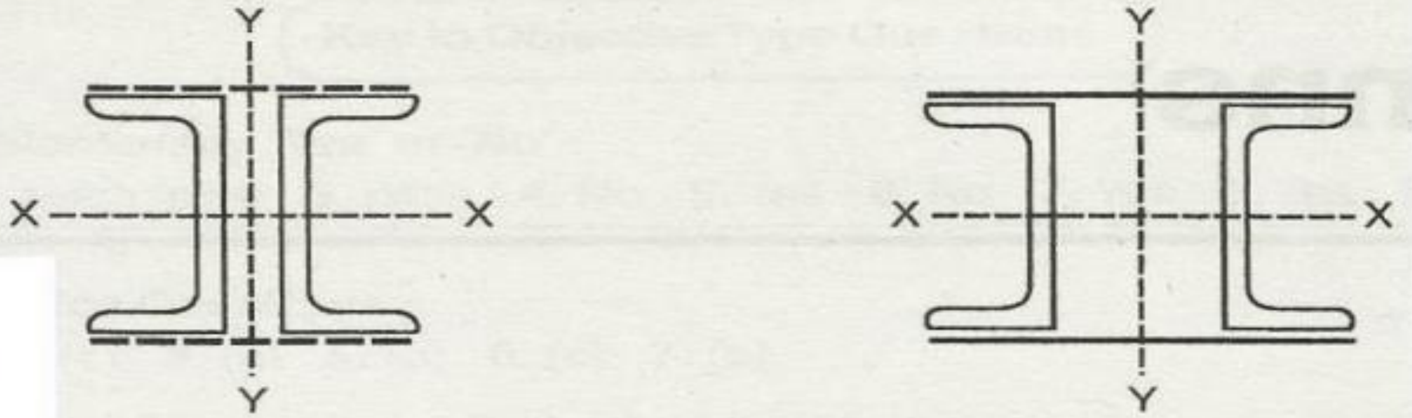
Common Sections For Columns

1. **I-section.** I-section can be used as columns. But ISHB section are more suitable as these provide minimum difference in two radii of gyrations. To get stronger section, additional plates can be attached on both flanges. For heavy column section, I-sections can be spaced to achieve the most economical sections.



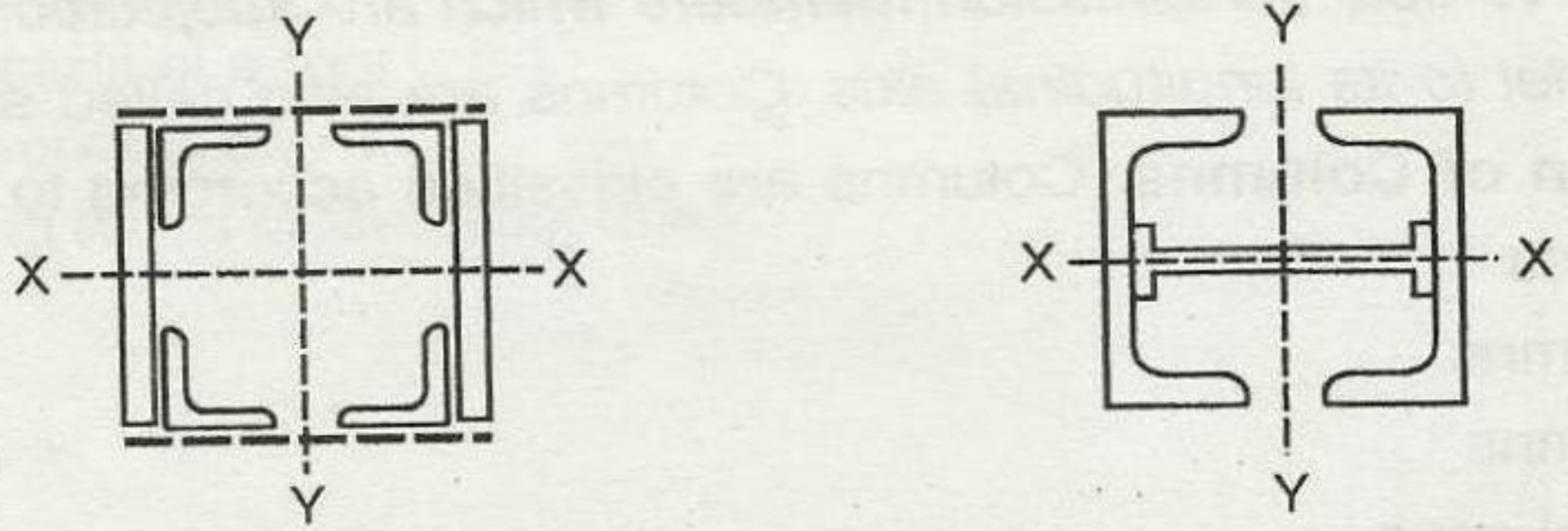
I-sections

2. Channel section. Single ISMC and ISLC are suitable as columns for light loads. Double ISJC, ISLC and ISMC can serve as good column sections when laced or battened and these can support moderate load. These can be spaced back to back for better strength and economy. Double channels with flanges butting and welded to toe to toe are also used as columns.



Channel Sections

3. Miscellaneous section. In addition to the above given sections, the combination of other sections can be used as column.

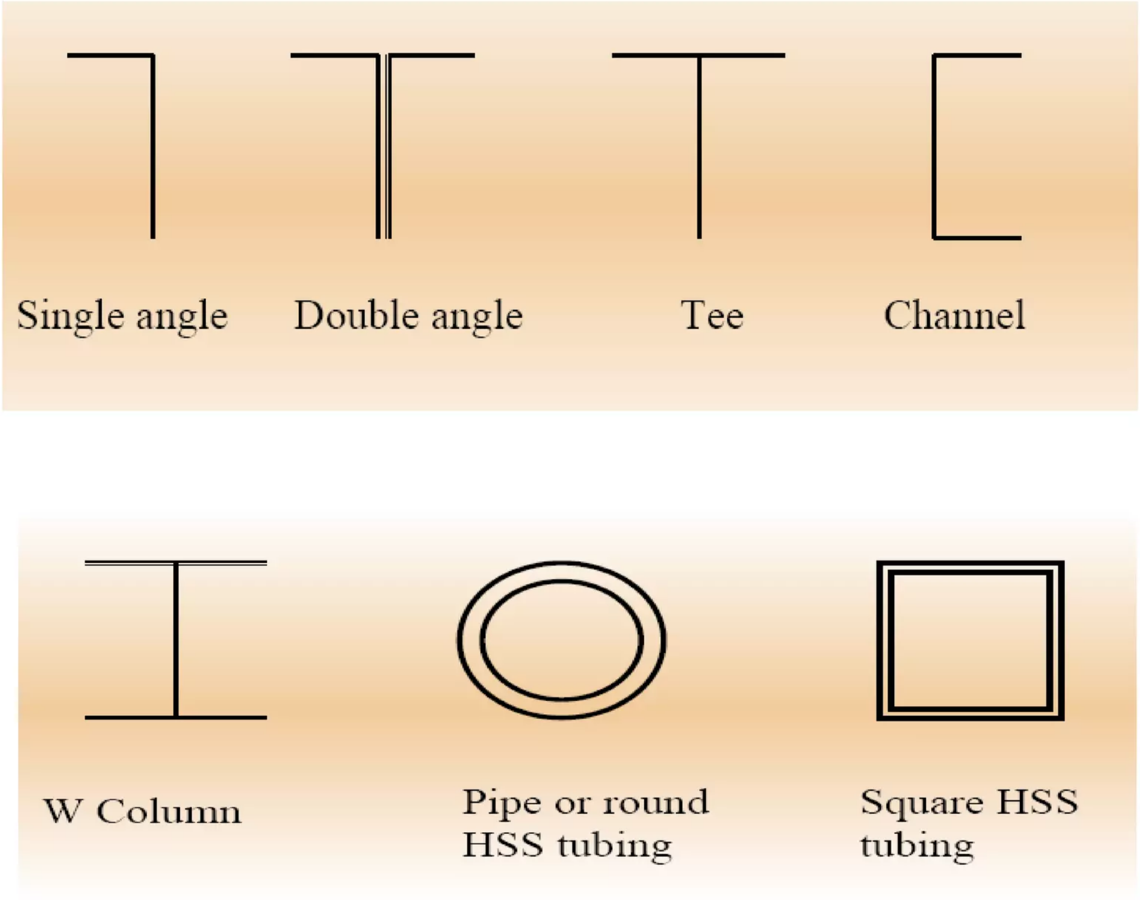


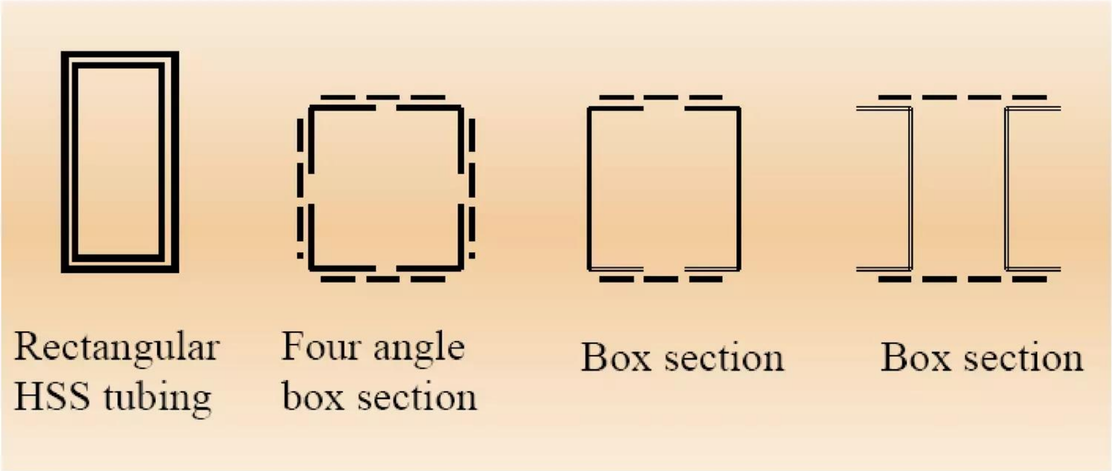
Miscellaneous Sections

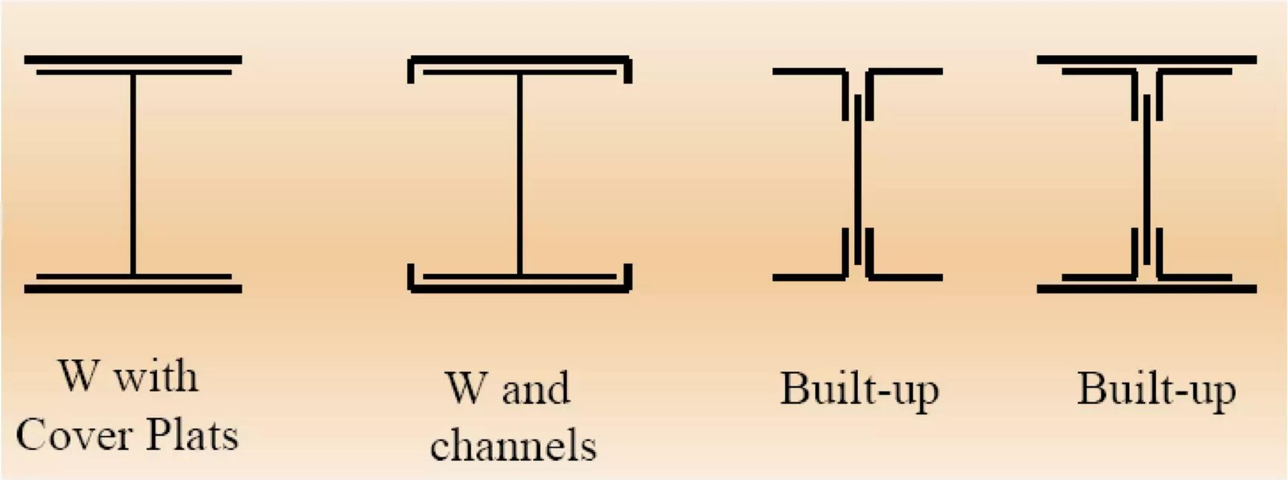
- Sections used for compression member

- In theory numerous shapes can be used for columns to resist given loads.
- However, from practical point of view, the number of possible solutions is severely limited by section availability, connection problems, and type of structure in which the section is to be used.

Figure 1. Types of Compression Members




Rectangular HSS tubing
Four angle box section
Box section
Box section


W with Cover Plats
W and channels
Built-up
Built-up

Effective length of compression member

- **Column End Condition And Effective Length**

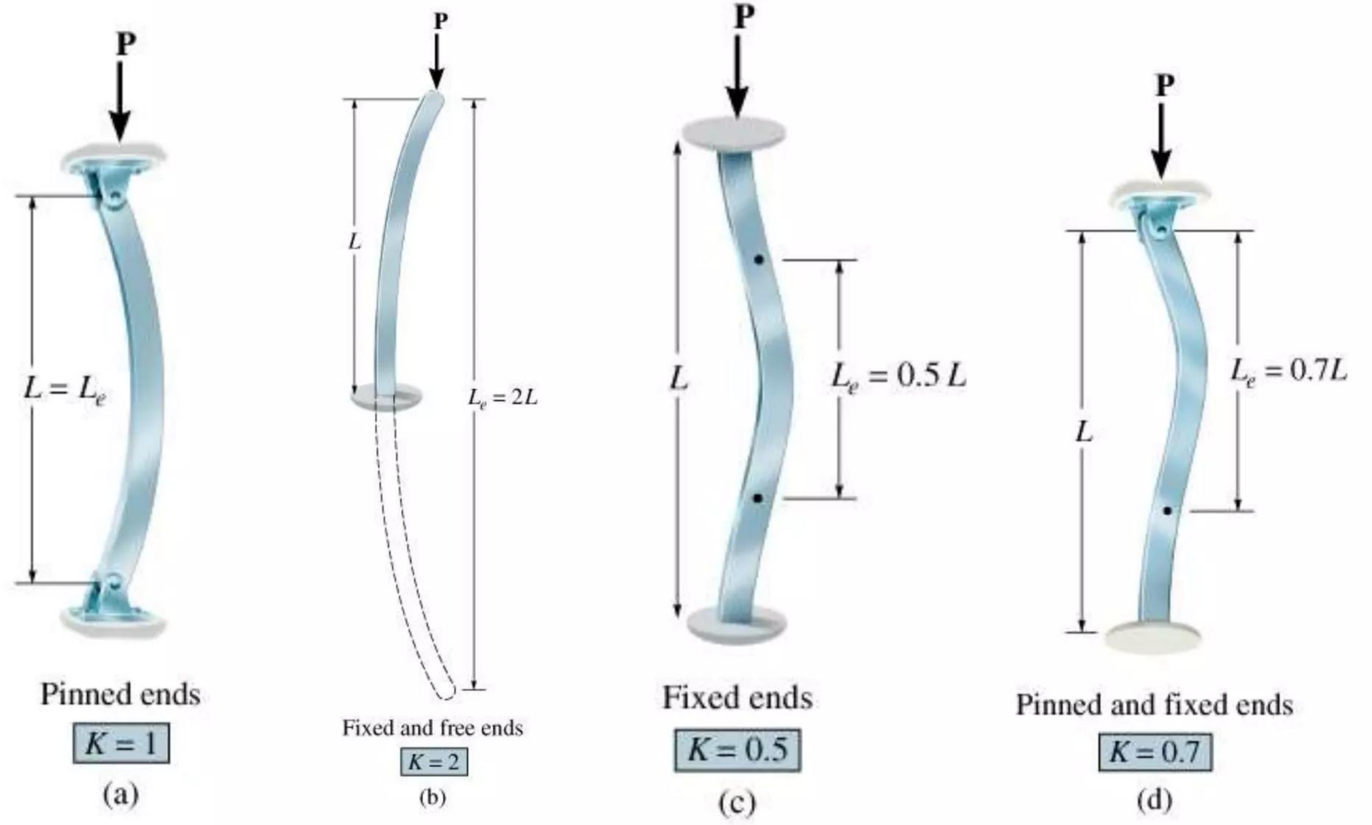
1.Both end hinged.

2.Both end fixed.

3.One end fixed and other hinged.

4.One end fixed and other free.

Effective length



- **Slenderness ratio (λ) :**

Slenderness Ratio =
effective length of column/Minimum radius of gyration

$$\lambda = le/r$$

If λ is more , its load carrying capacity will be less.

- Short compression member

1. $L/r \leq 88.85$ for $F_y = 250$ Mpa
2. Failure stress equal to yield stress
3. No buckling

- Long compression member

1. They will buckle elastically
2. Axial buckling stress is below proportional limit.

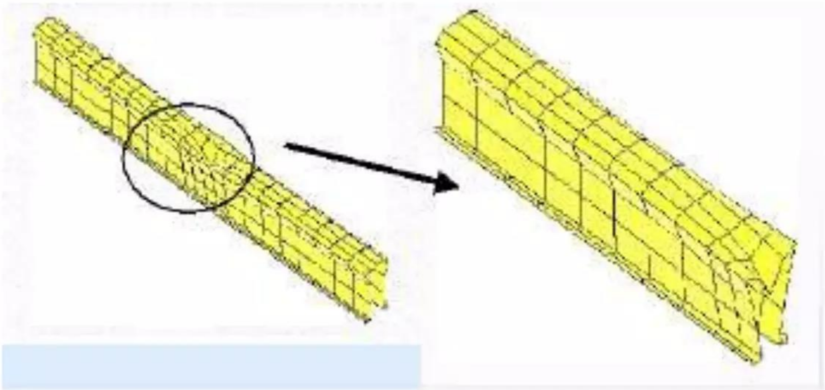
Compression Member Failure

- There are three basic types of column failures.
- One, a compressive material failure(very short and fat).
- Two, a buckling failure,(very long and skinny).
- Three, a combination of both compressive and buckling failures.(length and width of a column is in between a short and fat and long and skinny column).

10

Compression Member Failure

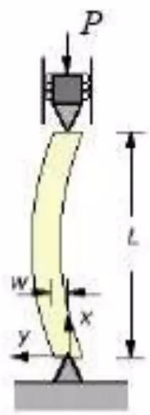
- **<u>Local Buckling</u>** This occurs when some part or parts of x-section of a column are so thin that they buckle locally in compression before other modes of buckling can occur



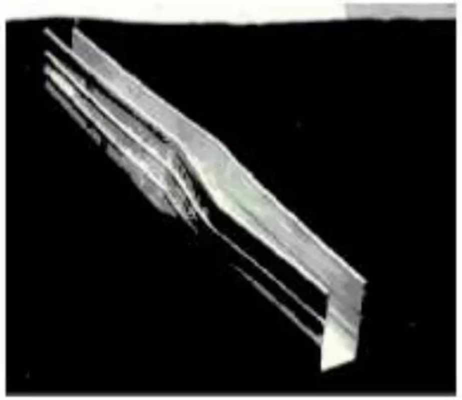
11

Compression Member Failure

- **<u>Flexural Buckling</u>** (also called Euler Buckling) is the primary type of buckling members are subjected to bending or flexure when they become unstable



Simply supported column subjected to axial load P



12

Compression Member Failure

- Squashing :

  When the length of column is relatively small and column is stocky and its component plates are prevented from local buckling, then column will be able to attain its full strength before failure.

Cross section classification

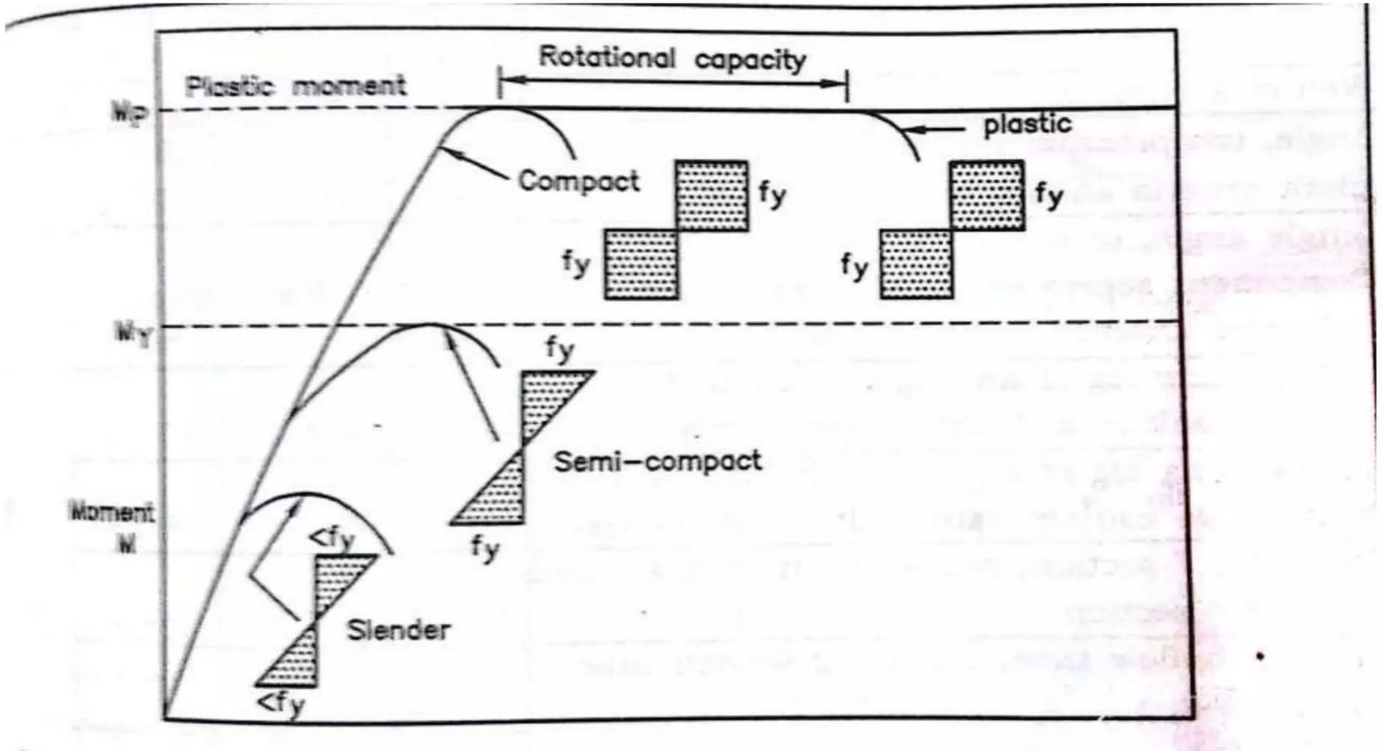


FIG. 5.4 MOMENT ROTATION BEHAVIOUR OF FOR CLASSES OF CROSS SECTIONS

Design compressive strength

7.1.2 The design compressive strength P_d, of a member is given by:

$$P < P_d$$

where

$$P_d = A_e f_{cd}$$

where

A_e = effective sectional area as defined in **7.3.2**, and

f_{cd} = design compressive stress, obtained as per **7.1.2.1**.

Clause 7.3.2

7.3.2 *Effective Sectional Area, A_e*

Except as modified in **3.7.2** (Class 4), the gross sectional area shall be taken as the effective sectional area for all compression members fabricated by welding, bolting and riveting so long as the section is semi-compact or better. Holes not fitted with rivets, bolts or pins shall be deducted from gross area to calculate effective sectional area.

IS 800: 2007 Clause 7.1.2.1

7.1.2.1 The design compressive stress, f_{cd}, of axially loaded compression members shall be calculated using the following equation:

$$f_{cd} = \frac{f_y / \gamma_{m0}}{\phi + \left[\phi^2 - \lambda^2\right]^{0.5}} = \chi f_y / \gamma_{m0} \le f_y / \gamma_{m0}$$

where

ϕ = $0.5\,[1 + \alpha\,(\lambda - 0.2) + \lambda^2]$

λ = non-dimensional effective slenderness ratio

$$= \sqrt{f_y / f_{cc}} = \sqrt{f_y \left(\frac{KL}{r}\right)^2 / \pi^2 E}$$

f_{cc} = Euler buckling stress = $\dfrac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$

where

KL/r = effective slenderness ratio or ratio of effective length, KL to appropriate radius of gyration, r;

α = imperfection factor given in Table 7;

χ = stress reduction factor (*see* Table 8) for different buckling class, slenderness ratio and yield stress

$$= \frac{1}{\left[\phi + \left(\phi^2 - \lambda^2\right)^{0.5}\right]}$$

λ_{m0} = partial safety factor for material strength.

Table 7 Imperfection Factor, α

(*Clauses* 7.1.1 *and* 7.1.2.1)

Buckling Class	a	b	c	d
α	0.21	0.34	0.49	0.76

Column buckling curves

- Classification of different sections under different buckling class a, b,c and d are given in Table 10 of IS 800: 2007 (page 44).
- The stress reduction factor χ , and the design compressive stress fcd, for different buckling class, yield stress and effective slenderness ratio is given in table 8 (page 37)
- Table 9(page 40) shows the design compressive stress, fcd for different buckling class a to d.

- The curve corresponding to different buckling class are presented in non-dimensional form as shown in the figure below. Using this curve one can find the value of fcd (design compressive stress) corresponding to non- dimensional effective slenderness ratio $\bar{\lambda}$ (page 35)

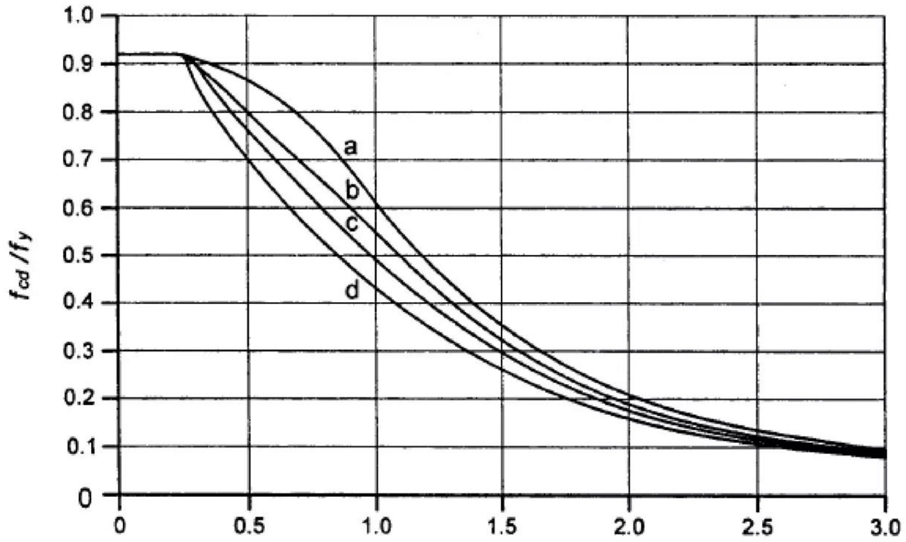
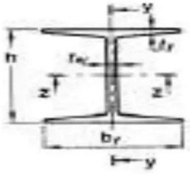
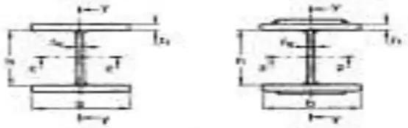
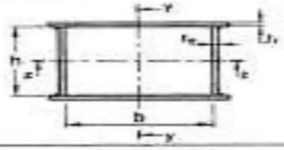


FIG. 8 COLUMN BUCKLING CURVES

Table 10 Buckling Class of Cross-Sections

(*Clause* 7.1.2.2)

Cross-Section (1)	Limits (2)	Buckling About Axis (3)	Buckling Class (4)
Rolled I-Sections 	$h/b_f > 1.2$: $t_f \leq 40$ mm	z-z y-y	a b
	$40 \leq$ mm $< t_f \leq 100$ mm	z-z y-y	b c
	$h/b_f \leq 1.2$: $t_f \leq 100$ mm	z-z y-y	b c
	$t_f > 100$ mm	z-z y-y	d d
Welded I-Section 	$t_f \leq 40$ mm	z-z y-y	b c
	$t_f > 40$ mm	z-z y-y	c d
Hollow Section 	Hot rolled	Any	a
	Cold formed	Any	b
Welded Box Section 	Generally (except as below)	Any	b
	Thick welds and $b/t_f < 30$	z-z	c
	$h/t_w < 30$	y-y	c
Channel, Angle, T and Solid Sections 		Any	c
Built-up Member 		Any	c

Angle struts

- Single angle strut: (IS : 800 cl. 7.5.1)

    The compression in single angle struts may be transfered either concentrically to its centroid through end gusset or eccentrically by connecting one of its legs to a gusset or adjacent member.

1. Concentric loading
2. Loaded through one leg $\sqrt{k_1 + k_2 + \Lambda^2_{vv} + k_3 \ \Lambda^2_{\phi}}$

- Double angle struts

1. Connected back to back on opposite sides of G.P.

The effective length kL in plane of end gusset shall be taken as between 0.7 and 0.85 times the distance between intersections.

2. Connected back to back to one side of G.P.(cl.7.5.2.2)

The outstanding legs shall be connected by tack bolting or tack welding spaced at a distance not exceeding 600 mm. (cl. 10.2.5.5)

THANK YOU