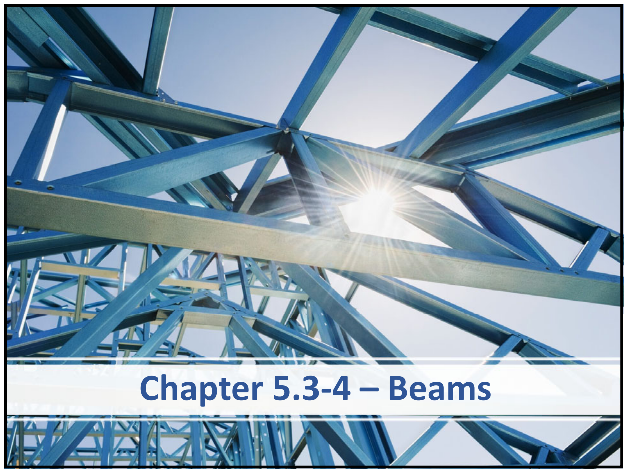
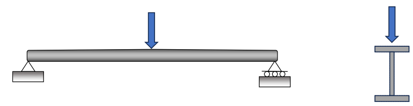


Chapter 5.3-4 – Beams

1

Chapter 5 – Stability

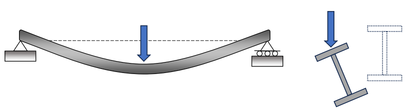
- If a beam remains ***stable*** up to the ***fully plastic condition***, the nominal moment strength can be taken as the plastic moment capacity; that is, $M_n = M_p$
- Otherwise: $M_n < M_p$
- Instability can be regarded as ***overall,*** or it can be ***local***.
- ***Overall buckling*** is illustrated below:



2

Chapter 5 – Stability

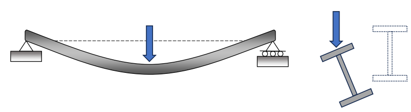
- If a beam remains ***stable*** up to the ***fully plastic condition***, the nominal moment strength can be taken as the plastic moment capacity; that is, $M_n = M_p$
- Otherwise: $M_n < M_p$
- Instability can be regarded as ***overall,*** or it can be ***local***.
- ***Overall buckling*** is illustrated below:



3

Chapter 5 – Stability

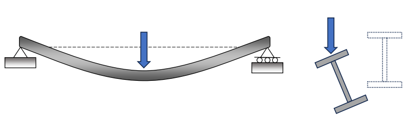
- If a beam remains ***stable*** up to the ***fully plastic condition***, the nominal moment strength can be taken as the plastic moment capacity; that is, $M_n = M_p$
- Otherwise: $M_n < M_p$
- When a beam bends, the ***compression*** region (above the neutral axis) is analogous to a column, and it will ***buckle*** if the member is slender enough.



4

Chapter 5 – Stability

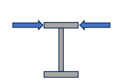
- If a beam remains ***stable*** up to the ***fully plastic condition***, the nominal moment strength can be taken as the plastic moment capacity; that is, $M_n = M_p$
- Otherwise: $M_n < M_p$
- Unlike a column, the tension portion restrains the compression portion of the cross section, and the outward deflection (***flexural buckling***) is accompanied by twisting (***torsion***).



5

Chapter 5 – Stability

- This form of ***instability*** is called ***lateral-torsional buckling*** (LTB).
- Lateral-torsional buckling can be prevented by bracing the beam against twisting at sufficiently close intervals.
- This can be accomplished with ***lateral bracing***

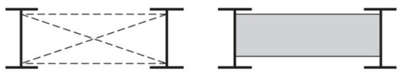


Lateral bracing, which prevents lateral translation, should be applied as close as possible to the compression flange.

6

Chapter 5 – Stability

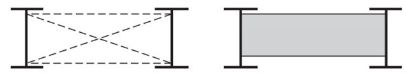
- This form of ***instability*** is called ***lateral-torsional buckling*** (LTB).
- Lateral-torsional buckling can be prevented by bracing the beam against twisting at sufficiently close intervals.
- Or this can be accomplished with ***torsional bracing***.



7

Chapter 5 – Stability

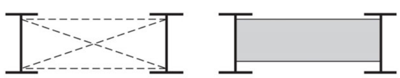
- This form of ***instability*** is called ***lateral-torsional buckling*** (LTB).
- Lateral-torsional buckling can be prevented by bracing the beam against twisting at sufficiently close intervals.
- ***Torsional bracing*** prevents twist directly; it can be either nodal or continuous, and it can take the form of either cross frames or diaphragms.



8

Chapter 5 – Stability

- This form of ***instability*** is called ***lateral-torsional buckling*** (LTB).
- Lateral-torsional buckling can be prevented by bracing the beam against twisting at sufficiently close intervals.
- As we will see, the ***moment strength*** depends in part on the ***unbraced length***, which is the distance between points of bracing.



9

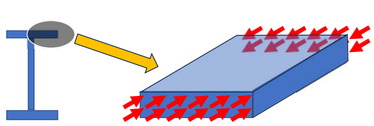
Chapter 5 – Stability

- Whether the beam can sustain a moment large enough to bring it to the ***fully plastic condition*** also depends on whether the cross-sectional integrity is maintained.
- This integrity will be lost if one of the ***compression elements of the cross-section buckles***.
- This type of buckling can be either compression flange buckling, called ***flange local buckling*** (FLB), or buckling of the compression part of the web, called ***web local buckling*** (WLB).
- The type of local buckling that occurs will depend on the ***width-to-thickness ratios*** of the compression elements of the cross section.

10

Chapter 5 – Stability

- Compression flange buckling, called ***flange local buckling.***
- Consider the cross-section below under compression.
- The ***flange*** is restrained by the web at one edge.

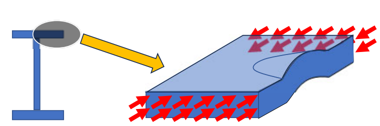


- Failure is localized at areas of high stress (maximum moment) or imperfections.

11

Chapter 5 – Stability

- Compression flange buckling, called ***flange local buckling.***
- Consider the cross-section below under compression.
- The ***flange*** is restrained by the web at one edge.

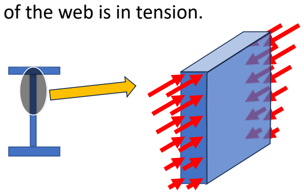


- Failure is localized at areas of high stress (maximum moment) or imperfections.

12

Chapter 5 – Stability

- Compression web buckling is called ***web local buckling***.
- Consider the cross-section below under compression.
- The ***web*** is restrained by the flange at one edge, and the other part of the web is in tension.

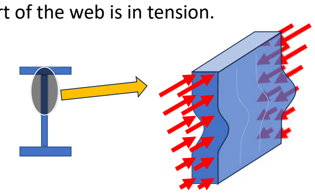


- Failure is localized at areas of high stress (maximum moment) or imperfections.

13

Chapter 5 – Stability

- Compression web buckling is called ***web local buckling***.
- Consider the cross-section below under compression.
- The ***web*** is restrained by the flange at one edge, and the other part of the web is in tension.

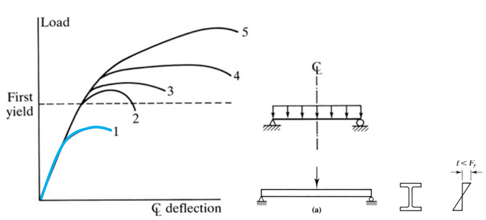


- Failure is localized at areas of high stress (maximum moment) or imperfections.

14

Chapter 5 – Stability

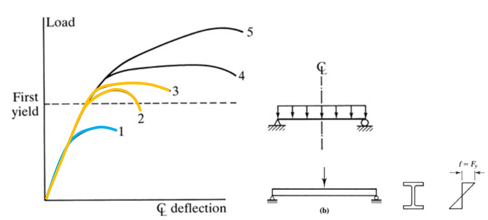
- The graph below shows the effects of ***local*** and ***lateral-torsional buckling***.
- ***Curve 1*** is the load-deflection curve of a beam that becomes unstable (in any way) and loses its load-carrying capacity before the first yield is attained.



15

Chapter 5 – Stability

- The graph below shows the effects of ***local*** and ***lateral-torsional buckling***.
- ***Curves 2*** and ***3*** correspond to beams that can be loaded past first yield but not far enough for the formation of a plastic hinge and the resulting plastic collapse.



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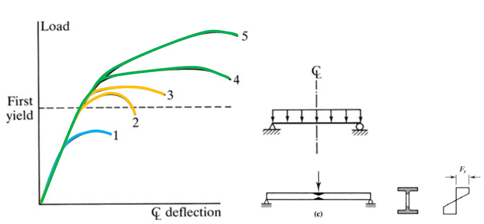
Chapter 5 – Stability

- The graph below shows the effects of ***local*** and ***lateral-torsional buckling***.
- If plastic collapse can be reached, the load-deflection curve will look like either ***curve 4*** or ***curve 5.***



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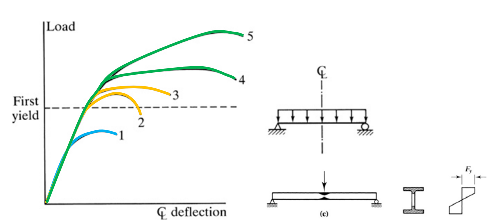
Chapter 5 – Stability

- The graph below shows the effects of ***local*** and ***lateral-torsional buckling***.
- ***Curve 4*** is for the case of uniform moment over the full length of the beam, and ***curve 5*** is for a beam with a variable bending moment (moment gradient).



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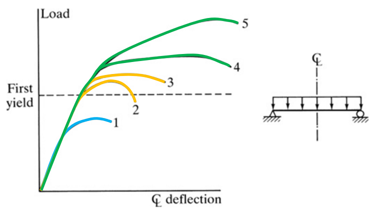
Chapter 5 – Stability

- The graph below shows the effects of ***local*** and ***lateral-torsional buckling***.
- ***Safe designs*** can be achieved with beams corresponding to any of these curves, but ***curves 1*** and ***2*** represent ***inefficient use of material.***



19

Chapter 5 – Classification of Shapes

- AISC classifies cross-sectional shapes as ***compact***, ***noncompact***, or ***slender***, depending on the values of the ***width-to-thickness ratios***.
- ***Compact*** sections have a slenderness ratio below a certain limit, allowing them to reach their ***full yield strength*** and form a ***plastic hinge without local buckling***.
- ***Non-compact*** sections have a higher slenderness ratio, meaning some elements will ***buckle under a lower stress level*** than the full yield strength F_y before the entire section can become fully plastic.

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Chapter 5 – Classification of Shapes

- AISC classifies cross-sectional shapes as ***compact***, ***noncompact***, or ***slender***, depending on the values of the ***width-to-thickness ratios.***
- For **I** shapes, the ratio for the projecting flange (an unstiffened element) is $b_f/2t_f$, and the ratio for the web (a stiffened element) is h/t_w.
- The classification of shapes is found in **Section B4** of the Specification, "Member Properties," in **Table B4.1b** (Table B4.1a is for compression members).

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Chapter 5 – Classification of Shapes

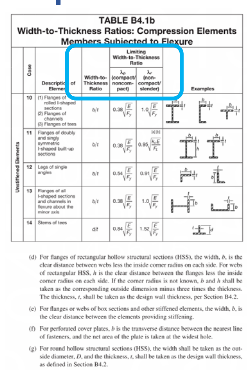
TABLE B4.1b
Width-to-Thickness Ratios: Compression Elements
Members Subjected to Flexure

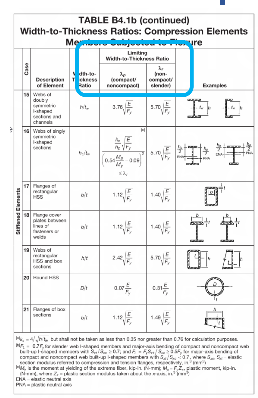
TABLE B4.1b (continued)
Width-to-Thickness Ratios: Compression Elements
Members Subjected to Flexure

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Chapter 5 – Classification of Shapes

- It can be summarized as follows:

  λ is the ***width-to-thickness ratio***,

  λ_p is the upper limit for the ***compact*** category, and

  λ_r is the upper limit for the ***noncompact*** category

- Then if $\lambda \le \lambda_p$ and the flange is continuously connected to the web, the shape is ***compact***;

  if $\lambda_p < \lambda \le \lambda_r$ the shape is ***noncompact***; and

  if $\lambda > \lambda_r$ the shape is ***slender***.

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Chapter 5 – Classification of Shapes

- The category is based on the worst ***width-to-thickness ratio*** of the cross-section.
- For example, if the ***web is compact*** and the ***flange is noncompact***, the shape is classified as ***noncompact***.
- From **AISC Table B4.1b** for hot-rolled **I**-shaped cross-sections.

Case 10: $\lambda = \dfrac{b_f}{2t_f}$ $\quad \lambda_p = 0.38\sqrt{\dfrac{E}{F_y}}$ $\quad \lambda_r = 1.0\sqrt{\dfrac{E}{F_y}}$

Case 15: $\lambda = \dfrac{h}{t_w}$ $\quad \lambda_p = 3.76\sqrt{\dfrac{E}{F_y}}$ $\quad \lambda_r = 5.70\sqrt{\dfrac{E}{F_y}}$

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Chapter 5 – Beams

Any questions?

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