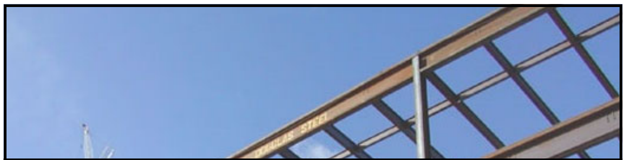


Chapter 1 Introduction to Steel Design

1

Chapter 1.1 – Structural Design

- The structural design of buildings, whether of structural steel or reinforced concrete, requires the determination of the overall ***proportions and dimensions*** of the supporting framework and the selection of the ***cross sections*** of individual members.
- In most cases, the layout of the structure will have been done by an architect.
- The ***structural engineer*** must work within the constraints imposed by this design.

2

Chapter 1.1 – Structural Design

- The design can be summed up as follows:

  The architect decides how the building should look, and the ***The engineer must ensure*** that it doesn't fall down.

- The ***first priority*** of the structural engineer: ***safety***.
- Other important considerations include ***serviceability*** (how well the structure performs in terms of appearance and deflection) and ***economy***.

3

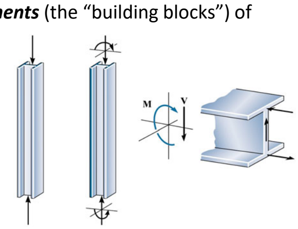
Chapter 1.1 – Structural Design

- An economical structure requires an efficient use of materials and construction labor.
- Although this objective can usually be accomplished by a design that ***requires a minimum amount of material***, savings can often be realized by using more material if it results in a simpler, more easily constructed project.
- In fact, materials account for a ***relatively small portion of the cost*** of a typical steel structure as ***compared with labor and other costs.***

4

Chapter 1.1 – Structural Design

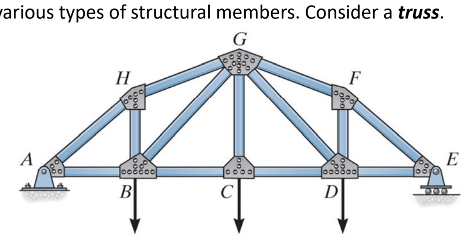
- The emphasis in this course will be on the design of ***individual structural steel members and their connections***.
- The ***structural engineer*** must select and evaluate the overall structural system to produce an efficient and economical design but cannot do so without a thorough understanding of the ***design of the components*** (the "building blocks") of the structure.
- Thus, ***component design*** is the focus of this course.



5

Chapter 1.1 – Structural Design

- Before discussing structural steel, we need to examine various types of structural members. Consider a ***truss***.

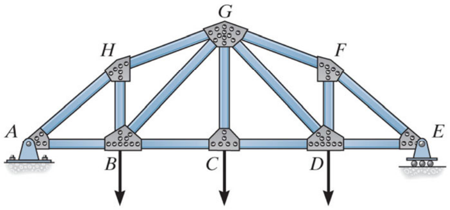


- In truss analysis, the connections are assumed to be pins and loads applied only at the joints.

6

Chapter 1.1 – Structural Design

- Before discussing structural steel, we need to examine various types of structural members. Consider a ***truss***.

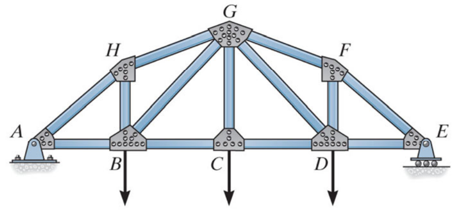


- Each component of the truss will be a two-force member, subject to either axial compression or tension.

7

Chapter 1.1 – Structural Design

- Before discussing structural steel, we need to examine various types of structural members. Consider a ***truss***.

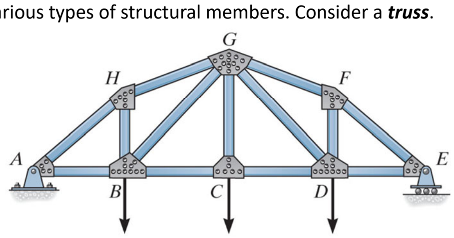


- For this loading case, each of the top chord members will be in ***compression***, and the bottom chord members will be in ***tension***.

8

Chapter 1.1 – Structural Design

- Before discussing structural steel, we need to examine various types of structural members. Consider a ***truss***.

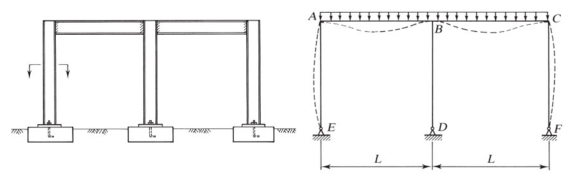


- The web members will either be in ***tension or compression***, depending on their location and orientation and on the location of the loads.

9

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

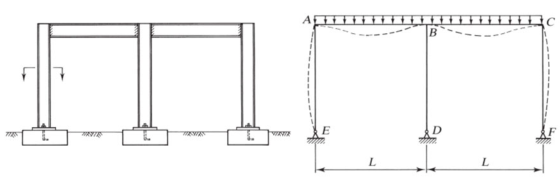


- The design and analysis of each frame in the system begins with the ***idealization of the frame as a two-dimensional structure***.

10

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

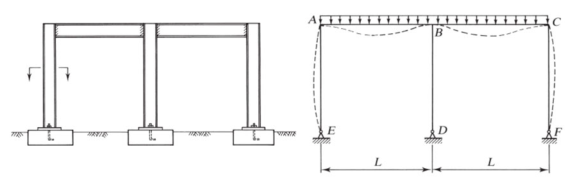


- Once the geometry and support conditions of the idealized frame have been established, the ***loading must be determined***.

11

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

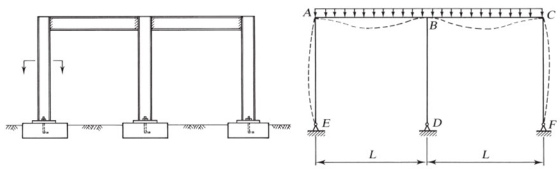


- The frame has ***uniformly distributed line load*** measured in force per unit length (kips/foot or kN/meter).

12

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

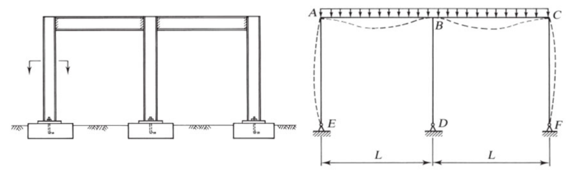


- The horizontal members ***AB*** and ***BC*** are subjected primarily to bending, or flexure, and are called ***beams***.

13

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

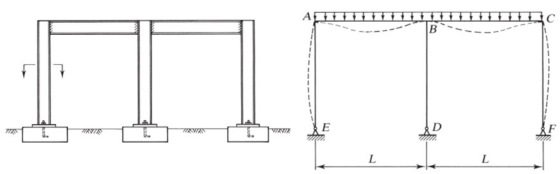


- The vertical member ***BD*** is subjected to moments transferred from each beam, but for the symmetrical frame shown, they are equal and opposite, thereby ***canceling each other***.

14

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

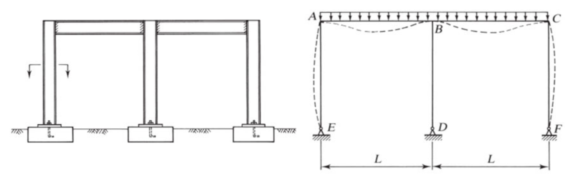


- Thus, member ***BD*** is subjected only to ***axial compression*** arising from the vertical loads.

15

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

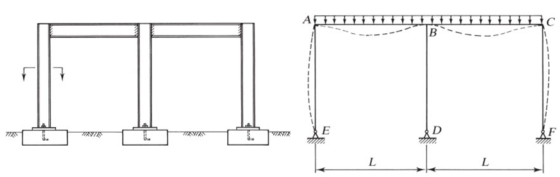


- Vertical compression members such as these are referred to as ***columns***.

16

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.

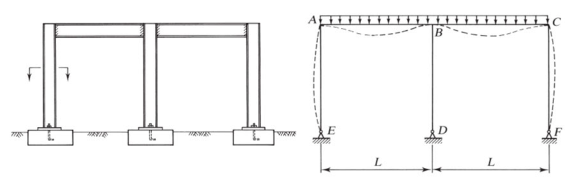


- The other two vertical members, ***AE*** and ***CF***, must resist not only ***axial compression*** from the vertical loads, but also a significant amount of ***bending***.

17

Chapter 1.1 – Structural Design

- The members of this ***frame*** are rigidly connected by welding and can be assumed to form a continuous structure.



- Such members are called ***beam-columns***.

18

Chapter 1.2 – Loads

- The forces that act on a structure are called ***loads***.
- They belong to one of two broad categories:
  dead loads and ***live loads***.
- ***Dead loads*** are those that are ***permanent***, including the weight of the structure itself, which is sometimes called the ***self-weight***.
- All the loads mentioned thus far are forces resulting from gravity and are referred to as ***gravity loads***.

19

Chapter 1.2 – Loads

- The forces that act on a structure are called ***loads***.
- They belong to one of two broad categories:
  dead loads and ***live loads***.

	lb/ft^3	kN/m^3
Aluminum	170	26.7
Concrete, cinder	108	17.0
Concrete, stone	144	22.6
Clay, dry	63	9.9
Clay, damp	110	17.3
Sand and gravel, dry, loose	100	15.7
Sand and gravel, wet	120	18.9
Masonry, lightweight concrete units	105	16.5
Masonry, normal weight concrete units	135	21.2
Plywood	36	5.7
Steel, cold-drawn	492	77.3
Wood, Douglas fir	34	5.3
Wood, southern pine	37	5.8
Wood, spruce	29	4.6

Walls	lb/ft^2	kN/m^2
4-in. (102-mm) clay brick	39	1.87
8-in. (203-mm) clay brick	79	3.78
12-in. (305-mm) clay brick	115	5.51
Frame Partitions and Walls		
Exterior stud walls with brick veneer	48	2.30
Windows, glass, frame and sash	8	0.38
Wood studs 2 × 4 in. (51 × 102 mm), unplastered	4	0.19
Wood studs 2 × 4 in. (51 × 102 mm), plastered one side	12	0.57
Wood studs 2 × 4 in. (51 × 102 mm), plastered two sides	20	0.96
Floor Fill		
Cinder concrete, per inch (mm)	9	0.017
Lightweight concrete, plain, per inch (mm)	8	0.015
Stone concrete, per inch (mm)	12	0.023
Ceilings		
Acoustical fiberboard	1	0.05
Plaster on tile or concrete	5	0.24
Suspended metal lath and gypsum plaster	10	0.48
Asphalt shingles	2	0.10
Fiberboard, $\frac{1}{2}$ in. (13 mm)	0.75	0.04

20

Chapter 1.2 – Loads

- The forces that act on a structure are called ***loads***.
- They belong to one of two broad categories:
  dead loads and ***live loads***.
- ***Live loads***, which can also be gravity loads, are those that are ***not as permanent*** as dead loads.
- They may or may not be acting on the structure at any given time, and the ***location may not be fixed***.
- Examples of live loads include furniture, equipment, and occupants of buildings.

21

Chapter 1.2 – Loads

- The forces that act on a structure are called ***loads***.
- They belong to one of two broad categories:
  dead loads and ***live loads***.

	Live Load			Live Load	
Occupancy or Use	lb/ft^2	kN/m^2	Occupancy or Use	lb/ft^2	kN/m^2
Assembly areas and theaters			Residential		
Fixed seats	60	2.87	Dwellings (one- and two-family)	40	1.92
Movable seats	100	4.79	Hotels and multifamily houses		
Garages (passenger cars only)	40	1.92	Private rooms and corridors	40	1.92
Office buildings			Public rooms and corridors	100	4.79
Lobbies	100	4.79	Schools		
Offices	50	2.39	Classrooms	40	1.92
Storage warehouse			First-floor corridors	100	4.79
Light	125	5.99	Corridors above first floor	80	3.83
Heavy	250	11.97			

22

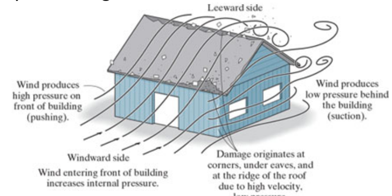
Chapter 1.2 – Loads

- If a ***live load*** is applied slowly and is not removed and reapplied an excessive number of times, the structure can be analyzed as if the load were ***static***.
- If the load is applied suddenly, as would be the case when the structure supports a moving crane, the ***effects of impact*** must be considered.
- In this course, all loading conditions in this book will be treated as ***static.***

23

Chapter 1.2 – Loads

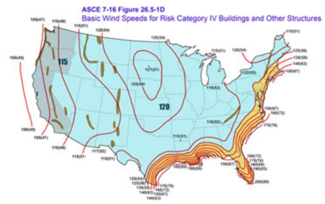
- ***Wind loads*** exerts a pressure or suction on the exterior surfaces of a building, and because of its transient nature, it properly belongs in the category of live loads.
- Because of the relative complexity of determining wind loads, however, wind is usually considered a separate category of loading.



24

Chapter 1.2 – Loads

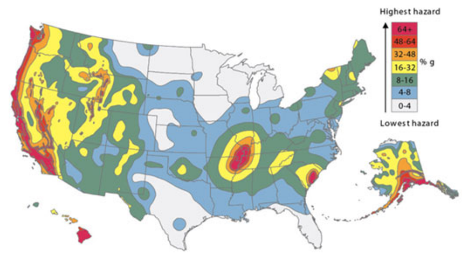
- ***Wind loads*** exerts a pressure or suction on the exterior surfaces of a building, and because of its transient nature, it properly belongs in the category of live loads.
- Because of the relative complexity of determining wind loads, however, wind is usually considered a separate category of loading.



25

Chapter 1.2 – Loads

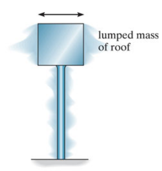
- ***Earthquake loads*** are another special category and need to be considered only in those geographic locations where there is a reasonable probability of occurrence



26

Chapter 1.2 – Loads

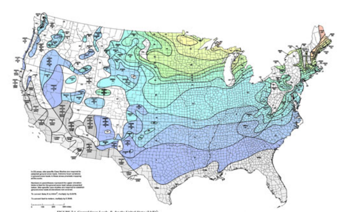
- A structural analysis of the effects of an earthquake requires an analysis of the structure's response to the ground motion produced by the earthquake.
- Simpler methods are sometimes used in which the effects of the earthquake are simulated by a system of ***horizontal loads***, similar to those resulting from wind pressure, acting at each floor level of the building.



27

Chapter 1.2 – Loads

- In some parts of the country, roof loading due to ***snow loads*** can be quite severe.
- Design loadings typically depend on the building's general shape and roof geometry, wind exposure, location, importance, and whether it is heated.



28

Chapter 1.3. - Building Codes

- Buildings must be designed and constructed according to the provisions of a ***building code.***
- These are legal documents containing requirements related to such things as structural safety, fire safety, plumbing, ventilation, and accessibility to the physically disabled.
- A ***building code*** has the force of law and is administered by a governmental entity such as a city, a county, or, for some large metropolitan areas, a consolidated government.

29

Chapter 1.3. - Building Codes

- ***Building codes*** do not give design procedures, but they do specify the design requirements and constraints that must be satisfied.
- Of particular importance to the structural engineer is the prescription of ***minimum live loads*** for buildings.

	Live Load			Live Load	
Occupancy or Use	lb/ft^2	kN/m^2	Occupancy or Use	lb/ft^2	kN/m^2
Assembly areas and theaters			Residential		
Fixed seats	60	2.87	Dwellings (one- and two-family)	40	1.92
Movable seats	100	4.79	Hotels and multifamily houses		
Garages (passenger cars only)	40	1.92	Private rooms and corridors	40	1.92
Office buildings			Public rooms and corridors	100	4.79
Lobbies	100	4.79	Schools		
Offices	50	2.39	Classrooms	40	1.92
Storage warehouse			First-floor corridors	100	4.79
Light	125	5.99	Corridors above first floor	80	3.83
Heavy	250	11.97			

30

Chapter 1.3. - Building Codes

- Although some large cities have their own building codes, many municipalities will modify a "***model***" building code to suit their needs and adopt it as modified.
- ***Model codes*** are written by various nonprofit organizations in a form that can be easily adopted by a governmental unit.
- Three national code organizations have developed model building codes:

  Uniform Building Code (UBC) (International Conference of Building Officials (ICBO) 1997)

  Standard Building Code (Southern Building Code Congress International (SBCCI), 1999)

  BOCA National Building Code (Building Officials and Code Administrators (BOCA), 1999)

31

Chapter 1.3. - Building Codes

- These codes have generally been used in different regions of the United States.
- The ***UBC*** has been essentially the only one used west of the Mississippi.
- The ***Standard Building Code*** has been used in the southeastern states.
- The ***BOCA National Building Code*** has been used in the northeastern part of the country.

32

Chapter 1.3. - Building Codes

- A unified building code, the ***International Building Code (IBC)*** (International Code Council, 2021), has been developed to eliminate some of the inconsistencies among the three national building codes.
- This was a joint effort by the three code organizations (***ICBO***, ***SBCCI***, and ***BOCA***).
- These organizations have merged into the ***International Code Council (ICC),*** and the new code has replaced the three regional codes.

33

Chapter 1.3. - Building Codes

- A unified building code, the ***International Building Code (IBC)*** (International Code Council, 2021), has been developed to eliminate some of the inconsistencies among the three national building codes.
- ***IBC Section 2205.1***, titled "General," mandates that the design, fabrication, and erection of structural steel in buildings must comply with the ***AISC 360*** (American Institute of Steel Construction) specification.
- Also, referencing specific seismic requirements in ***Section 2205.2*** and potentially other relevant AISC or related codes.

34

Chapter 1.3. - Building Codes

- Although it is not a building code, ***ASCE 7-22, Minimum Design Loads for Buildings and Other Structures*** (American Society of Civil Engineers (ASCE), 2022) is similar in form to a building code.
- This standard provides load requirements in a format suitable for adoption as part of a code.
- The ***IBC*** incorporates much of ***ASCE 7-22*** in its load provisions.
- The previous examples of dead and live loads given here came from ***ASCE 7-22.***

35

Chapter 1.4 - Design Specifications

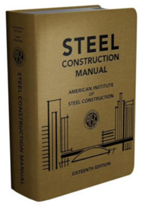
- ***Design specifications*** give more specific guidance for the design of ***structural members*** and their connections.
- They present the ***guidelines and criteria*** that enable a structural engineer to achieve the objectives mandated by a building code.
- Design specifications represent what is considered to be ***good engineering practice*** based on the latest research.
- They are periodically revised and updated by the issuance of supplements or completely new editions

36

Chapter 1.4 - Design Specifications

- The specifications of most interest to the ***structural steel designer*** are those published by the following organizations.
- ***American Institute of Steel Construction (AISC)***: This specification provides for the design of structural steel buildings and their connections (ANSI/AISC 360-22, 2022a).

AMERICAN INSTITUTE OF STEEL CONSTRUCTION AISC FOUNDED 1921

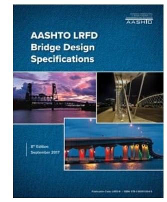


37

Chapter 1.4 - Design Specifications

- The specifications of most interest to the ***structural steel designer*** are those published by the following organizations.
- ***American Association of State Highway and Transportation Officials (AASHTO):*** This specification covers the design of highway bridges and related structures.

American Association of State Highway and Transportation Officials
AASHTO



38

Chapter 1.4 - Design Specifications

- The specifications of most interest to the ***structural steel designer*** are those published by the following organizations.
- ***American Railway Engineering and Maintenance-of-Way Association (AREMA)***: The AREMA Manual for Railway Engineering (MRE) covers the design of railway bridges and related structures (AREMA, 2023).

AREMA
AMERICAN RAILWAY ENGINEERING AND MAINTENANCE-OF-WAY ASSOCIATION

39

Chapter 1.4 - Design Specifications

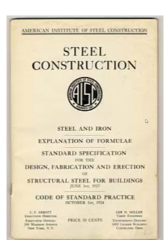
- The specifications of most interest to the ***structural steel designer*** are those published by the following organizations.
- ***American Iron and Steel Institute (AISI)***: This specification deals with cold-formed steel, which we discuss in Section 1.6 of this book (AISI S-100-16, 2016).

American Iron and Steel Institute

40

Chapter 1.4 - Design Specifications

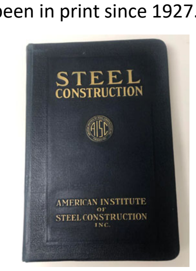
- The ***American Institute of Steel Construction (AISC)*** was founded in 1921 as a non-profit technical institute and trade association dedicated to establishing standards, promoting best practices, and providing resources for the structural steel design and construction industry in the United States.
- The first ***AISC Specification*** using allowable stress design was published in 1923.
- It was **9 pages** long!

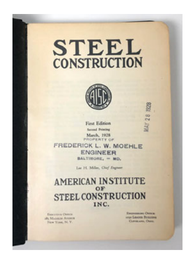


41

Chapter 1.4 - Design Specifications

- The ***Steel Construction Manual***, the premier reference for structural steel design and construction in the United States, has been in print since 1927.



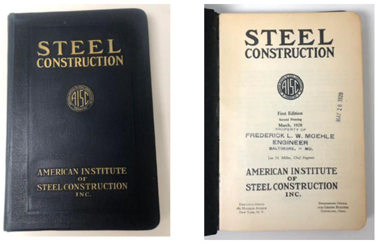


- It cost $1.50 That's $26.75 in today's dollars

42

Chapter 1.4 - Design Specifications

- The ***Steel Construction Manual***, the premier reference for structural steel design and construction in the United States, has been in print since 1927.

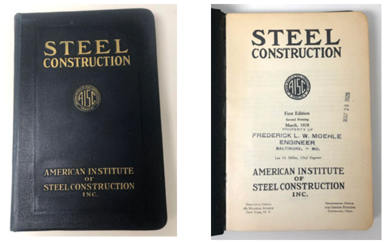


- The 16th edition of the AISC Manual is ***$500*** for non-members

43

Chapter 1.4 - Design Specifications

- The ***Steel Construction Manual***, the premier reference for structural steel design and construction in the United States, has been in print since 1927.

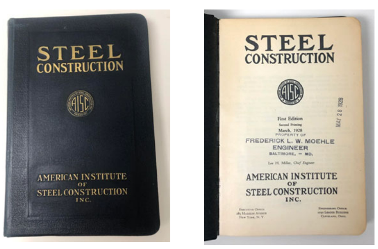


- The 16th edition of the AISC Manual is ***$250*** for members

44

Chapter 1.4 - Design Specifications

- The ***Steel Construction Manual***, the premier reference for structural steel design and construction in the United States, has been in print since 1927.

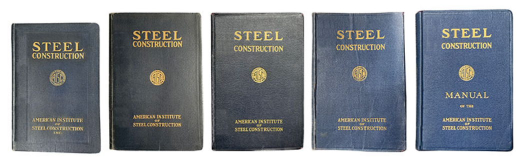


- The 16th edition of the AISC Manual is ***$125*** for students

45

Chapter 1.4 - Design Specifications

- The ***Steel Construction Manual***, the premier reference for structural steel design and construction in the United States, has been in print since 1927.



1st	2nd	3rd	4th	5th
1927	1934	1937	1941	1946

46

Chapter 1.4 - Design Specifications

- The ***Steel Construction Manual***, the premier reference for structural steel design and construction in the United States, has been in print since 1927.

6st	7th	8th	9th	10th
1963	1970	1980	1989	1986

Last ***ASD*** manual (9th, 1989)   1st ***LRFD*** manual (10th, 1986)

47

Chapter 1.4 - Design Specifications

- The ***Steel Construction Manual***, the premier reference for structural steel design and construction in the United States, has been in print since 1927.

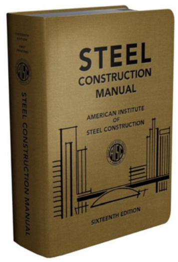
11th	12th	13th	14th	15th
1994	2001	2005	2011	2017

2nd ***LRFD*** manual (11th, 1994)   Unified ***ASD/LRFD*** manual (12th–14th, 2001–2011)

48

Chapter 1.4 - Design Specifications

- We will be using the 16th edition of the ***Steel Construction Manual*** (2023).



49

Chapter 1.5 - Structural Steel

- The earliest use of iron, the chief component of steel, was for small tools, in approximately 4,000 BCE.
- This material was in the form of wrought iron, produced by heating ore in a charcoal fire.
- The earliest known production of steel is seen in pieces of ironware excavated from an archaeological site in Anatolia (modern-day Turkey), which are nearly 4,000 years old, dating from 1,800 BCE.


The Sphinx Gate in Hattusa


Bronze Hittite figures of animals

50

Chapter 1.5 - Structural Steel

- In the latter part of the 18th century and in the early 19th century, ***cast iron and wrought iron*** were used in various types of bridges.


John Wilkinson

- The ***Iron Bridge*** is a cast-iron arch bridge that crosses the River Severn in Shropshire, England. Opened in 1781, it was the first major bridge in the world to be made of cast iron.

51

Chapter 1.5 - Structural Steel

- In the latter part of the 18th century and in the early 19th century, ***cast iron and wrought iron*** were used in various types of bridges.

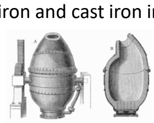

John Wilkinson

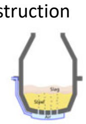
- Its success inspired the widespread use of cast iron as a structural material, and today the bridge is celebrated as ***a symbol of the Industrial Revolution***.

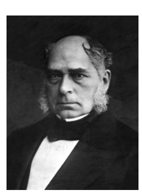
52

Chapter 1.5 - Structural Steel

- In the latter part of the 18th century and in the early 19th century, ***cast iron and wrought iron*** were used in various types of bridges.
- Steel, an alloy of primarily ***iron and carbon***, with fewer impurities and less carbon than cast iron, was first used in heavy construction in the 19th century.
- With the advent of the ***Bessemer converter*** in 1855, steel began to displace wrought iron and cast iron in construction



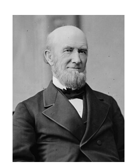



Henry Bessemer

53

Chapter 1.5 - Structural Steel

- In the United States, the first structural steel railroad bridge was the ***Eads Bridge***, constructed in 1874 in St. Louis, Missouri.


James Buchanan Eads

54

Chapter 1.5 - Structural Steel

- The ***Home Insurance Building*** was a skyscraper that stood in Chicago from 1885 to its demolition in 1931.
- Originally ten stories and 138 *ft* (42.1 m) tall, it was designed by William Le Baron Jenney in 1884 and completed the next year.

William Le Baron Jenney

55

Chapter 1.5 - Structural Steel

- The ***Home Insurance Building*** was a skyscraper that stood in Chicago from 1885 to its demolition in 1931.
- It was the first tall building to be supported both inside and outside by a fireproof ***structural steel frame***.

William Le Baron Jenney

56

Chapter 1.5 - Structural Steel

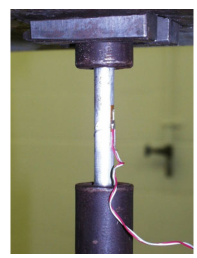
- The ***Home Insurance Building*** was a skyscraper that stood in Chicago from 1885 to its demolition in 1931.
- It is considered the ***world's first skyscraper***.

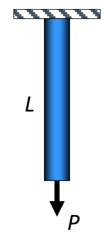
William Le Baron Jenney

57

Chapter 1.5 - Structural Steel

- The characteristics of steel that are of the most interest to ***structural engineers*** can be examined by a stress-strain plot.
- Consider a test specimen subjected to an axial load *P*.

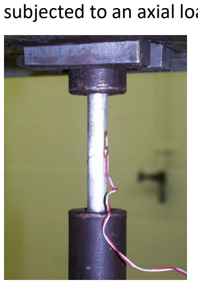


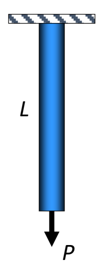


58

Chapter 1.5 - Structural Steel

- The characteristics of steel that are of the most interest to ***structural engineers*** can be examined by a stress-strain plot.
- Consider a test specimen subjected to an axial load *P*.





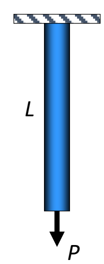
59

Chapter 1.5 - Structural Steel

- The characteristics of steel that are of the most interest to ***structural engineers*** can be examined by a stress-strain plot.
- Consider a test specimen subjected to an axial load *P*.

$$f = \frac{P}{A} \qquad \varepsilon = \frac{\delta}{L}$$

f = axial tensile stress
A = cross-sectional area
ε = axial strain
L = original length of the specimen
ΔL = the change in length



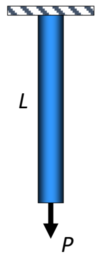
60

Chapter 1.5 - Structural Steel

- The characteristics of steel that are of the most interest to ***structural engineers*** can be examined by a stress-strain plot.
- Consider a test specimen subjected to an axial load *P*.

$$f = \frac{P}{A} \qquad \varepsilon = \frac{\delta}{L}$$

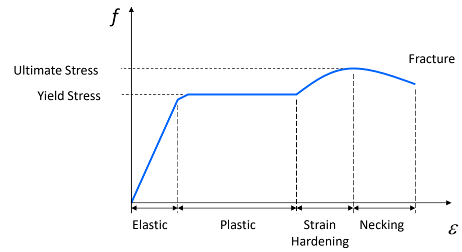
- Stress is denoted by ***f*** and strain by ε.
- Why not denote stress as σ?
- We use upper case ***F*** for force, maybe we use lower case ***f*** for stress because it's a small force.

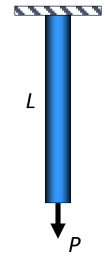


61

Chapter 1.5 - Structural Steel

- The characteristics of steel that are of the most interest to ***structural engineers*** can be examined by a stress-strain plot.
- Consider a test specimen subjected to an axial load *P*.

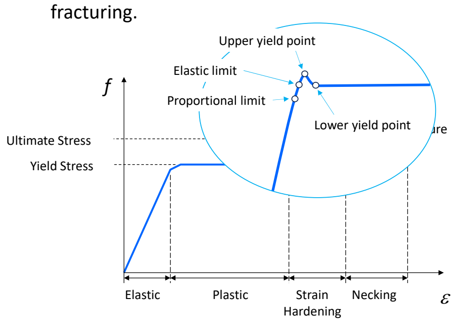


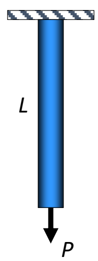


62

Chapter 1.5 - Structural Steel

- Steel exhibiting the behavior shown below is called ***ductile*** because of its ability to undergo large deformations before fracturing.



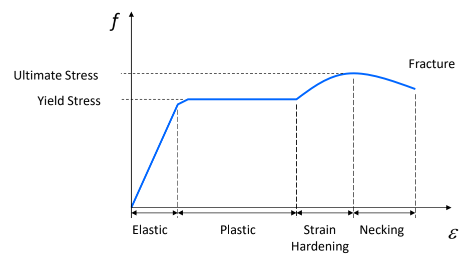


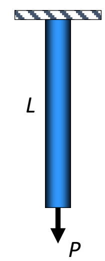
63

Chapter 1.5 - Structural Steel

- Ductility can be measured by the elongation, ***e***, defined as

$$e = \frac{L_f - L_0}{L_0} \qquad L_f = \text{length of specimen at fracture} \qquad L_o = \text{original length}$$

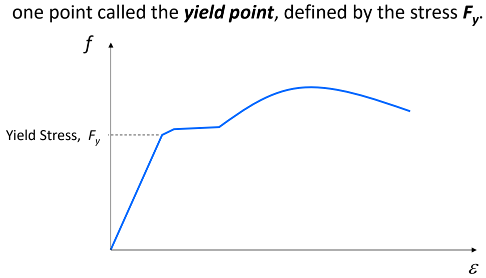




64

Chapter 1.5 - Structural Steel

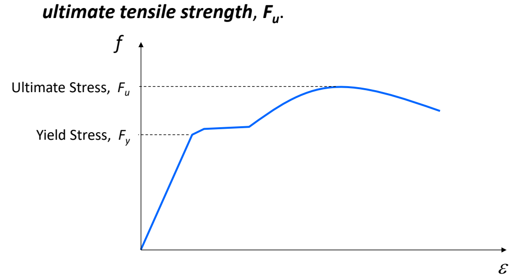
- Consider an idealized version of this stress–strain curve.
- The proportional limit, elastic limit, and the upper and lower yield points are all very close to one another and considered one point called the ***yield point***, defined by the stress F_y.



65

Chapter 1.5 - Structural Steel

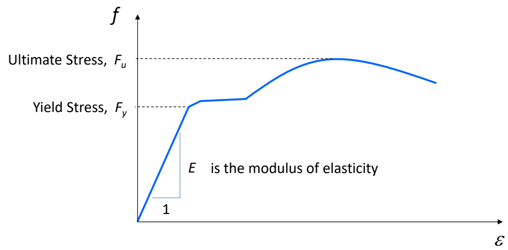
- Consider an idealized version of this stress–strain curve.
- The other point of interest to the structural engineer is the maximum value of stress that can be attained, called the ***ultimate tensile strength***, F_u.



66

Chapter 1.5 - Structural Steel

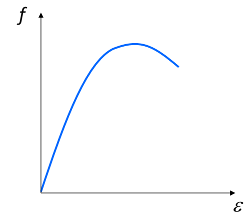
- Consider an idealized version of this stress–strain curve.
- The ratio of stress to strain within the elastic range, denoted ***E*** or modulus of elasticity, is the same for all structural steels and has a value of 29,000,000 psi or 200 GPa.



67

Chapter 1.5 - Structural Steel

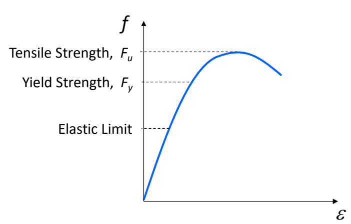
- Consider a typical stress–strain curve for high-strength steels.
- This material is less ductile than the mild steels.



68

Chapter 1.5 - Structural Steel

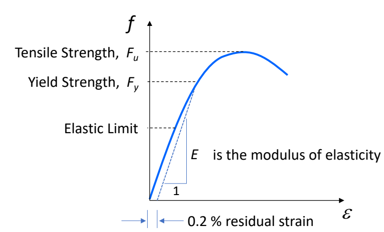
- Although there is a linear elastic portion and a distinct tensile strength, there is no well-defined yield point.
- Values of the limit stresses must be chosen.



69

Chapter 1.5 - Structural Steel

- A strain of 0.002 is usually selected, and this method of determining the yield strength is called the 0.2% offset method.



70

Chapter 1.5 - Structural Steel

- Different grades of structural steel are identified by the designation assigned to them by the ***American Society for Testing and Materials (ASTM)***.
- ***ASTM*** develops standards for defining materials in terms of their composition, properties, and performance, and it prescribes specific tests for measuring these attributes.
- One of the most used structural steels is a mild steel designated as ***ASTM A36***, or ***A36*** for short.

Yield stress: F_y = 36,000 *psi* = 36 *ksi*

Tensile strength: F_u = 58,000 to 80,000 *psi*

= 58 *ksi* to 80 *ksi*

71

Chapter 1.5 - Structural Steel

- Other commonly used structural steels are ***ASTM A572 Grade 50*** and ***ASTM A992***.

Property	A36	A572 Gr. 50	A992
Yield point, min.	36 *ksi*	50 *ksi*	50-65 *ksi*
Tensile strength, min.	58 to 80 *ksi*	65 *ksi*	65 *ksi*
Yield to tensile ratio, max.	--	--	0.85
Elongation in 8 in., min.	20%	18%	18%

- For more information about applicable material specifications, refer to ***Tables 2.4 to 2.6*** in the AISC Steel Construction Manual, 16th edition (AISC, 2023).

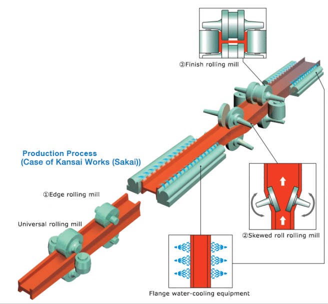
72

Chapter 1.6 - Standard Shapes

- In the design process outlined earlier, one of the objectives—and the ***primary emphasis*** of this course—is the selection of the appropriate cross sections for the individual members of the structure being designed.
- Most often, this selection will entail choosing a ***standard cross-sectional shape*** that is widely available rather than requiring the fabrication of a shape with unique dimensions and properties.
- The largest category of standard shapes includes those produced by ***hot-rolling***.

Chapter 1.6 - Standard Shapes

- In ***hot rolling***, metal stock is passed through one or more pairs of rolls to reduce the thickness, to make the thickness uniform, and/or to impart a desired mechanical property.

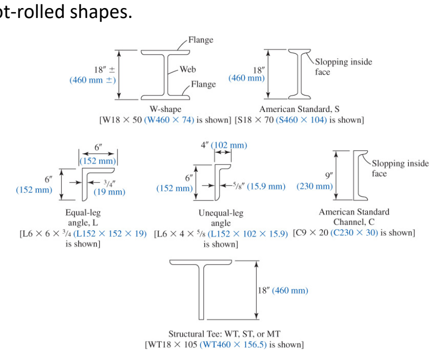


Chapter 1.6 - Standard Shapes

- Here are some cross sections of the more commonly used hot-rolled shapes.

Chapter 1.6 - Standard Shapes

- Here are some cross sections of the more commonly used hot-rolled shapes.

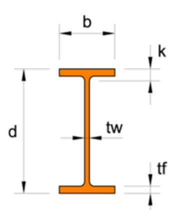


Chapter 1.6 - Standard Shapes

- The ***W-shape***, also called a ***wide-flange*** shape, consists of two parallel flanges separated by a single web.
- The orientation of these elements is such that the cross-section has ***two axes of symmetry***.
- A typical designation would be **W18 × 50.**

  The **W** indicates the type of shape,
  the **18** is the nominal depth (in.), and
  the **50** is the weight (lb.) per foot of length.

- The nominal depth is the approximate depth expressed in whole inches.

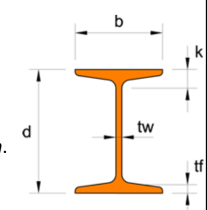


Chapter 1.6 - Standard Shapes

- The ***American Standard***, or ***S-shape***, is like the W-shape in having two parallel flanges, a single web, and two axes of symmetry.
- For an ***S-shape***, the inside faces of the ***flanges are sloping*** with respect to the outside faces.
- A typical designation would be **S18 × 70.**

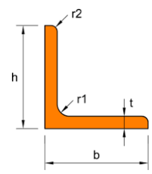
  The **S** indicates the type of shape,
  the **18** is the depth (in.), and
  the **70** is the weight (lb.) per foot of length.

- This shape was formerly called an ***I-beam***.



Chapter 1.6 - Standard Shapes

- The angle shapes are available in either equal-leg or unequal-leg versions.
- A typical designation is **L6 × 6 x ¾** or **L6 × 4 x ⅝**
- The three numbers are the lengths of each of the two legs as measured from the corner, or heel, to the toe at the other end of the leg, and the thickness, which is the same for both legs.
- In the case of the unequal-leg angle, the longer leg dimension is always given first.



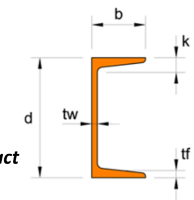
79

Chapter 1.6 - Standard Shapes

- The American Standard Channel, or ***C-shape***, has two flanges and a web, with only ***one axis of symmetry***.
- A typical designation is **C9 × 20**

  The **C** indicates the type of shape,
  the **9** is the total depth (in.), and
  the **20** is the weight (lb.) per foot of length.

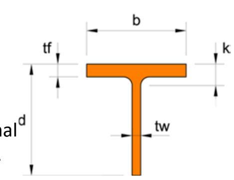
- For the channel, however, the depth is ***exact*** rather than nominal.
- The inside faces of the ***flanges are sloping***, just as with the American Standard shape



80

Chapter 1.6 - Standard Shapes

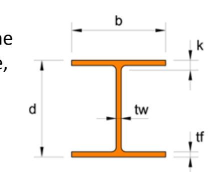
- The ***Structural Tee*** is produced by splitting an **I**-shaped member at mid-depth.
- This shape is sometimes referred to as a ***split-tee***.
- The prefix of the designation is either **WT**, **ST**, or **MT**, depending on which shape is the "parent."
- For example, **WT18 x 105** has a nominal depth of 18 in. and a weight of 105 lb. per foot.



81

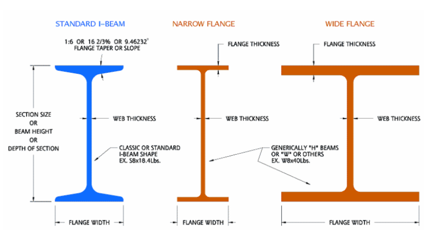
Chapter 1.6 - Standard Shapes

- The "**M**" is for "miscellaneous."
- The ***M-shape*** has two parallel flanges and a web, but it does not fit exactly into either the **W** or **S** categories.
- The ***HP*** shape, used for bearing piles, has parallel flange surfaces, approximately the same width and depth, and equal flange and web thicknesses.
- ***HP-shapes*** are designated in the same manner as the W-shape; for example, **HP14 x 117**.



82

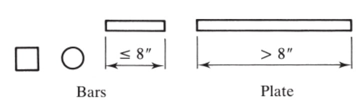
Chapter 1.6 - Standard Shapes



83

Chapter 1.6 - Standard Shapes

- Consider other frequently used cross-sectional shapes.

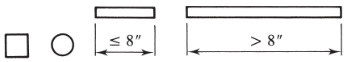


- Bars can have square, circular, or rectangular cross sections.
- If the width of a rectangular shape is 8 in. or less, it is classified as a ***bar***; if it is > 8 in., it is classified as a ***plate***.

84

Chapter 1.6 - Standard Shapes

- Consider other frequently used cross-sectional shapes.



Bars Plate

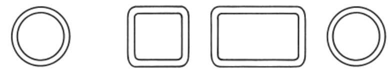
- The usual designation for both is **PL** (for plate, even though it could be a bar).
- Consider the **PL⅜ x 5 x 3'-2½"**

  The **PL** indicates the type of shape,
  the **⅜** is the thickness (in.),
  the **5** is the weight (lb.) per foot of length, and
  The **3'-2½"** is the length.

85

Chapter 1.6 - Standard Shapes

- Consider other frequently used cross-sectional shapes.



Steel pipe Hollow Structural Sections

- These hollow shapes can be produced either by bending plate material into the desired shape and welding the seam or by hot-working to produce a seamless shape.
- The shapes are categorized as steel pipe, ***round HSS***, and ***square and rectangular HSS***.
- The designation ***HSS*** is for "Hollow Structural Sections."

86

Chapter 1.6 - Standard Shapes

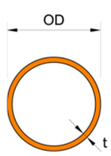
- Consider other frequently used cross-sectional shapes.

Steel pipe Hollow Structural Sections

- Steel pipe is available as standard, extra-strong, or double-extra-strong.

  For example, **Pipe 5Std, Pipe 5x-strong**, or **Pipe 5xx-strong**

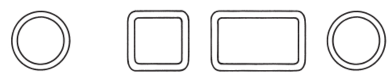
  The **5** is the outer diameter (in.).



87

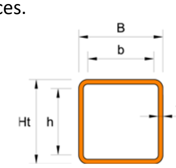
Chapter 1.6 - Standard Shapes

- Consider other frequently used cross-sectional shapes.



Steel pipe Hollow Structural Sections

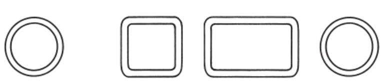
- ***Round HSS*** are designated by outer diameter and wall thickness, expressed to three decimal places.
- For example, **HSS 8.625 x 0.250**



88

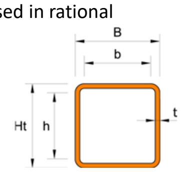
Chapter 1.6 - Standard Shapes

- Consider other frequently used cross-sectional shapes.



Steel pipe Hollow Structural Sections

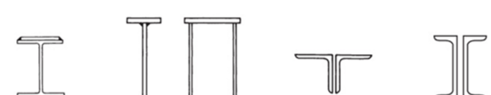
- ***Square HHS*** and ***Rectangular HSS*** are designated by nominal outer diameter and wall thickness, expressed in rational numbers.
- For example, **HSS 7 x 5 x ⅜**



89

Chapter 1.6 - Standard Shapes

- Other shapes are available, but those just described are the ones most frequently used.
- In most cases, one of these standard shapes will satisfy design requirements.
- If the requirements are especially severe, then a ***built-up*** section may be needed.



W-shape with cover plates Plate girders Double angle Double channel

90

Chapter 1 – Intro to Steel Design

Any questions?

91