

4.461: Building Technology 1
CONSTRUCTION AND MATERIALS

SCHOOL OF ARCHITECTURE AND PLANNING: MIT

Professor John E. Fernandez

Metals

Part I: Metals in Architecture

- Introduction
- Material Properties and Structural Morphology
 - i. Wood
 - ii. Masonry
 - iii. **Metals**
 - iv. Fabric
 - v. Composites

Part II: Metal Systems and Architecture

- Transparencies

Part III: New Materials and Systems

- Stainless Steels
- Panelized systems

Part IV: Resource Efficiency

- Embodied energy
- Sustainable practice

Part I: Metals in Architecture

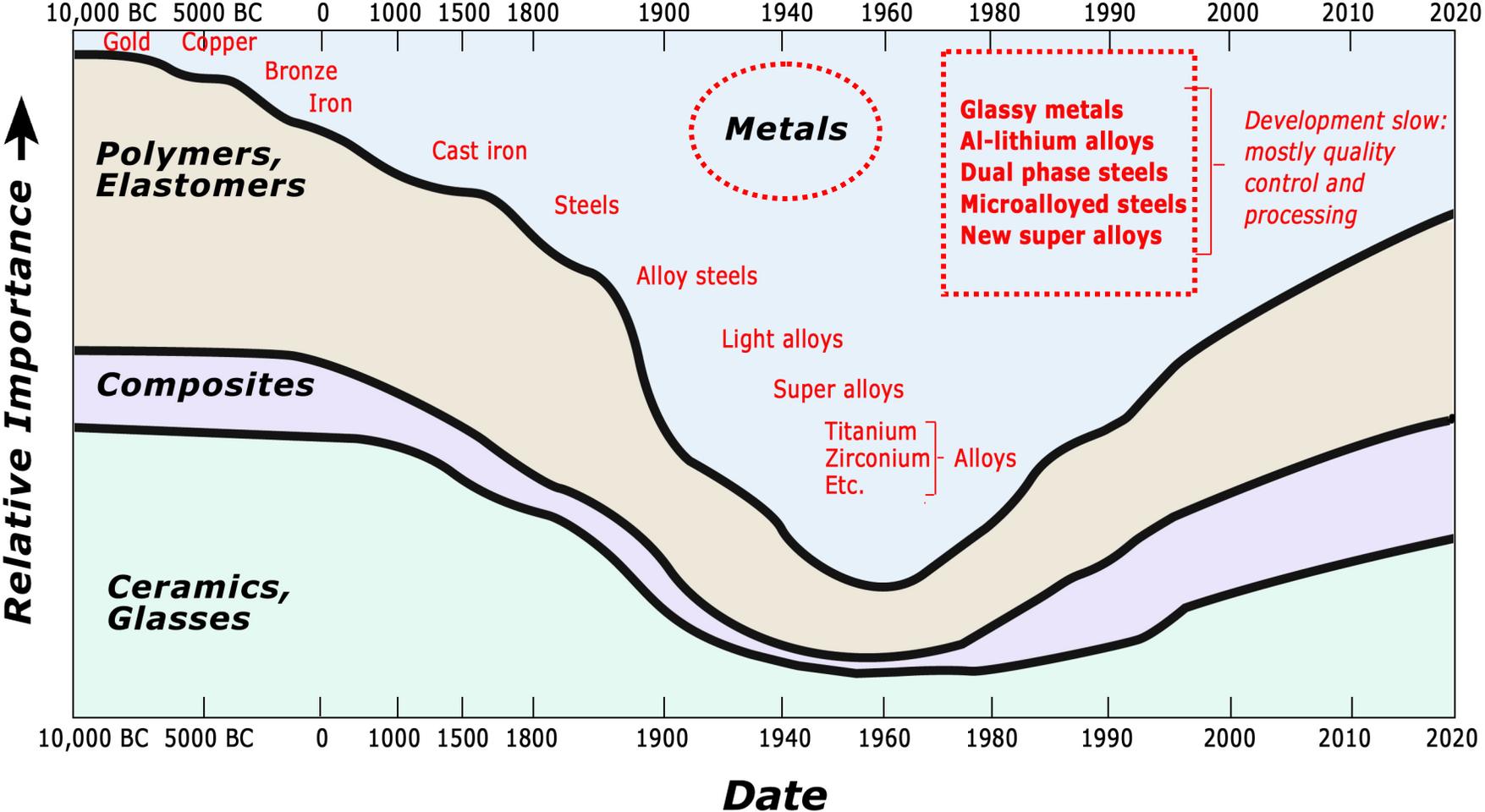
- Introduction
- Structure and skin



Metals

Part I: Metals in Architecture

- Introduction
 - i. Historical trajectory



Part I: Metals in Architecture

- Introduction: Steel Landmark developments

- i. Historical trajectory

| | |
|-----------|---|
| 1777-79 | First Cast iron bridge built in England |
| 1780-1820 | Numerous cast bridges built, arch-shaped with main girders of individual cast iron pieces forming bars or truss |
| ~1800 | Industrial production of rolled shapes begins in England |
| 1840 | Wrought iron begins to replace cast iron |
| 1846-50 | Brittania bridge over Menai Straits in Wales |
| 1870s | I-shapes rolled |
| 1855 | Development of the Bessemer process |
| 1870 | Introduction of basic liner in the Bessemer converter |
| 1890 | Steel permanently replaces wrought iron as principal building material |
| Currently | Steels having yield stresses varying from 24,000 to 100,000 psi are readily available |

Part I: Metals in Architecture

- Material Properties and Applications of various steels

Three types

1. Carbon steels
2. High-strength low-alloy steels
3. Alloy steels

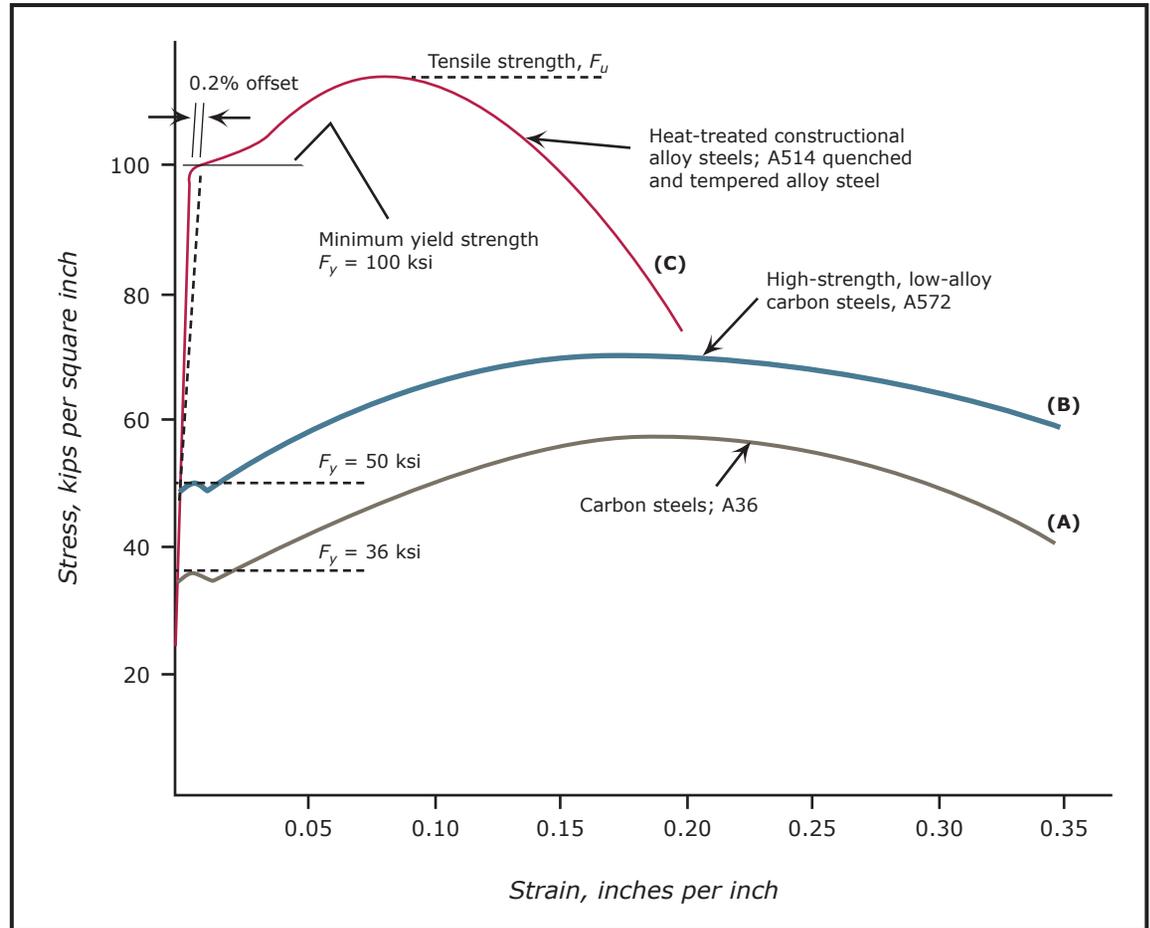


Image by MIT OCW.

Typical stress-strain curves

Part I: Metals in Architecture

- Material Properties and Applications of various steels

Carbon steels

Carbon steels are divided into four categories depending on the percentage of carbon:

- Low carbon: less than 0.15%
- Mild carbon: 0.15-0.29
- Medium carbon: 0.30-0.59%
- High carbon: 0.60-1.70%

Structural carbon steels are in the mild category: A36 has max. carbon from 0.25-0.29%. Increased carbon percent raises the yield stress but reduces ductility and makes welding more difficult.

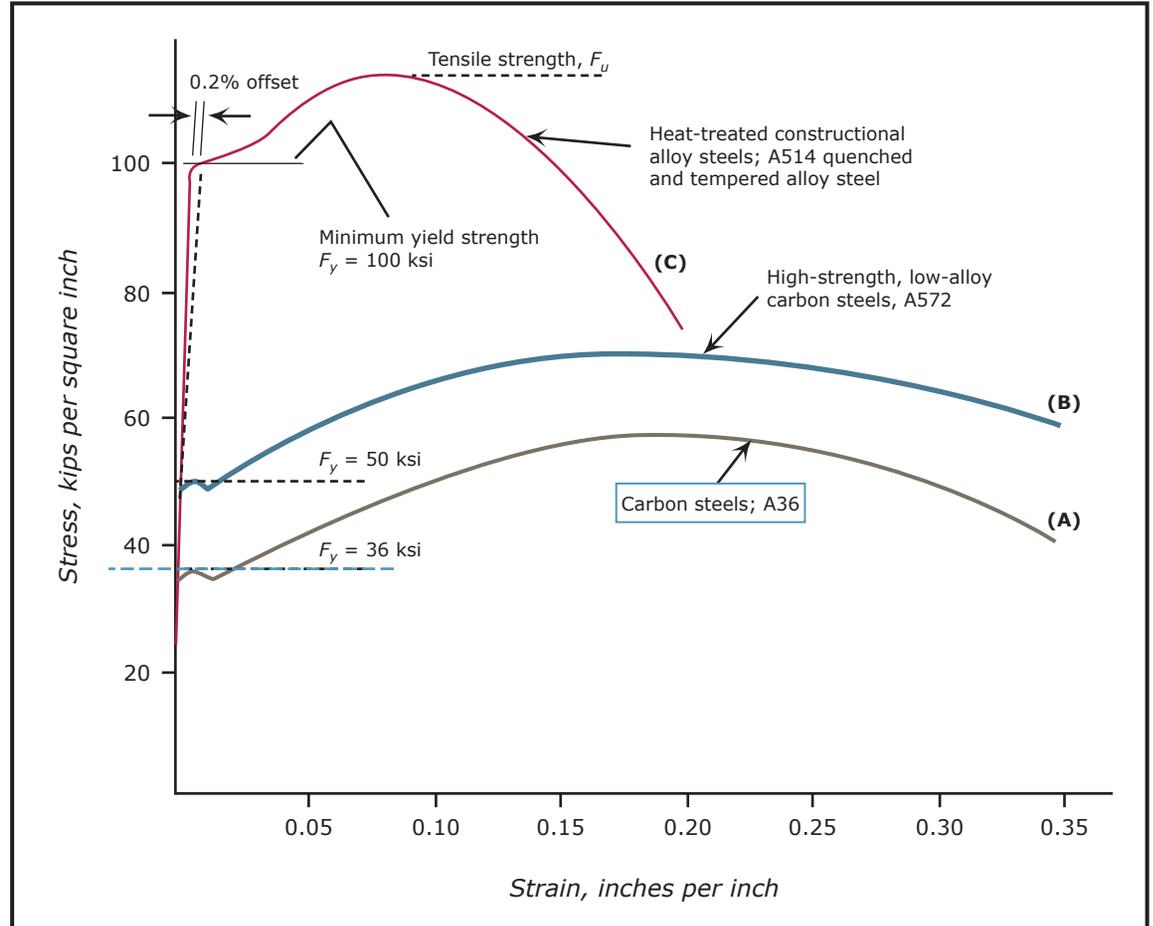


Image by MIT OCW.

Part I: Metals in Architecture

- Material Properties and Applications of various steels

High-strength low-alloy steels

The addition to carbon steels of small amounts of alloy elements such as chromium, columbium, copper, manganese, molybdenum, nickel, phosphorous, vanadium, zirconium improves some of the mechanical properties.

Additional strength is obtained through a fine-grained crystalline microstructure as opposed to the course graining of simple carbon steel.

This type of steel yields at stresses from 40-70 ksi.

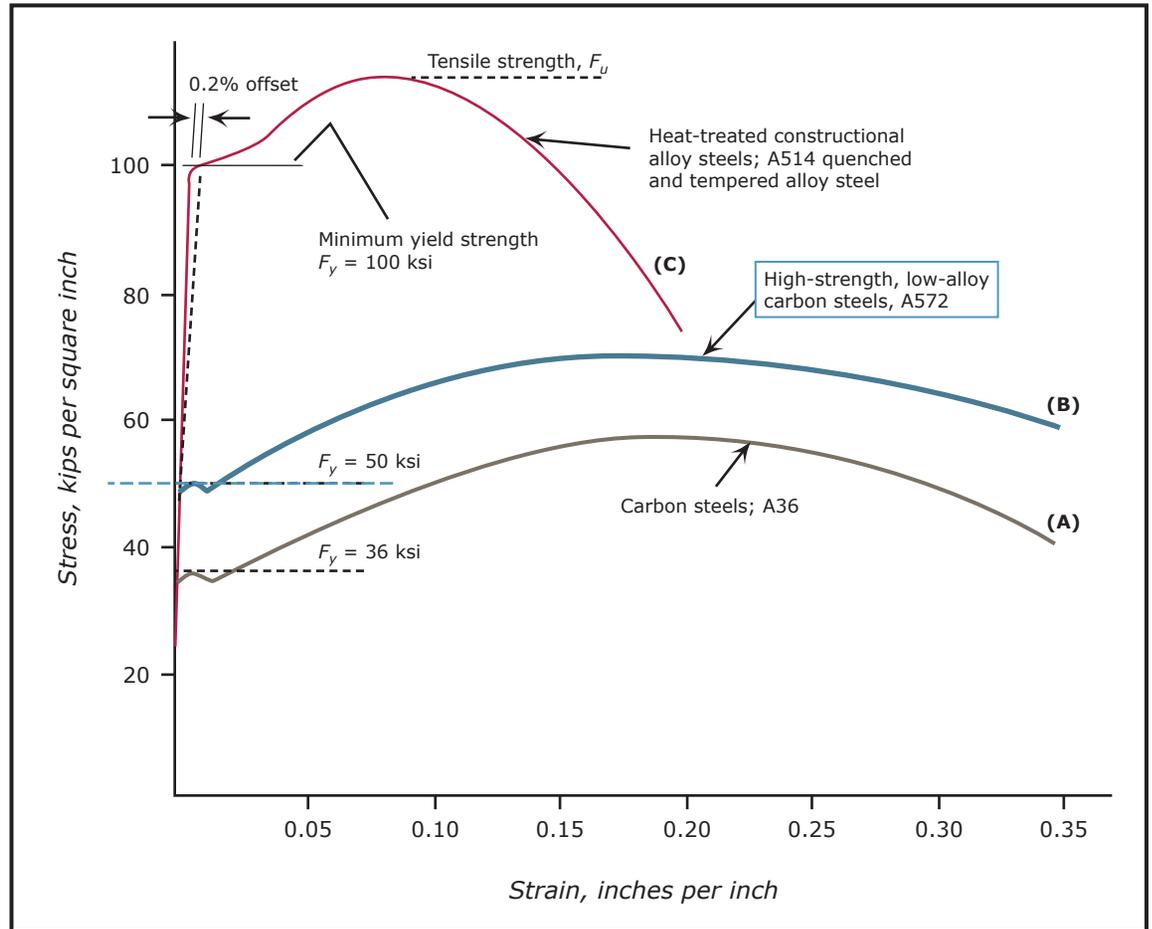


Image by MIT OCW.

Part I: Metals in Architecture

- Material Properties and Applications of various steels

Alloy steels

Low-alloy steel may be quenched and tempered to obtain yield strengths of 80 – 110 ksi. Maximum carbon content of 0.20% to limit the hardness of any coarse-grain microstructure.

The heat treatment consists of quenching [rapid cooling with water or oil from at least 1650 F to about 300-400 F], then tempering by reheating to at least 1150 F and allowing to cool. Tempering greatly improves toughness and ductility.

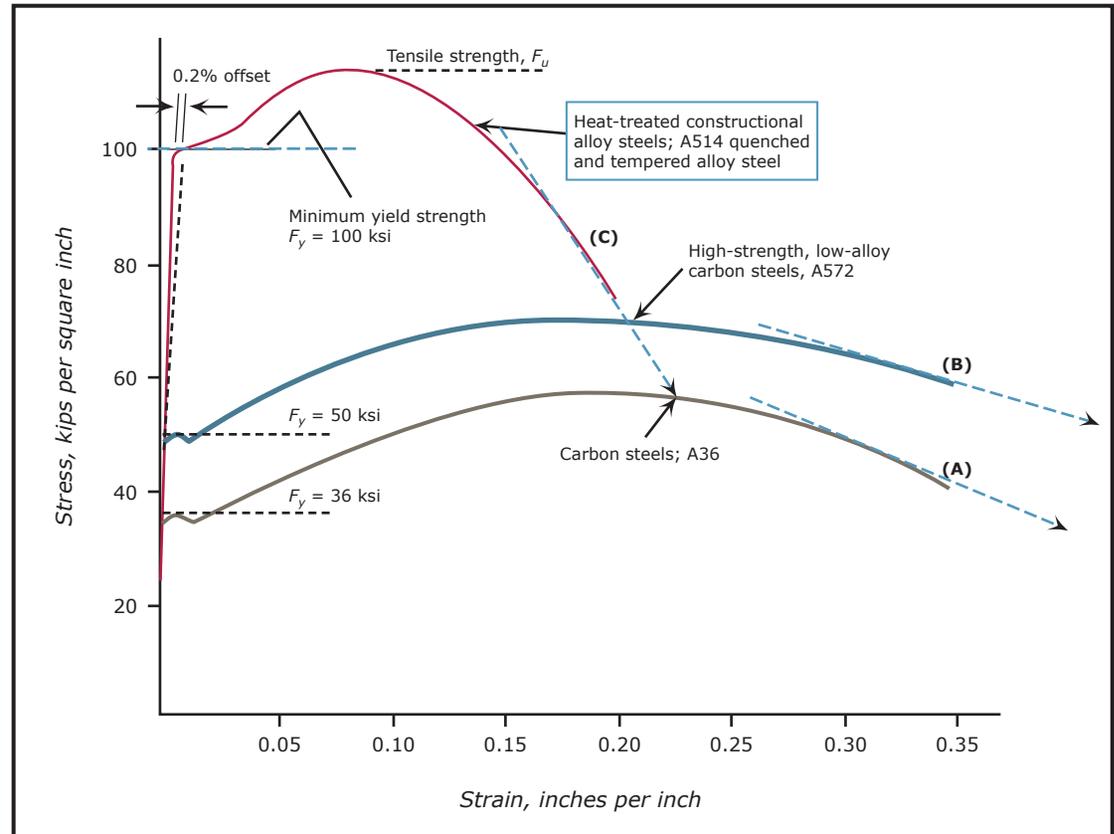


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Part I: Metals in Architecture

- **Material Properties and Applications of various steels**

| | |
|----------------------|--|
| A36 carbon | General structural purposes, bolted and welded. Mostly for buildings. |
| A53 carbon | Welded and seamless pipe |
| A500 carbon | Cold-formed welded and seamless round, square, rectangular, or special shape structural tubing for bolted and welded general structural purposes. |
| A501 carbon | Hot-rolled welded and seamless round, square, rectangular, or special shape structural tubing for bolted and welded general structural purposes. |
| A514 alloy | Plates in thickness of 6 in. and under, primarily for welded bridges. |
| A588 High S., Low A. | Structural shapes, plates and bars for welded buildings and bridges where weight savings or added durability are needed; atmospheric corrosion resistance is about four times that of A36 steel. |
| A913 High S., Low A. | Structural shapes for bolted and welded construction. |

Part I: Metals in Architecture

- Material Properties and Applications of various steels

Corrosion

Self-weathering steels have been widely adopted for conditions in which the surface of the steel is exposed to the weather. These steels are typically A588 for buildings and A709 for bridges.

Several rules are important to note:

1. For optimum performance in the unpainted condition, the structure should be boldly exposed to the weather.
2. The development of the protective oxide film is best achieved under normal exposure, wherein the surfaces are wet at night by dew formation and dry during daylight hours.
3. Because this wet-dry cycle cannot occur when the steel, regardless of its grade, is buried in the soil or immersed in water, the protective oxide will not form and the performance will resemble that of mild steel carbon exposed to the same conditions.

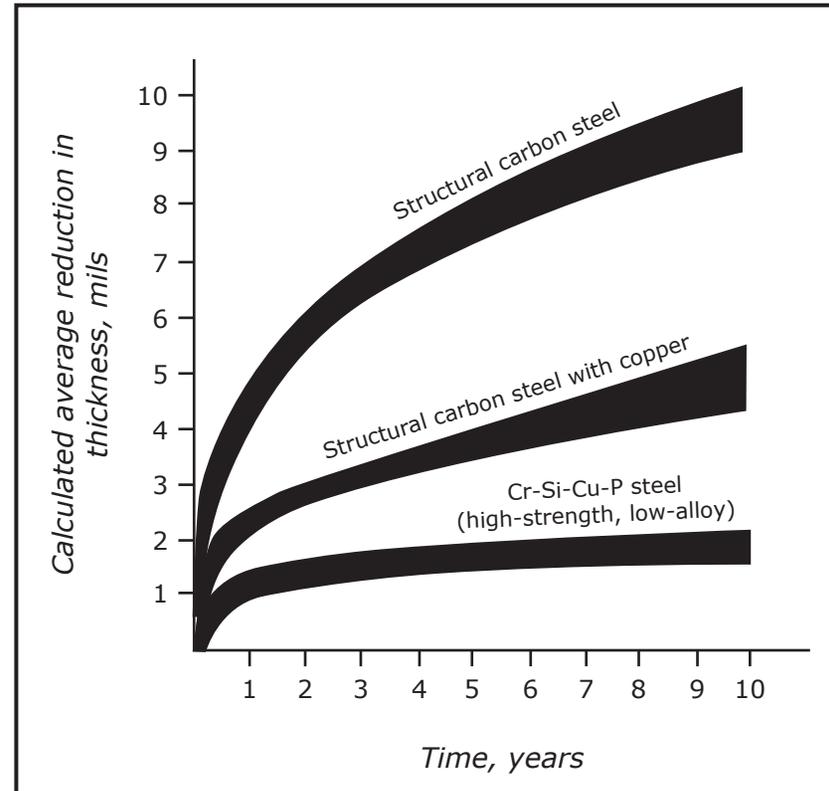


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Heat and strength

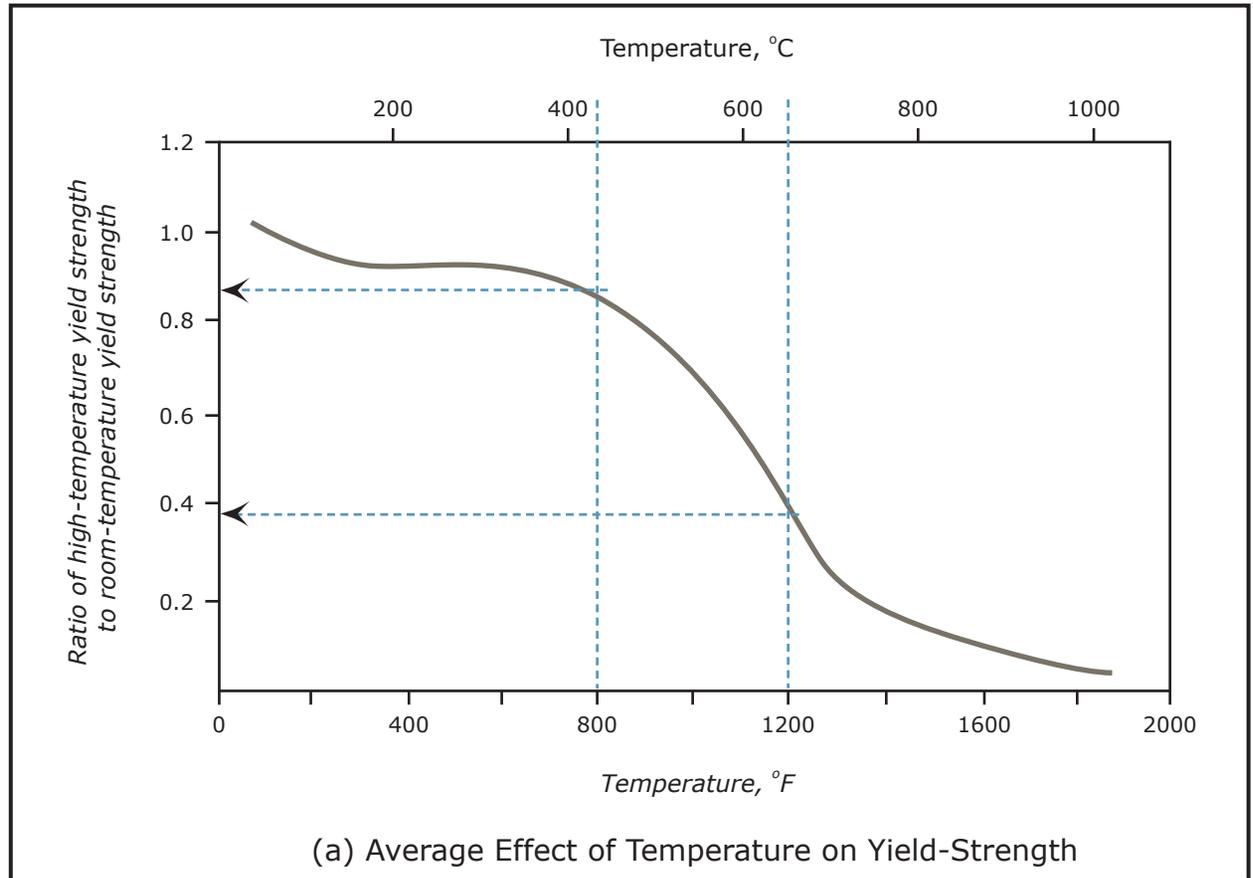


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Part I: Metals in Architecture

- Types of Structural Steel Members

American Institute of Steel Construction (AISC)

American Society for Testing and Materials

(ASTM) A6 Specification

Standard Hot-Rolled shapes

1. Wide-flange shape
2. American standard beam
3. American standard channel
4. Angle
5. Structural tee
6. Pipe section
7. Structural tubing
8. Bars
9. Plates

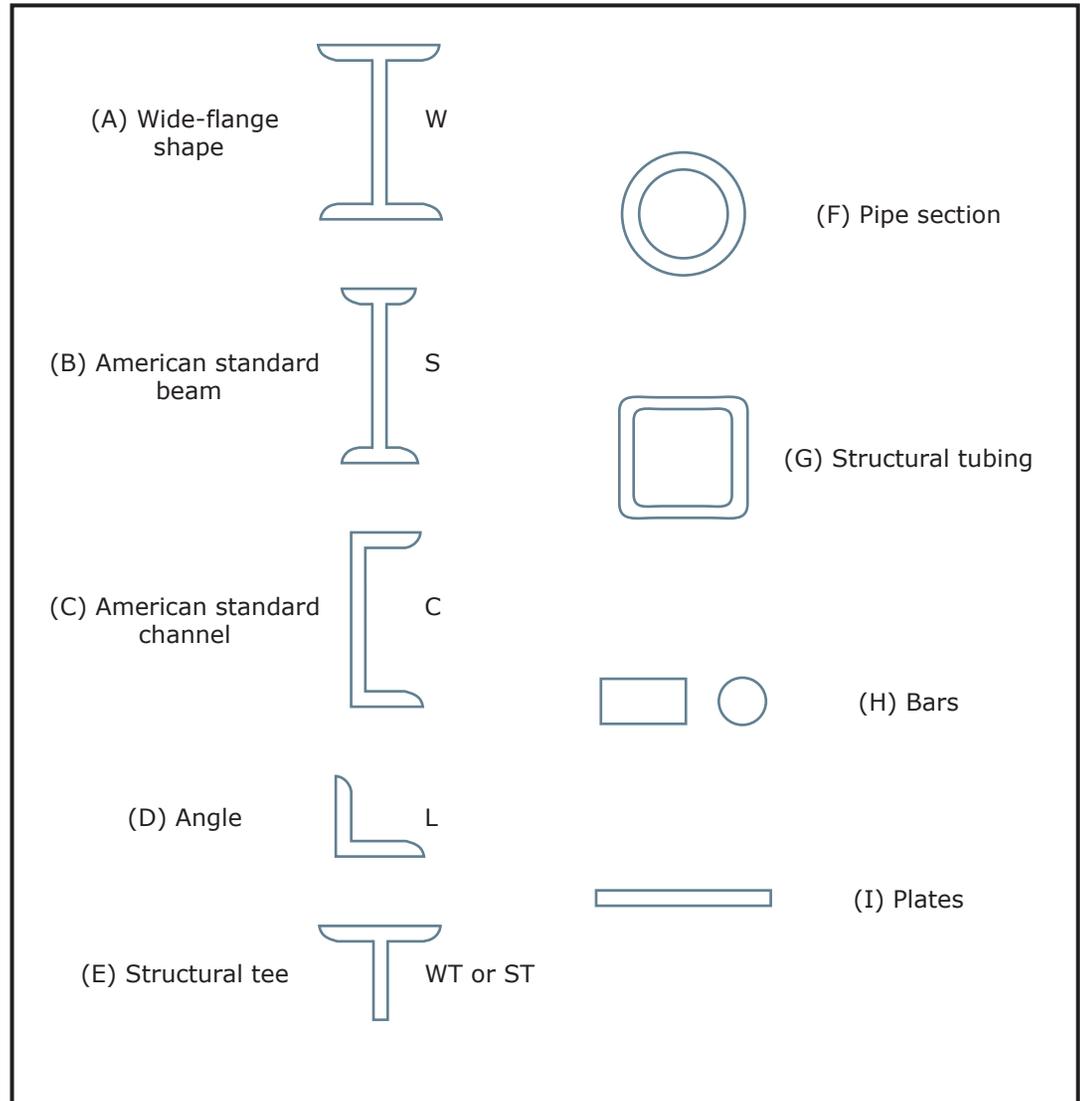


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Part I: Metals in Architecture

- Types of Structural Steel Members

American Institute of Steel Construction (AISC)

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(ASTM) A6 Specification

Standard Cold-Rolled shapes

1. Channels
2. Zees
3. I-Shaped double channels
4. Angle
5. Hat sections

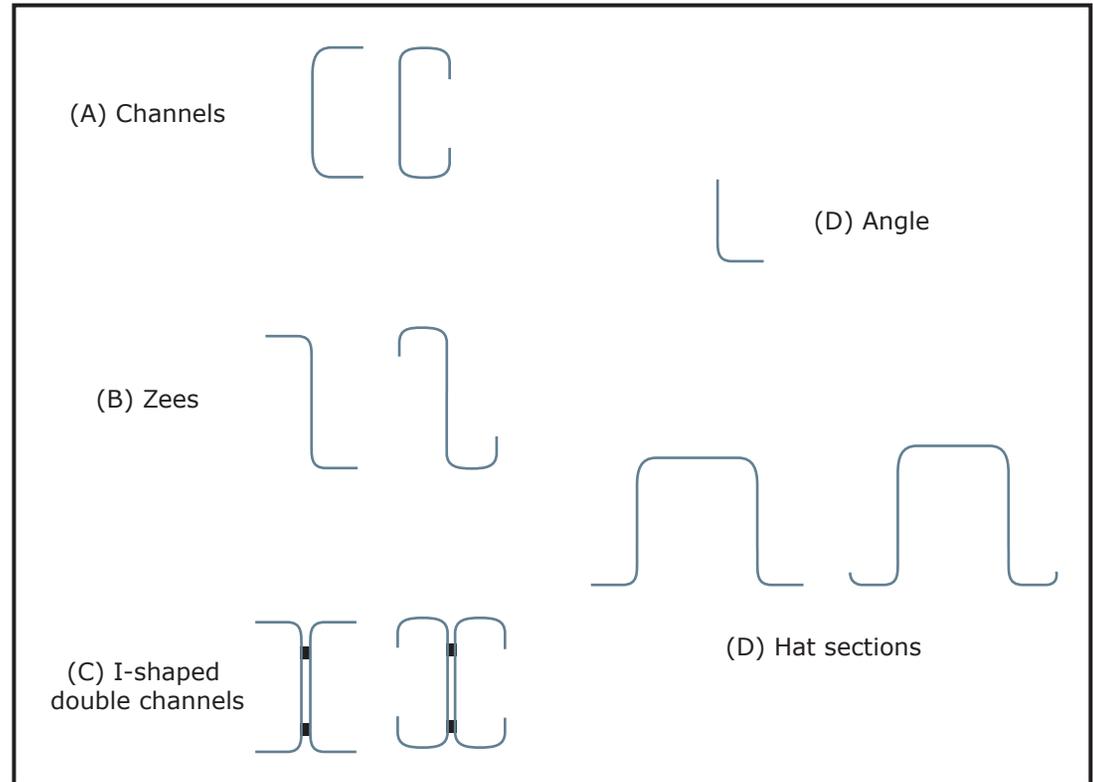
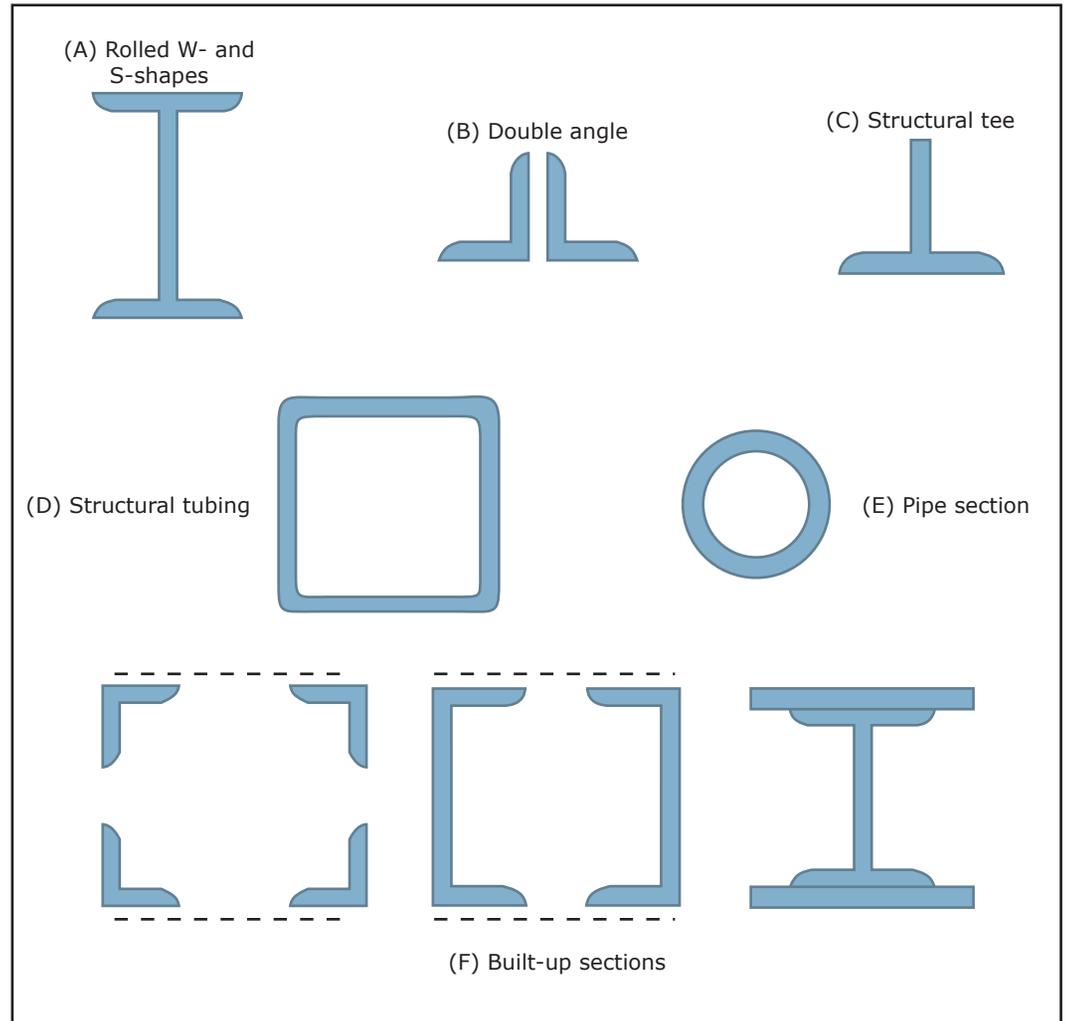


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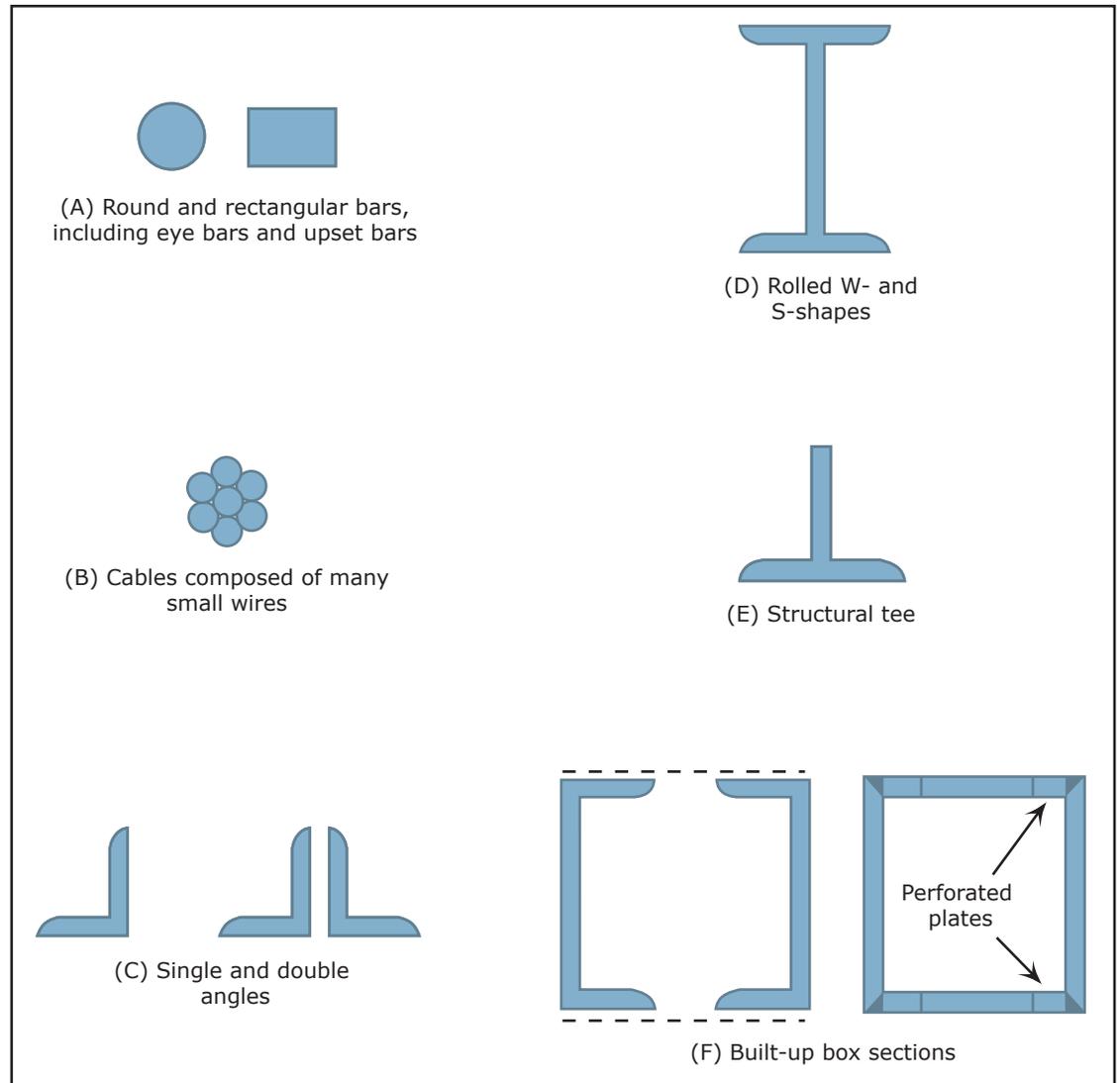
Part I: Metals in Architecture

- Typical compression members



Part I: Metals in Architecture

- Typical tension members



Part I: Metals in Architecture

- Typical beam members

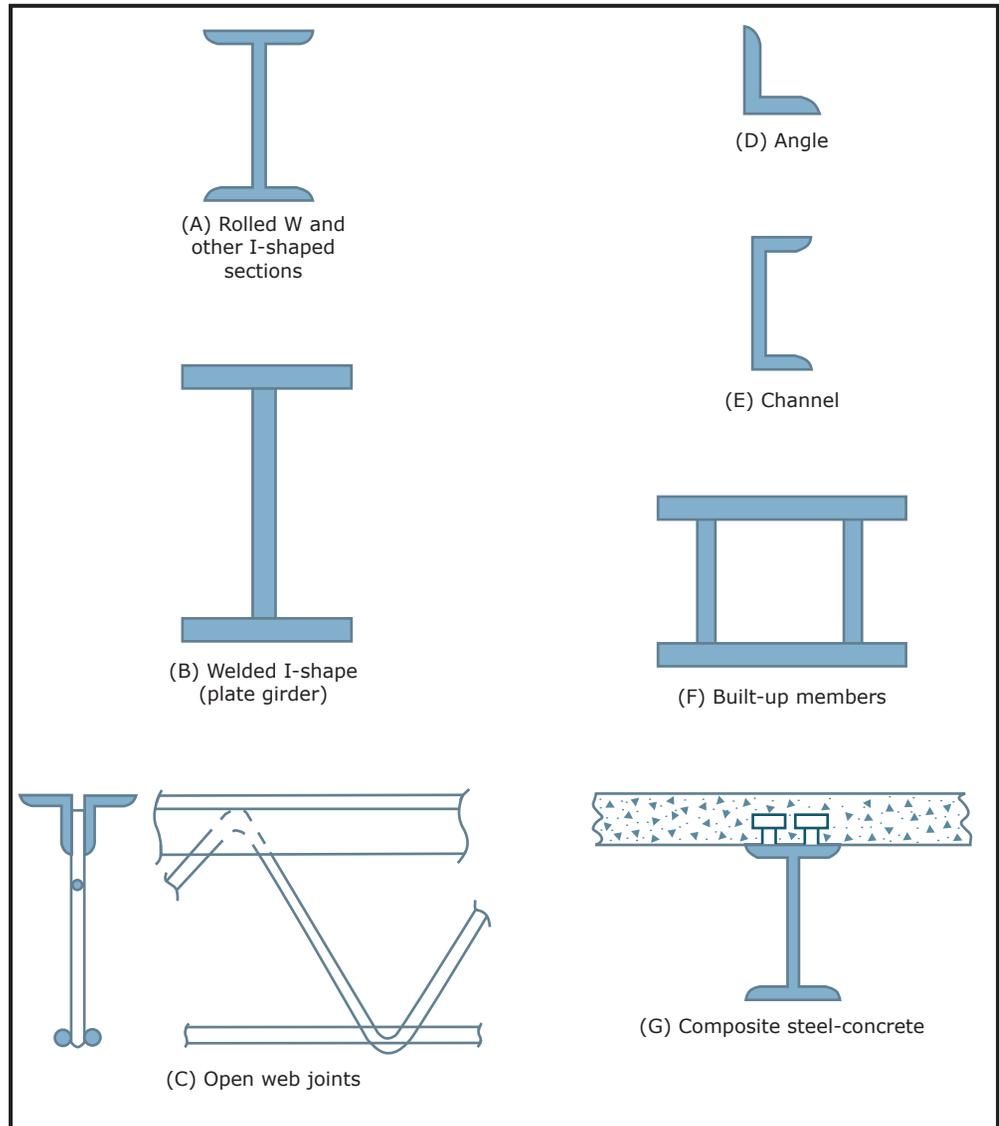


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Part I: Metals in Architecture

Joints

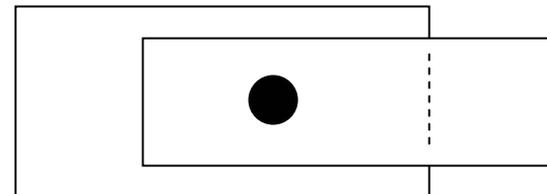
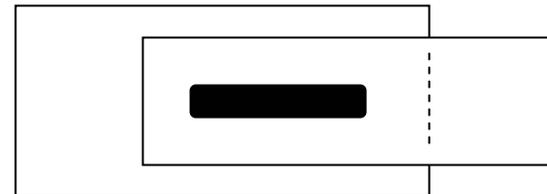
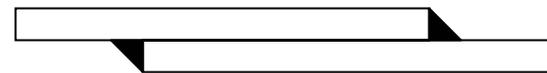
- Bolts
- Welds

Part I: Metals in Architecture

Joints

- Welds

1. Groove: connect structural members in the same plane or orthogonal planes.
2. Fillet: most commonly used to connect structural members not in the same plane
3. Slot and Plug: for member connections that need extra strength in shear



Part I: Metals in Architecture
Joints

Examples of groove welds

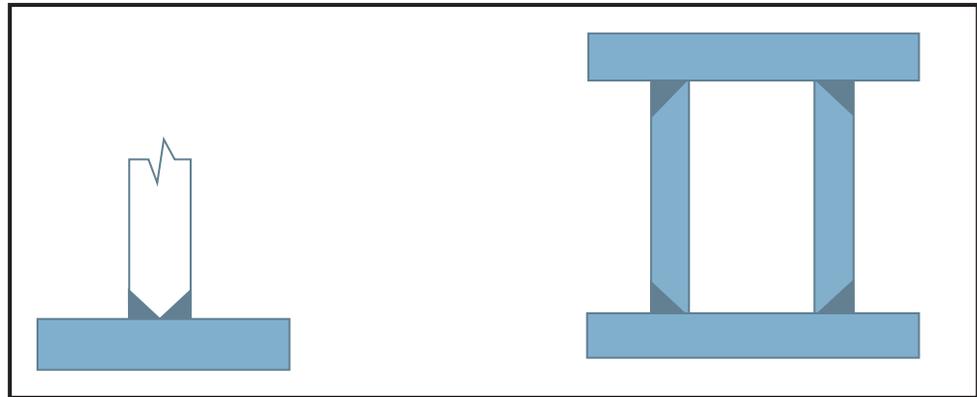
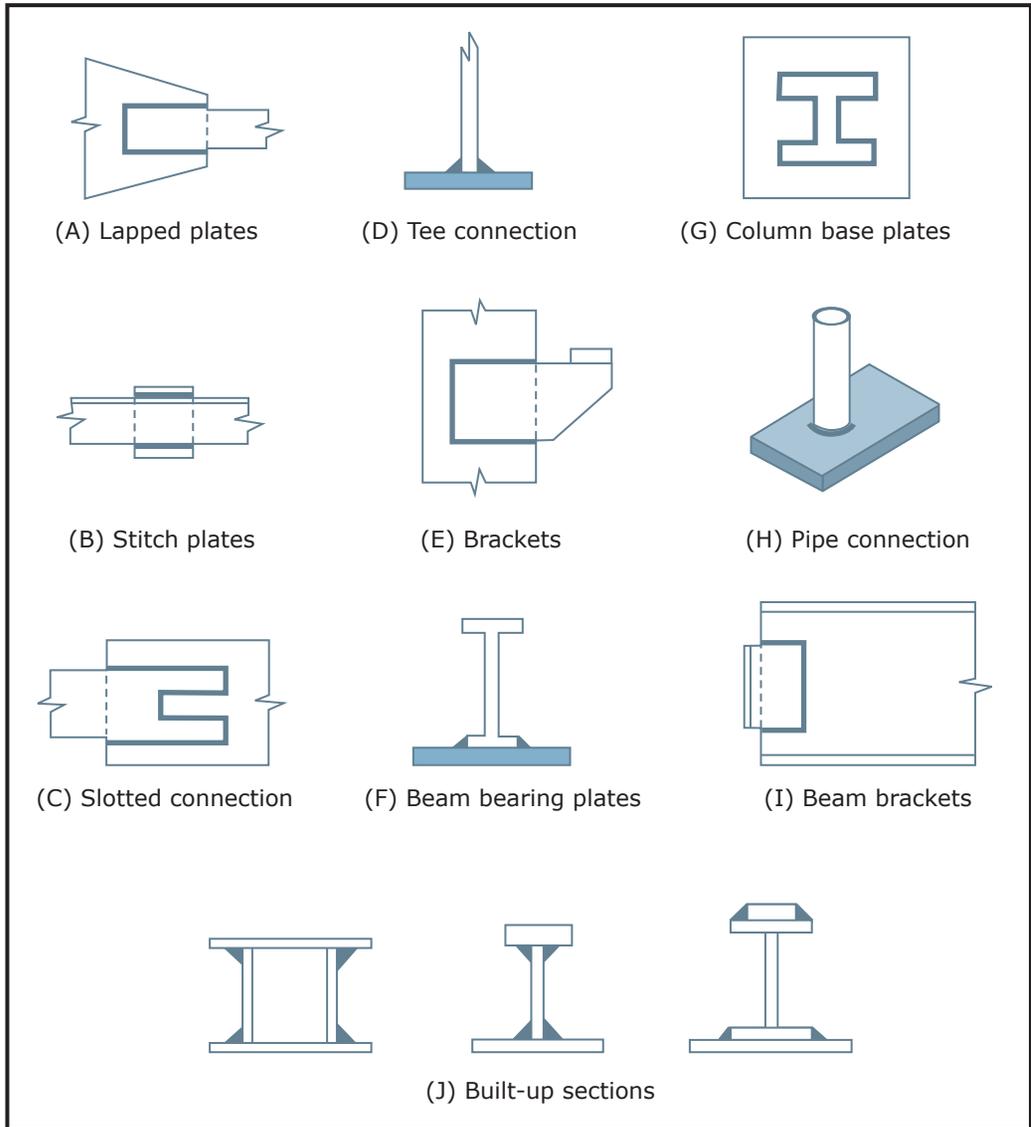


Image by MIT OCW.

Groove welds in tee joints

Part I: Metals in Architecture
Joints

Examples of fillet welds



Part I: Metals in Architecture
Joints

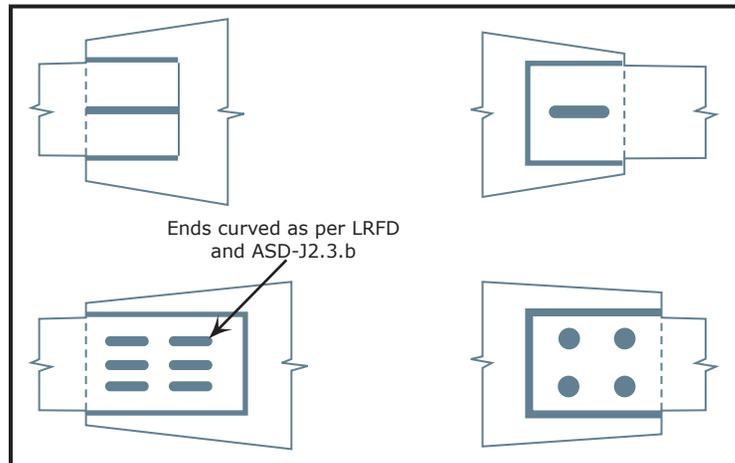
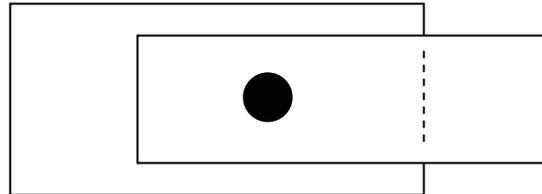
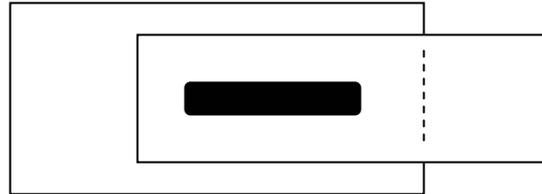


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Part I: Metals in Architecture

Joints

Standard welding symbols

| Basic Weld Symbols | | | | | | | | | |
|----------------------------|--------|-----------------|----------------|---------|--------|--|---|---------|-------------|
| Back | Fillet | Plug or Slot | Groove or Butt | | | | | | |
| | | | Square | V | Bevel | U | J | Flare V | Flare Bevel |
| | | | | | | | | | |
| Supplementary Weld Symbols | | | | | | | | | |
| Backing | Spacer | Weld All Around | Field Weld | Contour | | For other basic and supplementary weld symbols, see AWS A2.4 | | | |
| | | | | Flush | Convex | | | | |
| | | | | | | | | | |

Part I: Metals in Architecture

- Structural Morphology
 - i. Framed structures
 - ii. Shell-type structures
 - iii. Suspension-type structures
 - iv. Tube structures
towers (lattice)
bridges (plates)



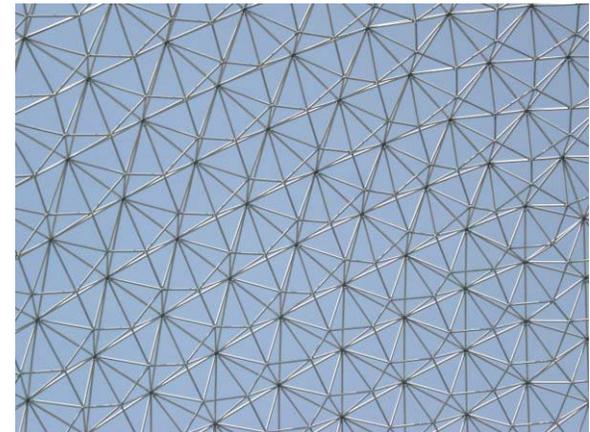
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Gewachshaus
Dusseldorf
Karl Krass



Biosphere
Montreal, Quebec
Buckminster Fuller



Images courtesy of Nicolas Janberg, photographer, and Structurae

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Millenium Bridge, London

Sir Anthony Caro and Lord Norman Foster

Image courtesy of Guido Morgenthal, photographer, and Structurae

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