DESIGN OF STEEL STRUCTURES

Syllabus

- Introduction
- Tension Members
- Connections
- Compression Members
- Flexural members (Beams)
- Members under Biaxial Bending
- Beam-column

References

1- Steel Design by Segui, Fourth Edition, 2007.
2- Structural Steel Design by Mc Cormac and Csernak, Fifth Edition, 2012.
3- AISC-LRFD Manual. Handbook and Specifications

CHAPTER ONE

INTROUDACTION

1.1 General

Structural steel is one of the basic materials used by structural engineers. Steel, as a structural material has exceptional strength, stiffness, and ductility properties. As a result of these properties, steel is readily produced in a extensive variety of structural shapes to satisfy a wide range of application needs. The wide spread use of structural steel makes it necessary for structural engineers to be well versed in its properties and uses. Following some of the required concepts that need to be understood:

- **Static's**
  - ✓ The ability to compute reactions on basic structures under given loading.
  - ✓ The ability to determine stability and determinacy
  - ✓ The ability to determine internal forces in statically determinate structures.
    - Develop shear and moment diagrams
  - ✓ The ability to solve truss problems (both 2D and 3D) by using
    - Method of joints
    - Method of sections
  - ✓ The ability to solve "machine" problems
  - ✓ The ability to compute of section properties including
    - Cross sectional area
    - Moments of Inertia for section of homogenous materials
    - Moments of Inertia for composite sections

- **Mechanics**
  - ✓ An understanding of stress and strain concepts
  - ✓ The ability to compute stress including
    - Axial stress
    - Bending stress
    - Shear stress (due to both bending and torsion)
    - Principle stress
    - Stress on arbitrary planes
  - ✓ The ability to compute the buckling capacity of columns
  - ✓ The ability to compute deflection in beams
  - ✓ The ability to compute reactions and internal forces for statically indeterminate structures.

➢ **Properties of Materials**

✓ The ability to read stress-strain diagrams to obtain critical material properties including:

- Yield stress
- Ultimate stress
- Modulus of Elasticity
- Ductility

✓ An understanding of the statistical variation of material properties.

➢ **Structural Analysis**

- An understanding of the nature of loads on structures
- The ability to compute and use influence diagrams.
- The ability to solve truss problems (forces and deflections)
- The ability to solve frame problems (forces and deflections)
- The ability to use at structural analysis software

➢ **Structural Engineering**

✓ Design of different structures (Buildings, bridges, dams, etc.):

- Satisfy needs or functions
- Support its own loads
- Support external loads

➢ **Steel Design**

✓ Selection of structural form .
✓ Determination of external loads.
✓ Calculation of stresses and deformations.
✓ Determination of size of individual members.

1.2 Advantages & Disadvantages of Steel as a Construction Material

✓ ***Advantages:***

1. High load resisting (High resistance)
2. High ductility and toughness
3. Easy control for steel structure
4. Elastic properties
5. Uniformity of properties
6. Additions to existing structure

✓ ***Disadvantages:***

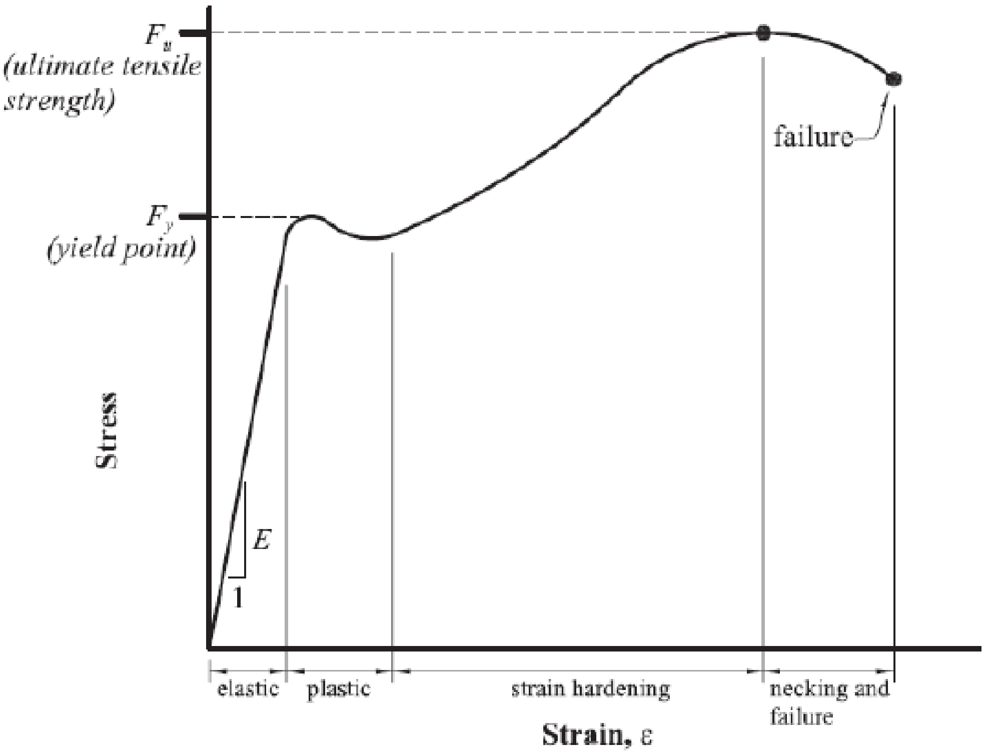
1. No ability to resist the fire (Fireproofing cost)
2. No ability to resist the corrosion (Maintenance cost)
3. High cost
4. Susceptibility to buckling, fatigue and brittle fracture

1.3 Materials

✓ ***Structural Steels***

For the purposes of the Specification for Structural Steel Buildings, four quantities are particularly important for a given steel type:

- The minimum yield stress (f_y).
- The specified minimum tensile strength (F_u).
- The modulus of elasticity (E_s).
- The shear modulus (**G**).



Stress–Strain Diagram for structural steel

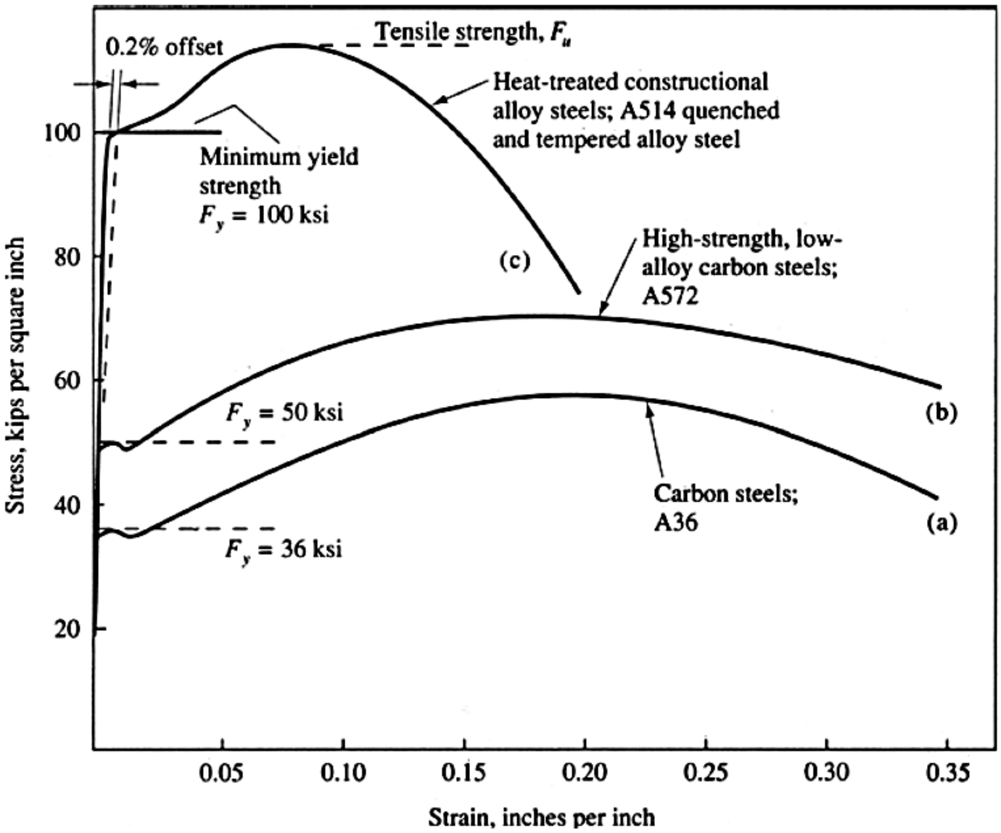
There are several types of steel as following :

- **Carbon Steels:**
  1. Low carbon **[C < (0.15%)]**.
  2. Mild carbon **[0.15% < C< 0.29%]** such as **A-36, A-53**.
  3. Medium carbon **[0.3% C < 0.59%] A-500, A-529**.
  4. High carbon **[0.6% < C < 1.7%] A-570**.

- **High-Strength Low-Alloy Steels:**
  Having f_y **40 ksi** to **70 ksi,** may include chromium, copper, manganese, nickel in addition to carbon. e.g. **A572, A618, A913,** and **A992**.

- **Alloy Steels:**

These alloy steels which are quenched and tampered to obtain f_y > **80 ksi**. They do not have a well-defined yield point, and are specified a yield point by the "offset method", example is **A852**.



Typical stress-strain curve for different types structural steel

✓ ***Bolts***

Bolting is a very common method of fastening steel members. Bolting is particularly cost effective in the field. The precursor to bolting was riveting. Riveting was a very dangerous and time consuming process. It involved heating the rivets to make them malleable then inserting them in hole and flattening the heads on both sides of the connection. The process required an intense heat source and a crew of three or more workers. In the mid 1900s, high strength bolts were introduced and quickly replaced rivets as the preferred method for connecting members together in the field because of their ease of installation and more consistent strengths. High strength is necessary since most bolts are highly tensioned in order to create large clamping forces between the connected elements. They also need lots of bearing and shear strength so as to reduce the number of fasteners needed. The types of bolts are:

- **Carbon Steel Bolts (A-307):**
  These are common non-structural fasteners with minimum tensile strength **(F_u)** of **60 ksi**.
- **High Strength Bolts (A-325):**
  These are structural fasteners (bolts) with low carbon, their ultimate tensile strength could reach **120 ksi**.

- **Quenched and Tempered Bolts (A-449):**
  These are similar to **A-307** in strength but can be produced to large diameters exceeding **1.5 inch**.

- **Heat Treated Structural Steel Bolts (A-490):**
  These are in carbon content (**up to 0.5%**) and has other alloys. They are quenched and re-heated (tempered) to **900^{o}F**. The minimum yield strength **(f_y)** for these bolts ranges from **115 ksi** upto **130 ksi**. The ultimate tensile strengths for **A490** bolts are **150 ksi**.

ASTM A325

ASTM A307

ASTM A490

Solid rivets

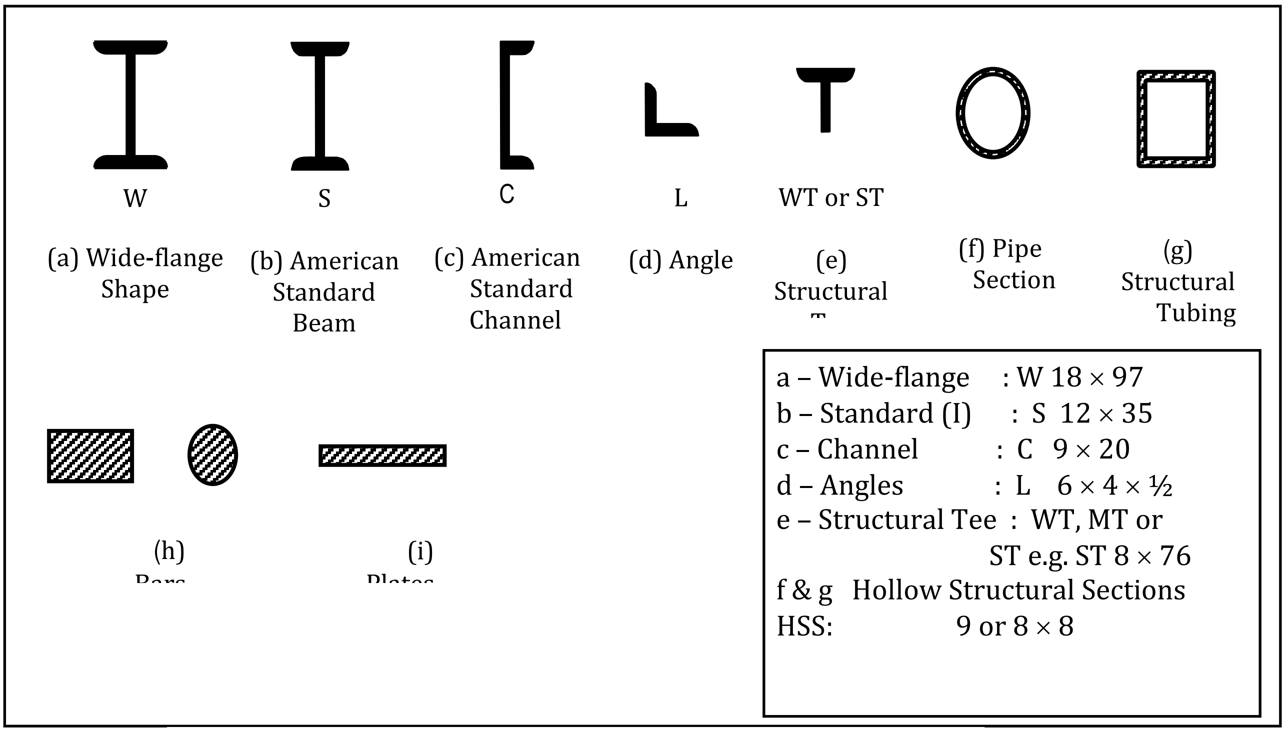
✓ ***Welding Materials:***

Welding is the process of uniting two metal parts by melting the materials at their interface so that they will bond together. A filler material is typically used to join the two parts together. The parts being joined are referred to as base metal and the filler is referred to as weld metal. Since structural welding is typically done by an electrical arc process, the weld metal is typically supplied via weld electrodes, sometimes known as welding rods.

The Shielded Metal Arc Welding (SMAW) Process Electrodes

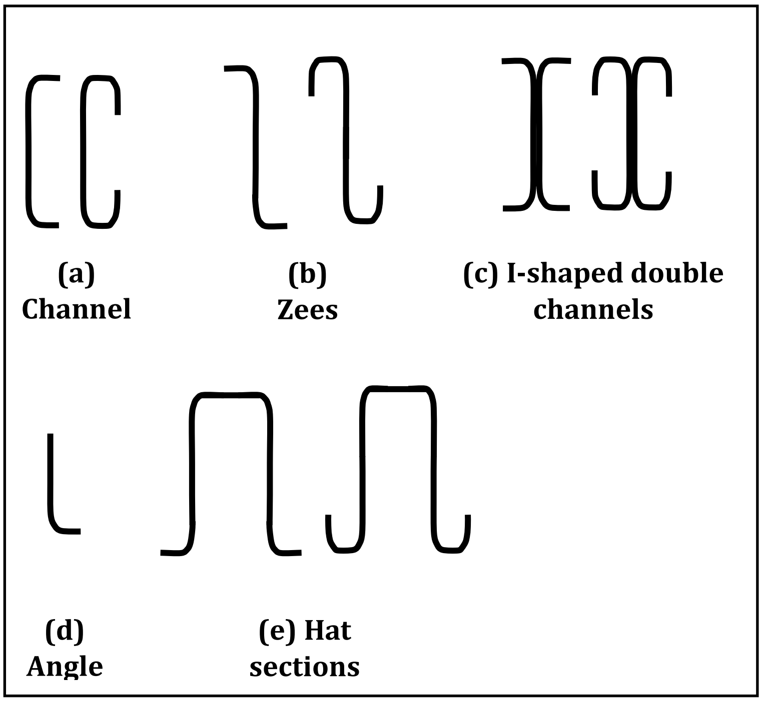
1.4 Type of Structural Steel Sections

✓ ***Hot-Rolled Sections:*** The Standard rolled shapes are shown in the figure.



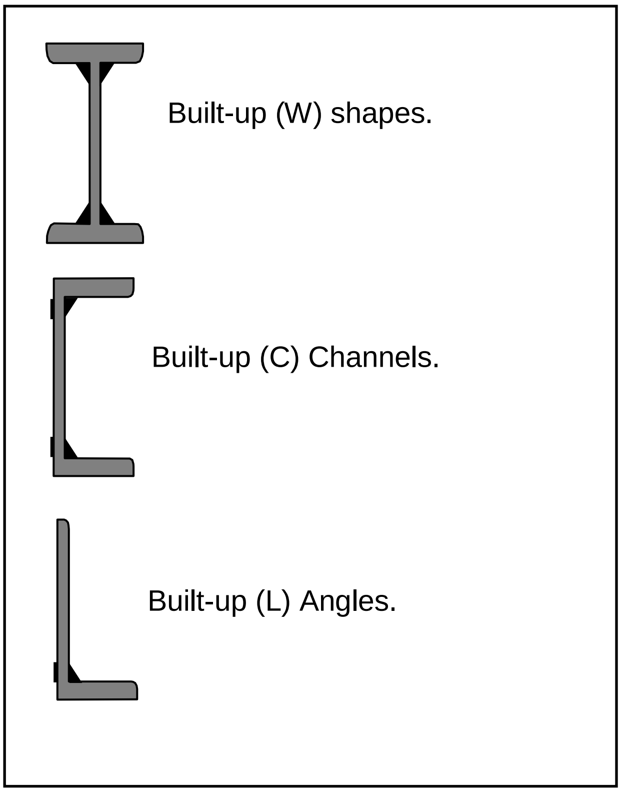
Standard rolled shapes

✓ ***Cold Formed Sections:*** as shown in the figure.



Cold Formed Sections

✓ ***Built-Up Sections:*** as shown in the figure.



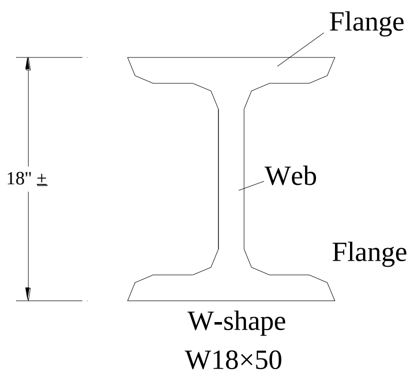
Built-up sections

1.5 Cross-Sections of Some of the more Commonly Used Hot-Rolled Shapes

✓ ***W- shape or Wide –flange Shape:*** For example :(W 18×50)
W-type shape.

18: section depth in inches .

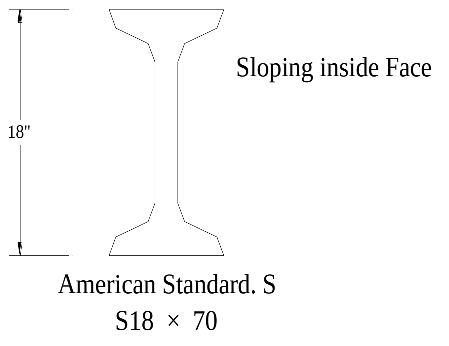
50: section weight in pounds per foot .



✓ ***S- shape or American standard S:*** For example :(S 18×70)
S-type of shape

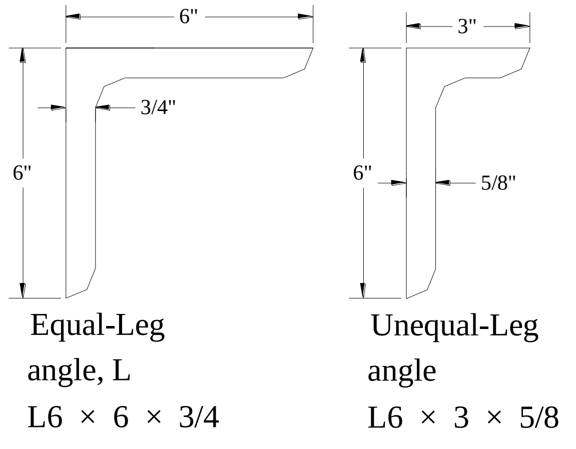
18: section depth in inches .

70: section weight in pounds per foot .

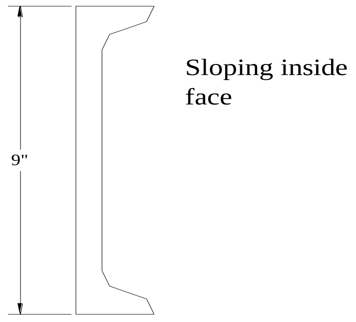


✓ ***L- shape or Angle shape:*** For example :

- (L6 ×L6 ×¾'')
- (L6 ×L3 ×5/8'')



C- shape: For example (C18 ×70)



1.6 Loads

1. Dead Loads: Also known as gravity loads, includes the weight of the structure and all fixed and permanent attachments.
2. Live Loads: Also belong to gravity loads, but their intensity and location may vary (non-permanent loads).
3. Highways / Rail Live Loads – Impact Loads
4. Snow Loads
5. Wind Loads
6. Earthquake Load
7. Thermal Loads
8. Other Loads: e.g.
   - ✓ Rain Loads
   - ✓ Hydrostatic Loads
   - ✓ Blast Loads.

**** Loads can be also classified to:***

1. Static Loads: applied slowly that the structure remains at rest during loading.
2. Dynamic Loads: applied rapidly to cause the structure to accelerate as a consequence of inertia forces.

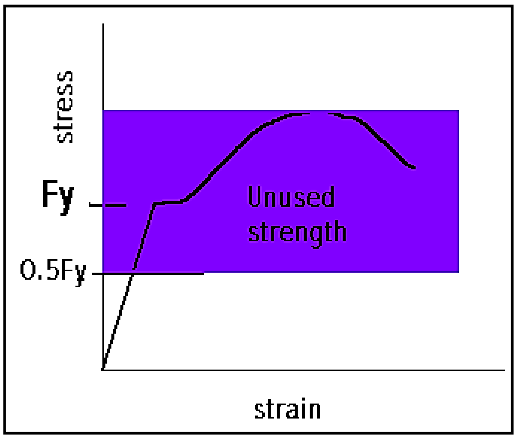
1.7 Philosophies of Design

Any design procedure require the confidence of engineer on the analysis of load effects and strength of the materials. The two distinct procedures employed by designers are **Allowable Stress Design (ASD) & Load & Resistance Factor Design (LRFD).**

- ✓ **Allowable Stress Design (ASD):**
  Safety in the design is obtained by specifying, that the effect of the loads should produce stresses that is a fraction of the yield stress f_y, say one half. This is equivalent to:

  FOS = Resistance, R/ Effect of load, Q $= f_y/0.5f_y = 2$

Since the specifications set limit on the stresses, it became allowable stress design (ASD). It is mostly reasonable where stresses are uniformly distributed over X-section (such on determinate trusses, arches, cables etc.).



Mathematical Description of ASD:

$$\frac{\phi R_n}{\gamma} \geq \sum Q_i$$

R_n = Resistance or Strength of the component being designed

Φ = Resistance Factor or Strength Reduction Factor

γ = Overload or Load Factors

Φ/γ = Factor of Safety FS

Q_i = Effect of applied loads

- ✓ **Load and Resistance Factor Design (LRFD):** To overcome the deficiencies of ASD, the LRFD method is based on **Strength of Materials.** It consider the variability not only in resistance but also in the effects of load and it provides measure of safety related to probability of failure. Safety in the design is obtained by specifying that the reduced Nominal Strength of a designed structure is less than the effect of factored loads acting on the structure

$$\phi R_n \geq n \sum \gamma Q_i$$

R_n = Resistance or Strength of the component being designed

Q_i = Effect of Applied Loads

n = Takes into account ductility, redundancy and operational imp .

Φ = Resistance Factor or Strength Reduction Factor

γ = Overload or Load Factors

Φ/γ = Factor of Safety FS

LRFD accounts for both variability in resistance and load and it achieves fairly uniform levels of safety for different limit states.

1.8 Building Codes

Buildings must be designed and constructed according to the provisions of a building code, which is a legal document 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.
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. Although the engineer is encouraged to investigate the actual loading conditions and attempt to determine realistic values, the structure must be able to support these specified minimum loads.

1.9 Design Specifications

The specifications of most interest to the structural steel designer are those..-; published by the following organizations.

1. **American Institute of Steel Construction (AISC)**: This specification provides for the design of structural steel buildings and their connections.
2. **American Association of State Highway and Transportation Officials (AASHTO):** This specification covers the design of highway bridges and related structures. It provides for all structural materials normally used in bridges, including steel, reinforced concrete and timber.
3. **American Railway Engineering and Maintenance-of-Way Association (AREMA):** The AREMA Manual of Railway Engineering covers the design of railway bridges and related Structures.
4. **American Railway Engineering Association (AREA)**.
5. **American Iron and Steel Institute (AISI):** This specification deals with cold-formed steel.