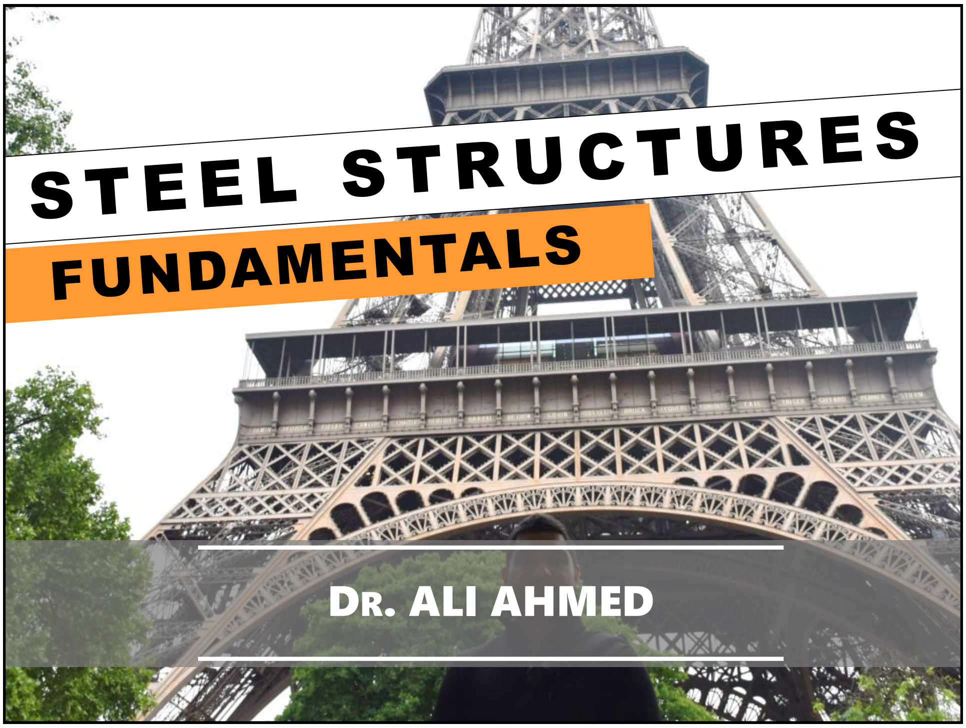
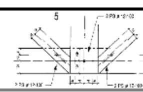


Course Introduction



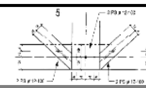
Course Code: **CE313**

Teachers: Dr. Rashid Hameed

Dr. Ali Ahmed

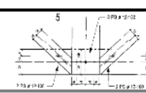
Engr. Muhammad Kashif

Course Learning Objectives



1. To describe various structural systems
2. To demonstrate the merits and demerits of steel construction
3. To study suitable values for various types of loads, specifications, design methods, limit states, various steel structural shapes, weld electrodes and built-up sections
4. To analyze and design tension members
5. To demonstrate the behavior of compression members in terms of buckling stability, overall buckling, local buckling, effective length factor, elastic buckling and inelastic buckling and to analyze and design compression members

Course Learning Objectives



6. To study the behavior of beams and to design beam
7. To design and draw plate girders, including proportioning and design of stiffeners
8. To design one complete truss including all the related members such as bracing, purlins and corrugated sheet
9. To design welded and bolted truss connections and must be able to demonstrate the salient features of all other types

THEORY PART GRADING

Class Participation: 10-20%

Class Participation includes Quizzes, Assignments, Presentation, Attendance

Mid Semester Exam: 30%

End Term/Final Exam: 50-60%

Attendance Requirement: 75%

Disclaimer: The grading criteria is subject to change but will be notified.

PRACTICAL PART GRADING

Quizzes

Class Design Calculations

Home Design Calculations

Drawing Sheets

The grading criteria (proportions and grade slabs) will be decided by the end of term

BOOKS

AISC Specifications 2010

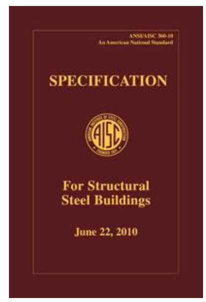
Download it free from AISC Website [link]

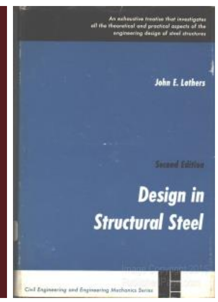
Steel Structures 3rd Edition by Dr. Zahid Ahmed Siddiqui

LRFD Steel Design Aids 4th Edition by Dr. Zahid Ahmed Siddiqui

Steel structures by John E. Lothers

Or any other book you like ☺





FUNDAMENTS OF STEEL DESIGN 7

WHAT'S COVERED?

What are steel structures

Merits & Demerits of steel structures

FUNDAMENTS OF STEEL DESIGN 8

This Week's Lecture

- Structural Engineering or Structural Designing
- Design Specifications
- Structural Design Methods
- Structural Design Procedure (Steps)
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- Design Strength

This Week's Lecture

- **Structural Engineering or Structural Designing**
- Design Specifications
- Structural Design Methods
- Structural Design Procedure (Steps)
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- Design Strength

STRUCTURAL ENGINEERING

Definition:

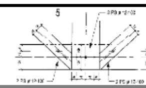
Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life.

STRUCTURAL ENGINEERING

Definition Reloaded:

It is an art of modeling materials we do not fully understand, into shapes we can not precisely analyze so as to with stand forces that we can not precisely assess, in such a way that public has no reason to suspect the extent of our ignorance.

This Week's Lecture



- Structural Engineering or Structural Designing
- Design Specifications
- Structural Design Methods
- Structural Design Procedure (Steps)
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- Design Strength

Specifications

What are specifications?

A set of design rules which include formulas that guide designer in checking strength, stiffness, proportions and other criteria that may govern the acceptability of the member.

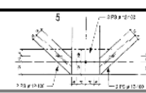
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AWS	American Welding Society
AASHTO	American Association of State Highway and Transportation Officials
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASTM	American Society for Testing and Materials
ASCE	American Society of Civil Engineers

Assignment

What are specifications for seismic design and detailing?

Write your answers on a single sheet of paper (hand written) and bring in the next class.

This Week's Lecture



- Structural Engineering or Structural Designing
- Design Specifications
- **Structural Design Methods**
- Structural Design Procedure (Steps)
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- Design Strength

STRUCTURAL DESIGN METHODS

- Basic Design Philosophy:
- Types of Loads
- Loads Combinations
- Live Load Reduction
- Factor of Safety
- Design Methods
  - Factor of Safety Comparison
- Limit State

BASIC DESIGN PHILOSOPHY

Load Effects = Maximum Internal Resistance Offered by Material

Load Effects x Factor of Safety = Maximum Internal Resistance Offered by Material

Occupancy or Use	Live Load (kg/m^2)
Private apartments, school class rooms	200
Offices	250
Fixed-seats, assembly halls, library reading rooms	300
Corridors	400
Movable seats assembly hall	500
Wholesale stores, light storage warehouses	600
Library stack rooms	750
Heavy manufacturing, heavy storage warehouses, sidewalks and driveways subject to trucking	1200

Types of Loads

- Self Weight:

  It is the part of dead load

  Let us calculate the self weight of the following concrete column with cross sectional dimensions 200mm x 200mm and height of 2 meters. Unit weight of reinforced concrete is 2400 kg/m3.

Types of Loads

- Imposed/Superimposed Loads:

  All loads other than the self weight are included under this head

- Service Loads:

  Maximum expected value of loads to act on the structure (No factor of safety)

- Factored Loads:

  Service loads increased by a factor of safety are called factored loads

Load transfer and calculations will be covered in the design part

Load Combinations

D	Dead Load
L	Live Load
L_r	Roof Live Load
W	Wind Load
S	Snow Load
E	Earthquake Load
R	Rainwater or Ice Load
H	Lateral Earth Pressure Load/Ground Water/Bulk Materials
F	Fluid Loads (Well defined pressure & Maximum Height)
T	Self-straining force

Load Combinations

Simplified Load Combinations: When S, R, H, F, E & T are taken equal to zero and Wind load is taken from previous codes.

D	Dead Load
L	Live Load
L_r	Roof Live Load
W	Wind Load
S	Snow Load
E	Earthquake Load
R	Rainwater or Ice Load
H	Lateral Earth Pressure Load/Ground Water/Bulk Materials
F	Fluid Loads (Well defined pressure & Maximum Height)
T	Self-straining force

Load Combinations

LRFD:

1. 1.4 D
2. 1.2 D + 1.6 L + 0.5 L_r
3. 1.2 D + 1.6 L_r + (L or 0.8 W)
4. 1.2 D + 1.3 W + 1.0 L + 0.5 L_r
5. 0.9 D + 1.3 W

LOAD COMBINATIONS

ASD:

1. D
2. D + L
3. D + 0.75 L + 0.75 L_r
4. D + 0.8 W
5. D + 0.6 W + 0.75 L + 0.75 L_r
6. 0.6 D + 0.8 W

LIVE LOAD REDUCTION

Live load may not be same always …

$$L = L_o\left(0.25 + \frac{4.57}{\sqrt{K_{LL}\,A_T}}\right)$$

L_o = Unreduced live load

A_T = Tributary area in m^2

K_{LL} = Live load element factor

= 4 (Interior Columns & Exterior Columns without cantilever slab)

= 3 (Edge columns with cantilever slabs)

= 2 (Corner columns with cantilever slabs & edge beams without cantilever slabs)

= 1 (All other members)

Factor of Safety

To bring a structure from State of Collapse to Usable State.

Reasons for use:

1. Uncertainties in applied forces/loads.
2. Uncertainties in material strength.
3. Limit deflection in service load conditions.
4. Cover poor workmanship.
5. Cover unexpected behavior.
6. Cover natural disasters.
7. Extra/Reverse stresses produced during fabrication/erection.
8. Cover residual stresses.

Various Design Methods

ASD

Allowable stress design method

LRFD

Load and resistance factor design method

Plastic Design

Allowable Stress Design (ASD)

Factor of safety is applied on the material strength:

Load Effects = Material Resistive Forces/F.O.S

- Conservative design technique (relatively expensive)
- Material remains usually in elastic range
- Factor of safety is called "Safety Factor" (Ω)
- Safety factor accounts for deviations of actual load from nominal loads

Load and Resistance Factor Design (LRFD)

Also Called: Ultimate Design, Limit State Design

Major F... Factor"

Minor F...

Limit st... s

intende...

Load ar... odes

are also considered.

Plastic Design Method

It is similar to LRFD

Analysis for loads is also performed considering the collapse mechanism of the structure.

- Full material strength is utilized
- Inelastic behavior of material is considered

Factor of Safety Comparison

F.O.S in ASD ≈ 1.67

F.O.S in LRFD Live Load ≈ 1.778 (1.6/0.9)

F.O.S in LRFD Live Load ≈ 1.333 (1.2/0.9)

Average F.O.S in LRFD ≈ 1.63 (2 Live 1 Dead Ratio)

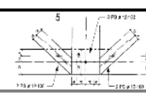
Limit State

Limit after which structure can not fulfil its intended use

Actual collapse is not necessary

Strength or Serviceability criteria

This Week's Lecture



- Structural Engineering or Structural Designing
- Design Specifications
- Structural Design Methods
- **Structural Design Procedure (Steps)**
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- Design Strength

Structural Design Procedure

- Objectives of Structural Designer
- Structural Design Procedure
- General Design Flowchart

Objectives of Structural Designer

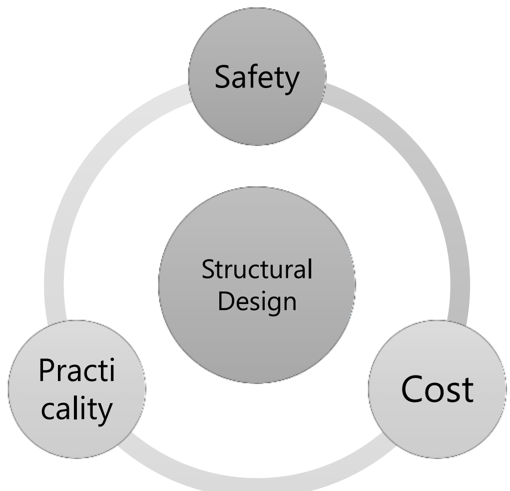
Design is a process by which an optimum solution is obtained:

Keep the following to minimum:

- Cost
- Weight
- Construction time
- Labor

Maximum efficiency of operation !

Objectives of Structural Designer



Objectives of Structural Designer

1. The structure shall **safely** support the applied loads
2. The **deflections & vibrations** should not be so excessive as to frighten the occupants or cause cracking
3. The **construction operation & cost** shall be kept to the minimum level without compromising the strength
4. The work should fit the available fabrication techniques available, available material & general construction practices.

Structural Design Procedure

Planning

Layout

Preliminary Structural Configuration

Loading

Trial Sections

Structural Analysis

Evaluation

Structural Design Procedure

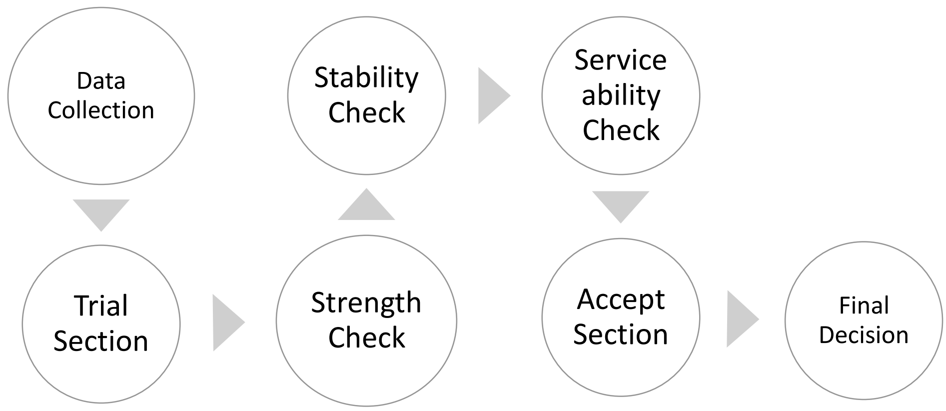
Redesign

Design of Assembly and Connections

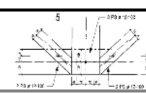
Final Decision

Preparation of Design Documents

General Design Flowchart



This Week's Lecture



- Structural Engineering or Structural Designing
- Design Specifications
- Structural Design Methods
- Structural Design Procedure (Steps)
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- Design Strength

Structural Steel

- Types of Structural Steel
- Weld & Electrode & Filler Materials
- Hot Rolled Steel Sections
- Built-up Sections
- Cold Formed Steel Sections

Types of Structural Steel

1. Low carbon steel: C< 0.15%
2. Mild carbon steel: C = 0.15 – 0.29%
3. Medium carbon steel: C = 0.3 – 0.59%
4. High carbon steel: C = 0.6 – 1.7%

E-value of steel = 185 Gpa to 230 Gpa (Average 200 Gpa)

Unit Weight = 7.85 gm/cm^3 = 7850 kg/m^3 = 77 kN/m^3

Weld Electrode & Filler Material

These are classified as: E XX

E stands for electrode

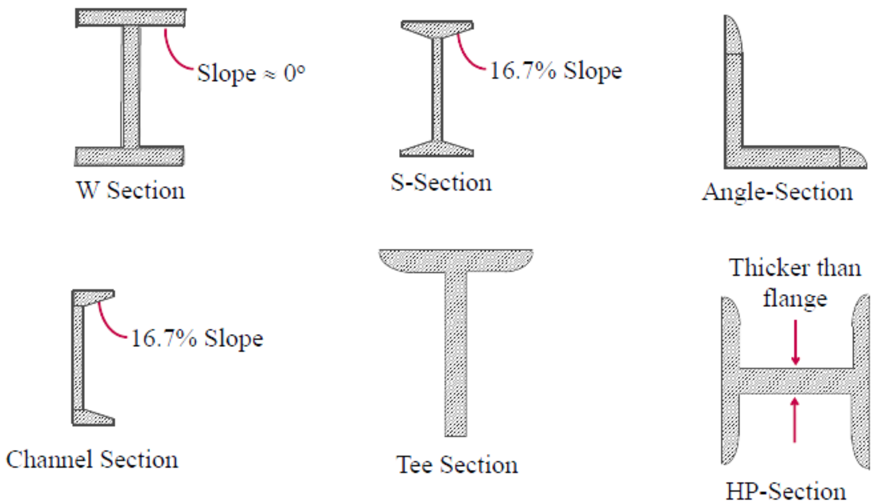
XX are digits indicating the ultimate tensile strength in ksi

E425, E495, E550, E690, E 760 are the SI equivalents of E60, E70, E80, E100, E110 respectively

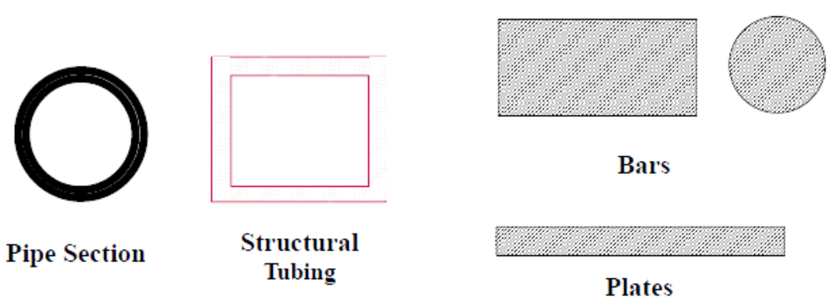
Hot Rolled Structural Shapes

Hot Rolled Structural Shapes

Hot Rolled Structural Shapes



Hot Rolled Structural Shapes



Hot Rolled Structural Shapes

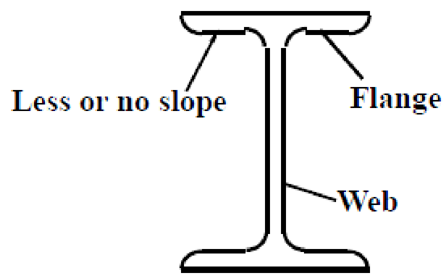
W Shapes: I shape with wide flange.

Doubly symmetric section

Width/Depth = 0.3 – 1.0

Web & Flange

Slope of Web



W410x60 means a W section with nominal depth of 410 mm and weight of 60 kgf/m.

Hot Rolled Structural Shapes

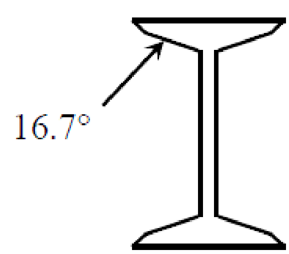
S Shapes: W shape with sloppy flange (avg. 16.7°).

Doubly symmetric section

Width/Depth = 0.25 – 0.85

Web & Flange

Slope of Web



S510x112 means an S section with nominal depth of 510 mm and weight of 112 kgf/m.

Hot Rolled Structural Shapes

M Shapes: Miscellaneous I Shapes

These are relatively light weight & used for smaller spans

M 310 x 17.6 means an M shape with nominal depth of 310mm and weight of 17.6 kgf/m

Hot Rolled Structural Shapes

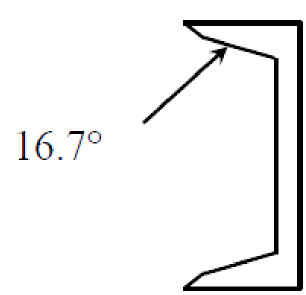
C Shapes: There shape is like channels

Doubly symmetric section

Width/Depth = 0.25 – 0.85

Web & Flange

Slope of Web



C150x19.3 means a C section with nominal depth of 150 mm and weight of 19.3 kgf/m.

Hot Rolled Structural Shapes

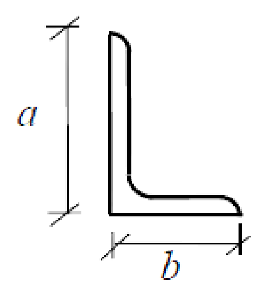
MC Shapes: Channels not classified as C Shapes

They were also called shipbuilding or Miscellaneous channels

Hot Rolled Structural Shapes

L Shapes: There shape is like angles

Equal angle sections/Unequal angle Sections



Legs or arms

Double Angle Sections

L89 x 76 x 12.7 means an angle section with leg dimensions as 89mm and 76mm and leg thickness is 12.7mm.

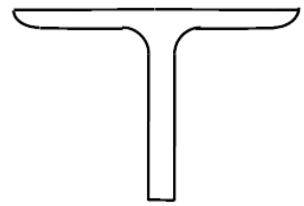
Is this equal or unequal angle section?

Hot Rolled Structural Shapes

T Shapes: These are called structural tees

Obtained by splitting W, S or M shapes

(WT, ST or MT)



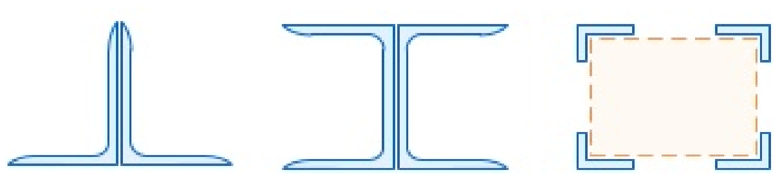
WT205 x 30 is a structural tee with nominal depth of 205mm and weight of 30kgf/m.

It is obtained by splitting W410 x 60 section

Built-up Sections

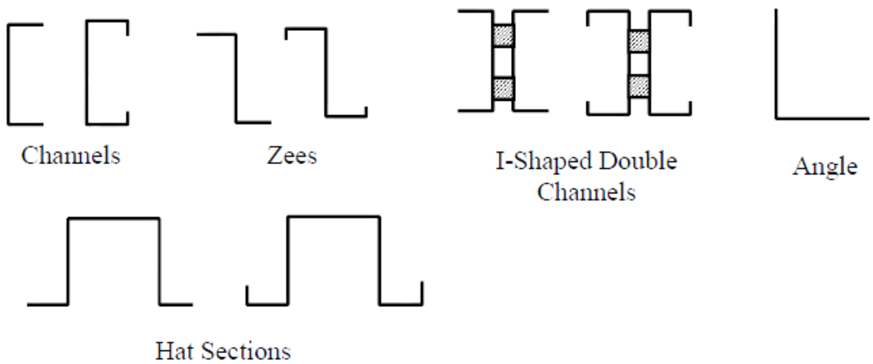
Sections formed by combining two or more standard hot rolled sections.

These are joined by either direct welding or by using Stay plates or Lacing

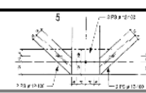


Cold Formed Shapes

These sections are derived from thin high strength steel alloy plates under normal temperature.



This Week's Lecture



- Structural Engineering or Structural Designing
- Design Specifications
- Structural Design Methods
- Structural Design Procedure (Steps)
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- Design Strength

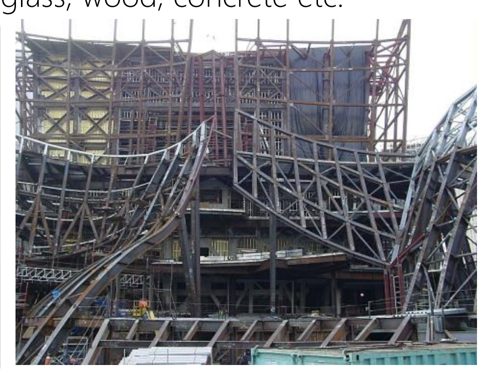
Miscellaneous Topics

- Cladding/Facade
- Von-Mises Yield Criteria
- Design Drawings

Cladding/Facade

The exterior covering on structural components or Visible external finish. (Façade is the outlook, cladding is the sheets etc. used but similar concept).

Can be made of steel, aluminum, glass, wood, concrete etc.



Von-Mises Yield Criterion

Named after German-American applied mathematician Richard von Mises.

For a ductile material, the inelastic action at any point in a body under any combination of stresses begins only when the strain energy of distortion per unit volume absorbed at the point is equal to the strain energy of distortion saved per unit volume at any point in a simple tensile bar stressed to the elastic limit under a state of uniaxial stress.

Von-Mises Yield Criterion

A material is safe as long as the maximum value of distortion energy per unit volume in that material remains smaller than the distortion energy per unit volume required to cause yield in a tensile test specified of the same material.

Design Drawings

Drawings showing what to construct.

Sufficiently large scale

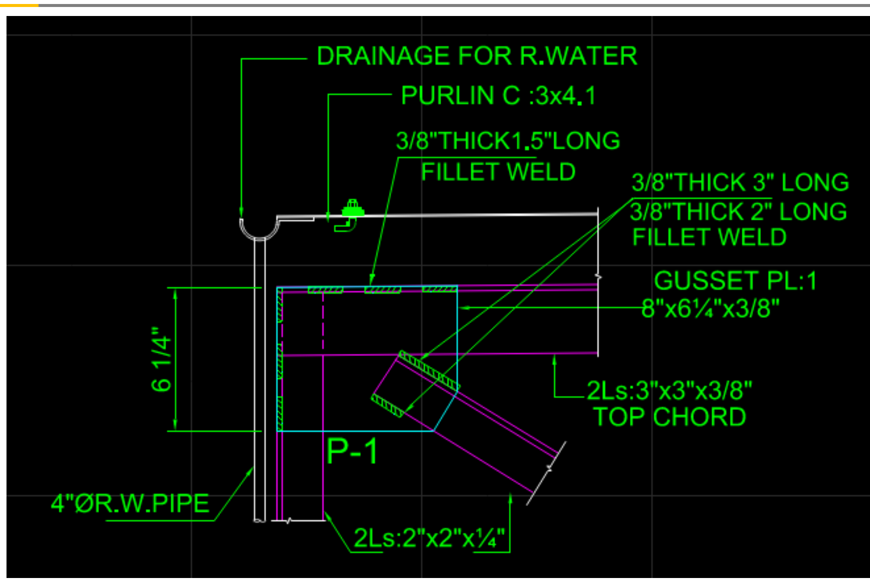
Complete dimensions

Connections.

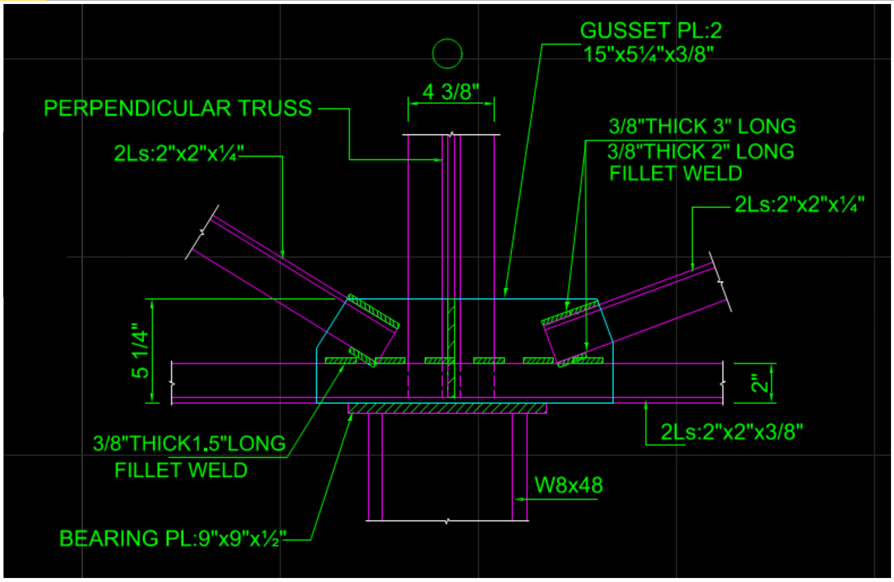
Required camber

...etc.

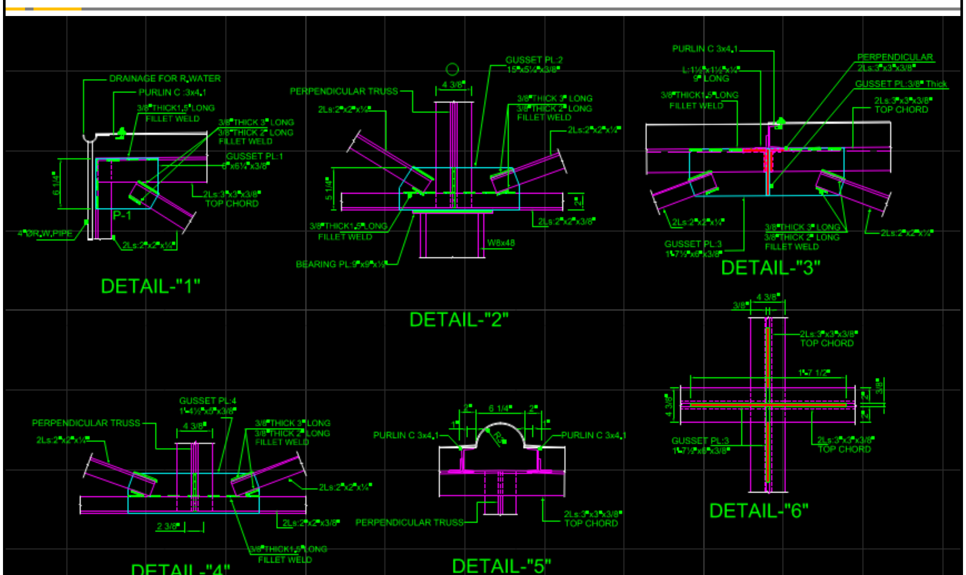
Design Drawings Samples



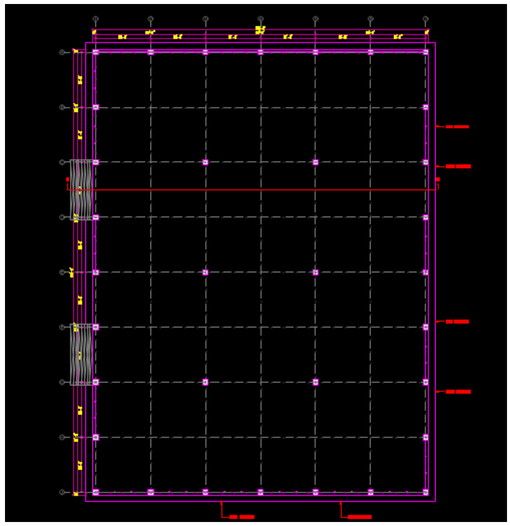
Design Drawings Samples



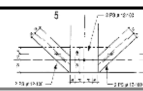
Design Drawings Samples



Design Drawings Samples



This Week's Lecture



- Structural Engineering or Structural Designing
- Design Specifications
- Structural Design Methods
- Structural Design Procedure (Steps)
- Types of Structural Steel Members/Shapes
- Miscellaneous Topics
- **Design Strength**

DESIGN STRENGTH

Tension Member Strength:

Fy Yield Strength of Steel

Fu Min Ultimate Strength of Steel

$$\Phi_t F_y A_g \quad \text{or} \quad \Phi_t F_u A_e$$

Φ_t Resistance Factor (0.9 for yielding and 0.75 for fracture)

Ag Gross Area of Cross Section

Ae Net Effective Area of Cross Section

DESIGN STRENGTH

Compression Member Strength:

Fcr Critical Stress (yielding)

$$\Phi_c F_{cr} A_g$$

Φ_C Resistance Factor in Bending equal of 0.9.

Ag Total/Gross Area of Cross Section

Design Strength

Bending Strength:

Fmax Maximum bending stress (local and overall stability)

$$\Phi_b F_{max} Z$$

Φ_b Resistance Factor in Bending equal of 0.9.

Z Plastic Section Modulus

Design Strength

Shear Strength:

τ_y Shear Yield Stress (0.6 Fy)

τu Ultimate Shear Stress (0.6 Fu)

$$\Phi_v \tau_y A_n \quad \text{or} \quad \Phi_v \tau_u A_g$$

Φ_v Resistance Factor in shear (0.9 for shear yielding and 0.75 for shear fracture)

An Net/Effective Area of Cross Section

Ag Total/Gross Area of Cross Section

DESIGN STRENGTH

Bearing Strength:

$$\Phi_{bp}(1.2F_u)L_c t \;\; \& \;\; \Phi_{bp}(2.4F_u)A_{bp}$$

Area under bearing pressure

Φ_{bp} Resistance Factor in Bearing (1.0)

Lc Clear Distance in the direction of force, edge of hole to edge of adjacent hole.

2.4Fu Maximum Available bearing stress

CAPACITY ANALYSIS VS DESIGN OF STR.

Q.1: Concrete Cube (6"x6"x6") – Strength = 10 N/mm^2

How much load can it take?

Q.1: Expected Load = 30 N – Strength = 10 N/mm^2

How much concrete area do we need?

Reading Assignment

Advantages and Disadvantages of ASD Method

Advantages and Disadvantages of LRFD Method

LRFD & ASD Load Combinations

Note: Simplified load combinations are already covered and most widely used

Some more Cold Formed Shapes