Steel Column Design

Steel Connections

- Capacity Analysis of Steel Columns
- Design of Steel Columns
- Connection Types
- Connection Analysis

Design of Steel Columns with AISC Strength Tables

Data:
- Column – length
- Support conditions
- Material properties – $F_y$
- Applied design load - $P_u$

Required:
- Column Size

1. Enter table with height, $KL = L_c$
2. Read allowable load for each section to find the smallest adequate size.
3. Tables assume weak axis buckling. If the strong axis controls the length must be divided by the ratio $r/\rho_y$
4. Values stop in table (black line) at slenderness limit, $KL/r = 200$
Design Example 1

Free standing column
Third floor studio space
Supports roof load = 20 psf DL + 30 psf SL
Pu = 1.2(20) + 1.6(30) = 72 psf
ØPn = 1600 (72) = 115200 lbs = 115.2 k
Steel Connections

Methods of Connections

Bolted

Welded
Steel Connections
Shop vs. Field Connections

Shop Connections:

- Welding preferably performed in the shop as opposed to the field due to controlled environment
- Members can be positioned for more economical welding (welding upside down is difficult)
- Welding may have an equipment advantage in the shop
- Shops use both welding and bolting

Field Connections:

- Bolting easily performed in the field and generally preferred when possible
- Bolting provides a method to erect the members and release the crane hook quickly

Steel Connections

Failure modes – Limit States

- Fasteners (bolts or welds)
  - shear
  - tension
  - bearing
- Connecting elements (plates or tees)
  - tension
  - block shear
  - tear out
- Supporting or supported members
Tension Connection: Example Angle – Bolts – Gusset Plate

Load Path

\[ \text{Angle} \rightarrow \text{Bolts} \rightarrow \text{Gusset plate} \rightarrow \text{Weld} \rightarrow \text{Support} \]

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Tension Connection – Angle Failure example

1. Tensile Yielding
2. Tensile Rupture
3. Block Shear
4. Bearing and Tearout at Bolt Holes
5. Bolt Shear
6. Bearing and Tearout at Bolt Holes
7. Block Shear
8. Tensile Rupture
9. Tensile Yielding
10. Tension Rupture in Weld
Tension Connection – Angle Failure

1. Tensile Yielding
   - at gross section \( R_n = F_y A_g \) \( \varphi = 0.9 \)
   - \( F_y = \) minimum yield stress, ksi
   - \( A_g = \) gross area of member, in\(^2\)

2. Tensile Rupture
   - Flat Bar
     - \( R_n = F_u A_e \) \( \varphi = 0.75 \)
     - \( F_u = \) minimum tensile strength, ksi
     - \( A_e = \) effective net area, in\(^2\)
   - Section (not flat)
     - \( A_e = A_n U \)
     - \( A_n = \) net area
     - \( U = \) shear lag factor (Table D3.1)
Tension Connection
Angle Failure

3. Block Shear

- \( R_n = 0.60 \, F_u \, Anv + U_{bs} \, F_u \, Ant \) \( \varphi = 0.75 \)
- \( Anv = \) net area in shear
- \( Ant = \) net area in tension
- \( U_{bs} = 1.0 \) (uniform stress) \( U_{bs} = 0.5 \) (non-uniform stress)
Tension Connection

Block Shear Example

Tension Connection - Bolt Failure

4. **Bearing and Tearout at Bolt Holes**
   - **Bearing**: deformation of material at the loaded edge of the bolt holes
   - **Tearout**: block shear rupture between bolts or at the edge due to bearing
Tension Connection - Bolt Failure

4. Bearing and Tearout at Bolt Holes
   - **Bearing**: deformation of material at the loaded edge of the bolt holes
   - **Tearout**: block shear rupture between bolts or at the edge due to bearing

![Image showing tearout and bearing]

5. Bolt Shear
   - Shear failure of the bolts along the shear plane (interface)

![Image showing bolt shear]
Tension Connection - Bolt Failure

5. Bolt Shear
   - Shear failure of the bolts along the shear plane (interface)
   - Single shear vs. double shear
   - $R_n = F_n A_b \quad \varphi = 0.75$
   - $F_n = $ nominal shear stress, $F_{nv}$ (or tensile stress $F_{nt}$)
   - $A_b = $ nominal bolt area (threaded or unthreaded)

![Shear plane diagram](image)

2 plies of material
(1 shear plane = Single Shear)
3 plies of material
(2 shear planes = Double Shear)

Tension Connection – Gusset Plate Failure

6. Bearing and Tearout at Bolt Holes

![Bearing and tearout diagram](image)
Tension Connection – Gusset Plate Failure

7. Block Shear

Tension Connection – Gusset Plate Failure

8. Tensile Rupture
9. Tensile Yielding

Tension Connection – Gusset Plate Failure

10. Tension Rupture in Weld
   • Shear failure on the effective throat of the weld
Steel Frame Construction

Messe Leipzig Glass Hall - Ian Ritchie Architects

Steel Frame Construction

Messe Leipzig Glass Hall - Ian Ritchie Architects
Branching Columns (tree columns)
Frei Otto

bridge in Pragsattel, Stuttgart, 1992
Schlaich, Bergermann und Partner
Branching Columns (tree columns)

Stuttgart Airport Terminal, Gerkan, Marg und Partner, Schlaich, Bergermann und Partner