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### Chapter 5 – Bearing Plates

- The design procedure for **column base plates** is similar to that for **beam bearing plates**, and for that reason, we consider them together.
- In addition, the determination of **the thickness of a column base plate** requires consideration of **flexure**.
- In both cases, the function of the plate is to **distribute a concentrated load to the supporting material**.

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### Chapter 5 – Bearing Plates

- Two types of beam bearing plates are considered:
  1. transmits the beam reaction to a support such as a concrete wall and
  2. transmits a load to the top flange of a beam.

- Although many beams are connected to columns or other beams, the type of support shown here is occasionally used, particularly at **bridge abutments**.

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### Chapter 5 – Bearing Plates

- Two types of beam bearing plates are considered:
  1. transmits the beam reaction to a support such as a concrete wall and
  2. transmits a load to the top flange of a beam.

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### Chapter 5 – Bearing Plates

- The design of the **bearing plate** consists of three steps.
  1. Determine the dimension  $l_b$  so that **web yielding** and **web crippling** are prevented.
  2. Determine dimension  $B$  so that area  $B \times l_b$  is sufficient to prevent the supporting material (usually concrete) from being crushed in bearing.
  3. Determine the thickness  $t$  so that the plate has sufficient bending strength.
- Web yielding, web crippling, and concrete bearing strength are addressed by **AISC in Chapter J, "Design of Connections."**

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### Chapter 5 – Web Yielding

- **Web yielding** is the compressive crushing of a beam web.
- This force could be an **end reaction** from a support of the column, or it could be a load delivered to the **top flange by a column or another beam**.

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### Chapter 5 – Web Yielding

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### Chapter 5 – Web Yielding

- Yielding occurs when the **compressive stress** on a horizontal section through the web reaches the **yield point**.
- When the load is transmitted through a plate, web yielding is assumed to take place on the nearest section of width  $t_w$ .
- In a rolled shape, this section will be at the toe of the fillet, a distance  $k$  from the outside face of the flange (this dimension is tabulated in the **dimensions and properties tables** in the Manual).

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### Chapter 5 – Web Yielding

- If the load is assumed to distribute itself at a slope of 1:2.5, the area **at the support** subject to yielding is:  $t_w(2.5k + \ell_b)$ .

- Multiplying this area by the yield stress gives the nominal strength for **web yielding** at the support:

$$R_n = F_{yw} t_w (2.5k + \ell_b) \quad \text{AISC Equation J10-3}$$

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### Chapter 5 – Web Yielding

- If the load is assumed to distribute itself at a slope of 1:2.5, the area **at the support** subject to yielding is:  $t_w(2.5k + \ell_b)$ .

- The bearing length  $\ell_b$  at the **support** should not be less than  $k$ , and  $F_{yw}$  is the specified minimum yield stress of the web material in *Ksi*.

$$R_n = F_{yw} t_w (2.5k + \ell_b) \quad \text{AISC Equation J10-3}$$

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### Chapter 5 – Web Yielding

- At the **interior load**, the length of the section subject to yielding is:  $2(2.5k) + \ell_b = 5k + \ell_b$

$$R_n = F_{yw} t_w (5k + \ell_b) \quad \text{AISC Equation J10-2}$$

- For **LRFD**, the design strength is:  $\phi R_n$  where  $\phi = 1.0$
- For **ASD**, the allowable strength is:  $R_n / \Omega$  where  $\Omega = 1.50$

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### Chapter 5 – Web Local Crippling

- **Web local crippling** is the buckling of the web caused by the compressive force delivered through the flange.
- For an **interior load**, the nominal strength for web local crippling is:

$$R_n = 0.80 t_w^2 \left[ 1 + 3 \left( \frac{\ell_b}{d} \right) \left( \frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{E F_{yw} t_f}{t_w}} (Q_f) \quad \text{AISC Equation J10-4}$$

where  $d$  is the total column depth, and  $Q_f$  is 1.0 for **W** and **C** shapes, box sections, and for **HSS** (connecting surface) in tension, or as given in **Section K1.3** for all other HSS conditions

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### Chapter 5 – Web Local Crippling

- For a **load at or near the support** (no greater than half the beam depth from the end), the nominal strength is:

$$R_n = 0.40t_w^2 \left[ 1 + 3 \left( \frac{\ell_b}{d} \right) \left( \frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{E F_{yw} t_f}{t_w}} (Q_f) \text{ for } \frac{\ell_b}{d} \leq 0.2$$

*AISC Equation J10-5a*

$$R_n = 0.40t_w^2 \left[ 1 + \left( \frac{4\ell_b}{d} - 0.2 \right) \left( \frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{E F_{yw} t_f}{t_w}} (Q_f) \text{ for } \frac{\ell_b}{d} > 0.2$$

*AISC Equation J10-5b*

- For **LRFD**,  $\phi = 0.75$ . The safety factor is  $\Omega = 2.00$

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### Chapter 5 – Concrete Bearing

- The material used for a beam support can be concrete, brick, or some other material, **but it usually will be concrete.**
- This material must resist the bearing load applied by the steel plate.
- The nominal bearing strength specified in **AISC J8** is the same as that given in the **American Concrete Institute's Building Code** (ACI, 2014).

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### Chapter 5 – Concrete Bearing

- If the plate covers the full area of the support, the nominal strength is:

$$P_p = 0.85 f'_c A_1 \quad \text{AISC Equation J8-1}$$

- If the plate does not cover the full area of the support,

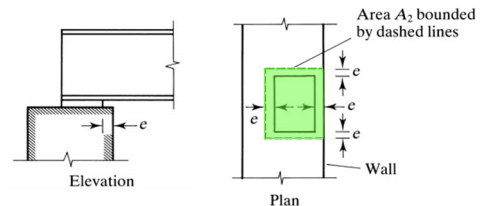
$$P_p = 0.85 f'_c A_1 \sqrt{\frac{A_2}{A_1}} \leq 1.7 f'_c A_1 \quad \text{AISC Equation J8-2}$$

where  $f'_c$  is the 28-day compressive strength of concrete, *ksi*,  
 $A_1$  is the bearing area, *in*<sup>2</sup>, and  
 $A_2$  is the full area of the support, *in*<sup>2</sup>.

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### Chapter 5 – Concrete Bearing

- If area  $A_2$  is not concentric with  $A_1$ , then  $A_2$  should be taken as the largest concentric area that is geometrically similar to  $A_1$ , as illustrated below.



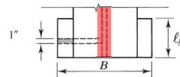
- For **LRFD**, the design bearing strength is  $\phi P_p$ , where  $\phi_c = 0.65$ .
- For **ASD**, the allowable bearing strength is  $P_p / \Omega_c$  where  $\Omega_c = 2.31$ .

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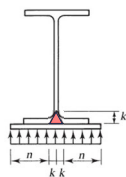
### Chapter 5 – Plate Thickness

- Once the **length and width of the plate** have been determined, the average bearing pressure is treated as a **uniform load on the bottom of the plate.**

- It is assumed to be supported at the top over a central width of  $2k$  and length  $\ell_b$ , as shown.



- The plate is then considered to **bend about an axis parallel to the beam span.**

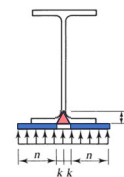
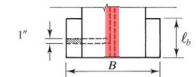


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### Chapter 5 – Plate Thickness

- Once the **length and width of the plate** have been determined, the average bearing pressure is treated as a **uniform load on the bottom of the plate.**

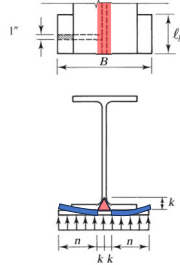
- The plate is treated as a cantilever of length  $n = (B-2k)/2$  and a width of  $\ell_b$ .



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### Chapter 5 – Plate Thickness

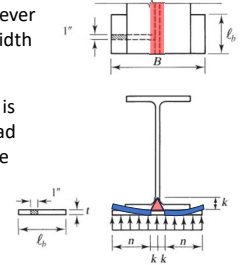
- Once the **length and width of the plate** have been determined, the average bearing pressure is treated as a **uniform load on the bottom of the plate**.
- The plate is treated as a cantilever of length  $n = (B-2k)/2$  and a width of  $\ell_b$ .



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### Chapter 5 – Plate Thickness

- Once the **length and width of the plate** have been determined, the average bearing pressure is treated as a **uniform load on the bottom of the plate**.
- The plate is treated as a cantilever of length  $n = (B-2k)/2$  and a width of  $\ell_b$ .
- For convenience, a **1-in width** is considered, with a uniform load ( $lb/in$ ) numerically equal to the bearing pressure ( $lb/in$ ).

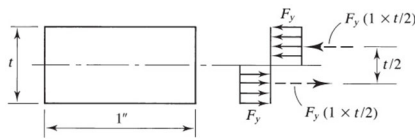


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### Chapter 5 – Plate Thickness

- Once the **length and width of the plate** have been determined, the average bearing pressure is treated as a **uniform load on the bottom of the plate**.
- The maximum bending moment in the plate is:

$$M_p = F_y \left( (1in) \frac{t}{2} \right) \left( \frac{t}{2} \right) = F_y \left( \frac{t^2}{4} \right)$$



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### Chapter 5 – Plate Thickness

- For **LRFD**: Since the design strength must at least equal the factored-load moment,

$$\phi_b M_p \geq M_u \quad \therefore 0.90 F_y \left( \frac{t^2}{4} \right) \geq \left( \frac{R_u}{B \ell_b} \right) (n) \left( \frac{n}{2} \right)$$

where  $R_u$  is the factored-load beam reaction.

$$t \geq \sqrt{\frac{2R_u n^2}{0.90 F_y B \ell_b}} \quad t \geq \sqrt{\frac{2.2 R_u n^2}{F_y B \ell_b}}$$

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### Chapter 5 – Plate Thickness

- For **ASD**: Since the allowable strength must at least equal the applied moment,

$$\frac{M_p}{\Omega_b} \geq M_o \quad \therefore \frac{F_y t^2}{4(1.67)} \geq \left( \frac{R_o}{B \ell_b} \right) (n) \left( \frac{n}{2} \right)$$

where  $R_o$  is the service-load beam reaction.

$$t \geq \sqrt{\frac{3.34 R_o n^2}{F_y B \ell_b}}$$

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### Chapter 5 – Plate Thickness

- Example 5.18:** Design a bearing plate to distribute the reaction of a **W18 x 71** with a span length of **18 ft**, center-to-center of supports.

The total service load, including the beam weight, is **10 k/ft**, with equal parts dead and live load. The beam is to be supported on reinforced concrete walls with  $f'_c = 4,000 \text{ psi}$ . For the beam,  $F_y = 50 \text{ ksi}$ , and  $F_y = 36 \text{ ksi}$  for the plate.

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### Chapter 5 – Plate Thickness

➤ **Example 5.18: LRFD Solution** - The factored load is:

$$w_L = 5k/ft \quad w_D = 5k/ft$$

$$w_u = 1.2(5k/ft) + 1.6(5k/ft) = 14k/ft$$

The reaction is:

$$R_u = \frac{w_u L}{2} = \frac{(14k/ft)(18ft)}{2} = 126k$$

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### Chapter 5 – Plate Thickness

➤ **Example 5.18: LRFD Solution**

Determine the  $\ell_b$  required to prevent **web yielding**.  
From **AISC Equation J10-3**, the nominal strength for this limit state is:

$$R_n = F_{yw} t_w (2.5k + \ell_b)$$

For  $\phi R_n \geq R_u$      $\phi R_n = \phi F_{yw} t_w (2.5k + \ell_b) \geq 126k$

From Table 1-1 (1-20):  $t_w = 0.495in$      $k = 1.21in$

$$\phi R_n = 1.0(50ksi)(0.495in)(2.5(1.21) + \ell_b) \geq 126k$$

Solving for  $\ell_b \geq 2.07in$

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### Chapter 5 – Plate Thickness

➤ **Example 5.18:** Use **AISC Equation J10-5** to determine  $\ell_b$  required to prevent web crippling.

Assume  $\ell_b/d > 0.2$  and try **Equation J10-5(b)**. For  $\phi R_n \geq R_u$

$$\phi R_n = \phi 0.40 t_w^2 \left[ 1 + \left( \frac{4\ell_b}{d} - 0.2 \right) \left( \frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{E F_{yw} t_f}{t_w}} (Q_f) \geq 126k$$

From Table 1-1 (1-20):  $t_f = 0.810in$      $d = 18.5in$

$$= (0.75)0.40(0.495in)^2 \left[ 1 + \left( \frac{4\ell_b}{18.5in} - 0.2 \right) \left( \frac{0.495in}{0.810in} \right)^{1.5} \right] \sqrt{\frac{29,000ksi(50ksi)0.810in}{0.495in}} \geq 126k$$

Solving for  $\ell_b \geq 2.02in$      $\frac{\ell_b}{d} = \frac{2.02in}{18.5in} = 0.11 < 0.2$     **N.G.**

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### Chapter 5 – Plate Thickness

➤ **Example 5.18:** Use **AISC Equation J10-5(a)** for  $\ell_b/d < 0.2$

$$\phi R_n = \phi 0.40 t_w^2 \left[ 1 + 3 \left( \frac{\ell_b}{d} \right) \left( \frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{E F_{yw} t_f}{t_w}} \geq 126k$$

$$= (0.75)0.40(0.495in)^2 \left[ 1 + 3 \left( \frac{\ell_b}{18.5in} \right) \left( \frac{0.495in}{0.810in} \right)^{1.5} \right] \sqrt{\frac{29,000ksi(50ksi)0.810in}{0.495in}} \geq 126k$$

Solving for  $\ell_b \geq 1.46in$      $\frac{\ell_b}{d} = \frac{1.46in}{18.5in} = 0.08 < 0.2$     **O.K.**

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### Chapter 5 – Plate Thickness

➤ **Example 5.18:** Try  $\ell_b = 6in$ .

Determine dimension **B** from a consideration of bearing strength.

If we conservatively assume that the full area of the support is used, the required plate area  $A_1$  can be found as follows:

$$\phi_c P_p = \phi_c 0.85 f'_c A_1 \geq R_u \quad \text{AISC Equation J8-1}$$

$$= (0.65)0.85(4ksi)A_1 \geq 126k \quad \text{O.K.}$$

Solving for  $A_1 \geq 57.01in^2$

The minimum value of **B**:  $B = \frac{A_1}{\ell_b} = \frac{57.01in^2}{6in} = 9.50in$

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### Chapter 5 – Plate Thickness

➤ **Example 5.18:** The flange width of a **W18 x 71** is 7.64 in, making the plate slightly wider than the flange, which is desirable.

Rounding up, try **B = 10 in**.

Compute the required plate thickness:

$$n = \frac{B-2k}{2} = \frac{10in - 2(1.21in)}{2} = 3.79in$$

$$t \geq \sqrt{\frac{2.2R_u n^2}{F_y B \ell_b}} = \sqrt{\frac{2.2(126k)(3.79in)^2}{36ksi(10in)6in}} = 1.36in$$

Use a **PL 1½ x 6 x 10**

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### Chapter 5 – Plate Thickness

**Other Consideration:**

- If the beam is not **laterally braced** at the load point (in such a way as to prevent relative lateral displacement between the loaded compression flange and the tension flange), the Specification **requires that web sideway buckling** be investigated (AISC J10.4).
- When loads are applied to both flanges, **web compression buckling** must be checked (AISC J10.5).

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### Chapter 5 – Column Base Plates

- The design of **column base plates** requires consideration of bearing pressure on the supporting material and **bending of the plate**.
- A major difference is that **bending in beam bearing plates is in one direction**, whereas **column base plates are subjected to two-way bending**.
- Moreover, **web crippling and web yielding are not factors** in column base plates design.

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### Chapter 5 – Column Base Plates

- The background and development of the plate thickness equation are presented here in **LRFD** terms.
- After some simple modifications, the corresponding **ASD** equation will be given.
- Column base plates can be categorized as **large** or **small**.
- **Small plates** are those whose dimensions are approximately the same as the column dimensions.
- Furthermore, **small plates** behave differently when lightly loaded than when they are more heavily loaded.

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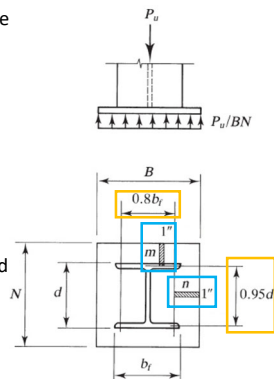
### Chapter 5 – Column Base Plates

- The thickness of **large plates** is determined from consideration of the bending of **the portions of the plate that extend beyond the column outline**.
- Bending is assumed to take place about **axes at mid-depth** of the plate near the edges of the column flanges.

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### Chapter 5 – Column Base Plates

- Two of the axes are parallel to the **web** and  $0.8b_f$  apart.
- Two axes are parallel to the **flanges** and  $0.95d$  apart.
- The two 1-inch cantilever strips are labeled **m** and **n**.
- To determine the required plate thickness, use the larger of **m** and **n** and call it **ℓ**
- Replace  $ℓ_b$  with **N**



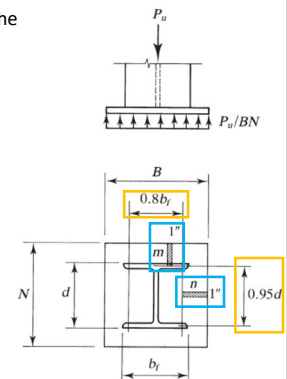
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### Chapter 5 – Column Base Plates

- Two of the axes are parallel to the **web** and  $0.8b_f$  apart.
- Two axes are parallel to the **flanges** and  $0.95d$  apart.
- The two 1-inch cantilever strips are labeled **m** and **n**.

$$t \geq \sqrt{\frac{2P_u \ell^2}{0.9BNF_y}}$$

$$t \geq \ell \sqrt{\frac{2P_u}{0.9BNF_y}}$$



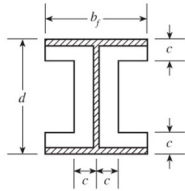
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### Chapter 5 – Column Base Plates

- **Lightly loaded small base plates** can be designed by using the **Murray–Stockwell method** (Murray, 1983).

$$t \geq c \sqrt{\frac{2P_0}{0.9A_H F_y}} \quad P_0 = \frac{P_u}{BH} (b_f d)$$

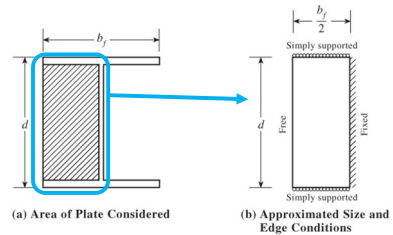
where  $A_H$  is the H-Shaped area, and  $c$  is the dimension to give a stress of  $P_0/A_H$  equal to the design bearing stress of the supporting material



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### Chapter 5 – Column Base Plates

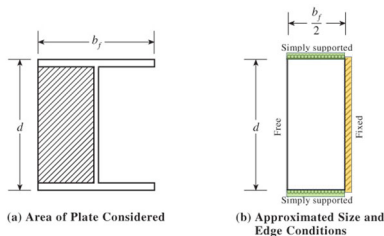
- For more **heavily loaded base plates** (the boundary between lightly loaded and heavily loaded plates is not well defined).
- In this case, **two-way bending** of the portion of the plate between the web and the flanges is analyzed.



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### Chapter 5 – Column Base Plates

- As shown below, this plate segment is assumed to be: **fixed** at the web, **simply supported** at the flanges, and **free** at the other edge.

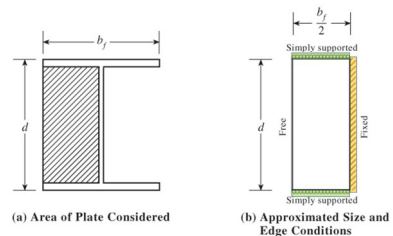


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### Chapter 5 – Column Base Plates

- The required thickness is:

$$t \geq n' \sqrt{\frac{2P_u}{0.9BN F_y}} \quad n' = \frac{1}{4} \sqrt{b_f d}$$



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### Chapter 5 – Column Base Plates

- These three approaches were combined by Thornton (1990b), and a summary of the resulting unified procedure follows.

$$t \geq \ell \sqrt{\frac{2P_u}{0.9F_y BN}} \quad \ell = \max(m, n, \lambda n')$$

$$m = \frac{N - 0.95d}{2} \quad n = \frac{B - 0.8b_f}{2} \quad \lambda = \frac{2\sqrt{X}}{1 + \sqrt{1 - X}} \leq 1$$

$$X = \frac{4db_f}{(d + b_f)^2} \left( \frac{P_u}{\phi_c P_p} \right) \quad n' = \frac{1}{4} \sqrt{b_f d} \quad \phi_c = 0.65$$

where  $P_p$  is the nominal bearing strength from **AISC Equation J8-1 or J8-2**

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### Chapter 5 – Column Base Plates

- There is **no need to determine** whether the plate is large or small, lightly loaded, or heavily loaded.

$$t \geq \ell \sqrt{\frac{2P_u}{0.9F_y BN}} \quad \ell = \max(m, n, \lambda n')$$

$$m = \frac{N - 0.95d}{2} \quad n = \frac{B - 0.8b_f}{2} \quad \lambda = \frac{2\sqrt{X}}{1 + \sqrt{1 - X}} \leq 1$$

$$X = \frac{4db_f}{(d + b_f)^2} \left( \frac{P_u}{\phi_c P_p} \right) \quad n' = \frac{1}{4} \sqrt{b_f d} \quad \phi_c = 0.65$$

where  $P_p$  is the nominal bearing strength from **AISC Equation J8-1 or J8-2**

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### Chapter 5 – Column Base Plates

➤ As a simplification,  $\lambda$  can always be conservatively taken as 1.0

$$t \geq \ell \sqrt{\frac{2P_u}{0.9F_yBN}} \quad \ell = \max(m, n, \lambda n')$$

$$m = \frac{N - 0.95d}{2} \quad n = \frac{B - 0.8b_f}{2} \quad \lambda = \frac{2\sqrt{X}}{1 + \sqrt{1 - X}} \leq 1$$

$$X = \frac{4db_f}{(d + b_f)^2} \left( \frac{P_u}{\phi_c P_p} \right) \quad n' = \frac{1}{4} \sqrt{b_f d} \quad \phi_c = 0.65$$

where  $P_p$  is the nominal bearing strength from **AISC Equation J8-1 or J8-2**

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### Chapter 5 – Column Base Plates

➤ This procedure is given in **Part 14** of the Manual.

$$t \geq \ell \sqrt{\frac{2P_u}{0.9F_yBN}} \quad \ell = \max(m, n, \lambda n')$$

$$m = \frac{N - 0.95d}{2} \quad n = \frac{B - 0.8b_f}{2} \quad \lambda = \frac{2\sqrt{X}}{1 + \sqrt{1 - X}} \leq 1$$

$$X = \frac{4db_f}{(d + b_f)^2} \left( \frac{P_u}{\phi_c P_p} \right) \quad n' = \frac{1}{4} \sqrt{b_f d} \quad \phi_c = 0.65$$

where  $P_p$  is the nominal bearing strength from **AISC Equation J8-1 or J8-2**

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### Chapter 5 – Plate Thickness

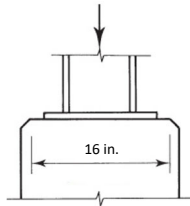
➤ **Example 5.19:** A **W12 x 65** is used as a column and is supported by a concrete pier as shown below.

➤ The top surface of the pier is 16 in by 16 in. Design an **A36** ( $F_y = 36 \text{ ksi}$ ) base plate for a column dead load of 100 k and a live load of 200 k. The concrete strength is 4 ksi.

➤ **LRFD** solution - The factored load is

$$P_u = 1.2(100k) + 1.6(200k) = 440k$$

➤ From **Table 1-1** for a **W12 x 65**  
 $b_f = 12.0 \text{ in}$     $d = 12.1 \text{ in}$



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### Chapter 5 – Plate Thickness

➤ **Example 5.19:** Compute the required bearing area.

$$P_p = 0.85f'_c A_1 \sqrt{\frac{A_2}{A_1}} \leq 1.7f'_c A_1 \quad \text{AISC Equation J8-2}$$

Compute the required bearing area. For  $\phi_c P_p \geq P_u$

$$\phi_c P_p = (0.65)0.85(4\text{ksi})A_1 \sqrt{\frac{16\text{in}(16\text{in})}{A_1}} \geq 440.0k$$

Solving for  $A_1$ :  $A_1 \geq 154.84 \text{ in}^2$

$$\phi_c 1.7f'_c A_1 = (0.65)1.7(4\text{ksi})(154.84 \text{ in}^2) = 684.39k \geq 440.0k$$

O.K.

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### Chapter 5 – Plate Thickness

➤ **Example 5.19:** The plate must be at least as large as the column:

$$b_f d = 12.0\text{in}(12.1\text{in}) = 145.20 \text{ in}^2 < 154.84 \text{ in}^2 \quad \text{O.K.}$$

For  $B = N = 14 \text{ in}$ .  $A_1$  provided =  $14\text{in}(14\text{in}) = 196 \text{ in}^2$

The dimensions of the cantilever strip are:

$$m = \frac{N - 0.95d}{2} = \frac{14\text{in} - 0.95(12.1\text{in})}{2} = 1.25\text{in}$$

$$n = \frac{B - 0.8b_f}{2} = \frac{14\text{in} - 0.8(12.0\text{in})}{2} = 2.220\text{in}$$

$$n' = \frac{1}{4} \sqrt{b_f d} = \frac{1}{4} \sqrt{(12\text{in})(12.1\text{in})} = 3.01\text{in}$$

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### Chapter 5 – Plate Thickness

➤ **Example 5.19:** As a conservative simplification, let  $\lambda = 1.0$ :

$$\ell = \max(m, n, \lambda n') = \max(1.25\text{in}, 2.2\text{in}, 3.01\text{in}) = 3.01\text{in}$$

The required plate thickness is:

$$t \geq \ell \sqrt{\frac{2P_u}{0.9F_yBN}} = 3.01\text{in} \sqrt{\frac{2(440.0k)}{0.9(36\text{ksi})14\text{in}(14\text{in})}} = 1.121\text{in}$$

Use a **PL 1½ x 14 x 14**

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**Chapter 5 – Beams**

Any questions?

