COLUMN BASE PLATES - DESIGN TO ERECTION –

Tom Murray
Emeritus Professor
Virginia Tech
Blacksburg, VA
Column Base Plates

[Diagram of column base plates with annotations: Fillet Weld, STL Column, NUT & WASHER, BASE PL, GROUT, CONC FOUND, ANCHOR ROD, ANCHOR NUT, DAMAGE THREADS, COLUMN, BASE PL, ANCHOR ROD, GROUT, CONCRETE FOUNDATION]
Types of Column Base Plates

Compressive Axial Loads

Base Plates with Small Moments

Tensile Axial Loads

Base Plates with Large Moments
PERTINENT SECTIONS AND TABLES

Chapter J Design of Connections
Table J3.2 Nominal Strength of Fasteners and Threaded Parts
J8. Column Bases and Bearing on Concrete

Chapter M Fabrication and Erection
M2.2 Thermal Cutting
M2.8 Finish of Column Bases
M4.4 Fit of Column Compression Joints and Base Plates
Types of Column Base Plates

TOPICS

- Base Plate and Anchor Rod Material and Details
- Base Plates for Axial Compression
- Base Plates for Tension
- Base Plates for Axial Compression and Moment
- Shear Anchorage
- Column Erection Procedures
- Result of Poor Anchor Rod Placement
Base Plate and Anchor Rod Materials and Details
Base Plate Material

- Typical A36
- 1/8” (3mm) increments to 1-1/4 in (32 mm) then ½ in. (6 mm)
- Minimum thickness ½ in. (13 mm), typical ¾ in. (20 mm)

Fabrication and Finishing

- Plate is thermally cut
- Holes drilled or thermally cut
- *Specification* Section M2.2 has requirements for thermal cutting
- Finishing: *Specification* Section M2.8
  - ≤ 2 in. (50 mm) milling not generally required
  - 2 – 4 in. (50 – 100 mm) straightened by pressing or milling
  - > 4 in. (100 mm) milling required
    - Only mill where column bears
- Bottom surface with grout need not be milled
- Top surface not milled if complete-joint-penetration (CJP) welds
Base Plate Welding

- Fillet welds preferred up to ¾ in. (20 mm) then groove welds
- Avoid all around symbol
- Weld for wide-flange columns subject to axial compression
  Weld on one side of column flanges to avoid rotating the section:

- HSS subject to axial compression: Weld flats only
- Shear, Tension, Moment, and Combinations
  Size weld for forces not all around
  No weld at fillets of wide-flange columns
  Must weld at corners of HSS if tension or moment
- Shop welded preferred
- Very heavy base plates may be field welded after grouting
## Anchor Rod Materials and Details

### Anchor Rod Material

<table>
<thead>
<tr>
<th>Material ASTM</th>
<th>Tensile Strength $F_u$ (ksi)</th>
<th>Nominal Tensile Stress $F_{nt} = 0.75F_u$ (ksi)</th>
<th>Nominal Shear Stress (X type)$^{[a, b]}$ $F_{nv} = 0.50F_u$ (ksi)</th>
<th>Nominal Shear Stress (N type)$^{[a, c]}$ $F_{nv} = 0.40F_u$ (ksi)</th>
<th>Maximum Diameter (in.)</th>
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<tr>
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<td>140</td>
<td>105</td>
<td>70.0</td>
<td>56.0</td>
<td>4</td>
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</table>

$^{[a]}$ Nominal stress on unthreaded body for cut threads (based on major thread diameter for rolled threads)
$^{[b]}$ Threads excluded from shear plane
$^{[c]}$ Threads included in the shear plane
$^{[d]}$ Preferred material specification
$^{[e]}$ See F1554 Gr 36

- Preferred ASTM F1554 Gr 36 except when high tension and or moment.
Anchor Rod Materials and Details

Anchor Rod Material

- Unified Course (UNC) threads
- Standard Hex Nuts permitted but Heavy Hex nuts required for oversize holes and with high strength anchor rods.
- Hooked anchor rods have very low pull-out strength but OK for axial compression only.
- Headed rods or rods with nuts are preferred.
Anchor Rod Materials and Details

Anchor Rod Material

- Use of plate washers at bottom of rods can cause erection problems and should be avoided.
- Drilled-in epoxy anchor rods may be used for light loads
- Wedge-type anchors should not be used because of potential loosing during erection.
Anchor Rod Materials and Details

Anchor Rod Holes and Washers

- Oversize holes required because of placement tolerances.
- Recommended hole and washer sizes are in Design Guide 1 (Table 2-3) and AISC 14th Ed. Manual (Table 14-2).

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<tr>
<td>2½</td>
<td>3⅛</td>
<td>5½</td>
<td>⅜</td>
</tr>
</tbody>
</table>

Notes: 1. Circular or square washers meeting the size shown are acceptable.
2. Adequate clearance must be provided for the washer size selected.
3. See discussion in Section 2.6 regarding the use of alternate ⅛-in. hole size for 3/4-in.-diameter anchor rods, with plates less than 1⅛-in. thick.

- Smaller holes may be used when axial compression only.
- Plate washers required when tension and/or moment.
Anchor Rods Material and Details

Anchor Rod Sizing and Layout

• Recommendations
  Use ¾ in. (22 mm) minimum diameter.
  Use Grade 36 rod up to about 2 in. (50 mm) diameter.
  Thread at least 3 in. (75 mm) beyond what is needed.
  Minimum ½ in. (12 mm) distance between edge of hole and edge of plate.
  Use symmetrical pattern whenever possible.
• Provide ample clearance for nut tightening.
• Coordinate anchor bolt placement with reinforcement location.

- Minimum of four anchor rods.
- Base plate to resist eccentric gravity load of 300 lb (1,300 N) 18 in. (450 mm) from extrem outer face of column in each direction.
- 300 lb (1,300) represents weight of iron worker with tools.
- Exception: Post-type columns weighing less than 300 lb.

Note: Smallest of anchor rods on a 4 in. by 4 in. (100 mm by 100 mm) pattern is generally sufficient.
Column Base Plates

**DESIGN CONSIDERATIONS**

- Base Plate Bending Strength
- Concrete Crushing
- Concrete Anchorage for Tension Forces
- Shear Resistance
- Anchor Rod Tension Design
- Anchor Rod Shear Design
- Anchor Rod Embedment
- Constructability
Base Plates for Axial Compression
Design for Axial Compression

Column Base Plate Design Limit States

- Base Plate Bending
- Concrete Crushing
Design for Axial Compression

Column Base Plate Bending

\[ f_{pu} = \frac{R_u}{(BxN)} \text{ = pressure due to reaction} \]

Let \( m' = \max(n \text{ and } m) \)

\[ M_u = f_{pu} \left(1 \right) \left(m'^2/2 \leq \phi M_p\right) \]

\[ \phi M_p = 0.9 \ F_y \ Z_x = 0.9x \ 1 \ x \ t_p^2/4 \) \ F_y \]

Substituting:

\[ t_{p, \min} = \sqrt{\frac{2 \ f_{pu} \ (m'^2)}{0.9 \ F_y}} \]
Column Base Plate Bending

- Lightly Loaded Base Plate
- Required concrete bearing area is less than $b_f d_c$. 

![Diagram showing bearing area with labels d, b_f, and Bearing Area]
**Design for Axial Compression**

**Column Base Plate Bending**
- Lightly Loaded Base Plate

Replace \( m' \) with \( \ell = \max\{m, n, \lambda n'\} \), where

\[
\lambda = \frac{2\sqrt{X}}{1 + \sqrt{1 - X}} \leq 1.0
\]

\[
n' = \frac{1}{4} \sqrt{db_f}
\]

\[
X = \left( \frac{4db_f}{(d + b_f)^2} \right) \frac{P_u}{\phi P_p}
\]


\[
t_{p,\text{min}} = \sqrt{\frac{2f_{pu}\ell^2}{0.9F_y}}
\]
Design for Axial Compression

HSS Sections
• Bend lines.

![Diagram of HSS Sections](image)
Concrete Crushing

**Specification Section J8. Column Bases and Bearing on Concrete**

\[ \phi_c = 0.65 \]

(a) On the full area of a concrete support

\[ P_p = 0.85f'_c A_1 \]  

\[ (J8-1) \]

(b) On less than the full area of a concrete support

\[ \text{Note: The limit } \leq 1.7f'_c \text{ is equivalent to } A_2/A_1 \leq 4 \]  

where

\[ P_p = 0.85f'_c A_1 \sqrt{A_2 / A_1} \leq 1.7f'_c A_1 \]

\[ f'_c = \text{specified compressive strength of concrete, ksi (Mpa)} \]

\[ A_1 = \text{area of steel bearing on concrete, in.}^2 \]

\[ A_2 = \text{area of the portion of the supporting surface that is geometrically similar to and concentric with the loaded area, in.}^2 \]
Ex.: Determine if the base plate shown is adequate.

Column: W10x33  \( d = 9.73 \text{ in.} \)  \( b_f = 7.96 \text{ in.} \)
PL 1-\( \frac{1}{2} \) x 18 x 1’-6” A36

Concrete Pedestal:
- 24 in. by 24 in. (assume square)
- \( f_c' = 3.0 \text{ ksi} \)
- \( P_u = 250 \text{ kips} \)
Concrete Crushing

\[ A_1 = 18 \times 18 = 324 \text{ in}^2 \]  (Plan area of base plate)
\[ A_2 = (24)(24) = 576 \text{ in}^2 \]  (Plan area of concrete pedestal)
\[ A_2/A_1 = 576/324 = 1.78 < 4 \]

\[
\phi P_p = \phi 0.85 \ f'_c \ A_1 \sqrt{\frac{A_2}{A_1}} \\
= 0.65 \ (0.85 \times 3.0) \ (324)\sqrt{1.78} \\
= 716 \text{ k} > 250 \text{ k} \quad \text{OK}
\]
**Plate Bending**

\[ n = 5.82 \text{ in.} \quad m = 4.38 \text{ in.} \]

\[ n' = (1/4)\sqrt{db_f} \]
\[ = (1/4)\sqrt{9.73 \times 7.96} \]
\[ = 2.20 \text{ in.} \]

\[ X = \left( \frac{4db_f}{(d + b_f)^2} \right) \frac{P_u}{\phi P_p} \]
\[ = \left( \frac{4 \times 9.73 \times 7.96}{(9.73 + 7.96)^2} \right) \frac{250}{716} = 0.333 \]
Plate Bending

\( n = 5.82 \text{ in.} \quad m = 4.38 \text{ in.} \)

\[
n' = \frac{1}{4}\sqrt{db_f} = \frac{1}{4}\sqrt{9.73 \times 7.96} = 2.20 \text{ in.}
\]

\[
X = \frac{4db_f}{(d + b_f)^2} \frac{P_u}{\phi P_p} = \frac{4 \times 9.73 \times 7.96}{(9.73 + 7.96)^2} \frac{250}{716} = 0.333
\]
Plate Bending

\[ \lambda = \frac{2\sqrt{X}}{1 + \sqrt{1 - X}} = \frac{2\sqrt{0.333}}{1 + \sqrt{1 - 0.333}} \]
\[ = 0.635 \leq 1.0 \]
\[ \lambda n' = 0.635 \times 2.20 = 1.40 \text{ in.} \]

\[ \ell = \max \{m, n, \lambda n'\} \]
\[ = \max \{4.38, 5.82, 1.40\} = 5.82 \text{ in} \]

\[ f_{pu} = \frac{R_u}{BN} = \frac{250}{(18 \times 18)} \]
\[ = 0.772 \text{ ksi} \]
Plate Bending

\[ t_p = \sqrt{\frac{2f_{pu} \ell^2}{0.9F_y}} = \sqrt{\frac{2 \times 0.772 \times 5.82^2}{0.9 \times 36}} \]

= 1.27in. ≤ 1.5in. OK

**PL 1-½ x 18 x 1’-6” A36 is Adequate.**
Design for Axial Compression

Variation of $\phi P_n$ with Base Plate Thickness with Increasing Axial Force

$$BN = b_f d$$
Design for Axial Compression

Was the base plate too strong?
Base Plates for Axial Tension
Design for Tensile (Uplift) Forces

Connection Limit States

• Anchor Rod Tensile Strength
• Concrete Pull-out Strength
• Concrete Anchorage Tensile Strength
• Base Plate Bending Strength
Design for Tensile (Uplift) Forces

Anchor Rod Tensile Strength

- Tensile Strength
  \[ \phi T_n = \phi F_{nt} A_b \]
  where \( \phi = 0.75 \)
  \[ F_{nt} = 0.75F_u \]
  \( F_u \) = specified minimum tensile strength of anchor rod
  - = 58 ksi (300 MPa) for Gr 36
  - = 75 ksi (400 MPa) for Gr 55
  - = 125 ksi (650 MPa) for Gr 125

Notes: \( A_b \) is the nominal area of the anchor rod = \( \pi d^2 / 4 \).
  0.75 in 0.75\( F_u \) account for rupture (tensile) area.
See AISC 14\textsuperscript{th} Ed. Manual Table 7-17 for actual areas.
Ex. Determine the design strength, $\phi T_n$, for the limit state of anchor rod tension rupture. 4 - $\frac{3}{4}$ in. (20 mm) diameter, Grade 36 anchor rods

$$\phi T_n = 4 \times 0.75 \times (0.75 F_u) A_b$$

$$= 4 \times 0.75 \times (0.75 \times 58) \times (\pi \times 0.75^2 / 4)$$

$$= 4 \times 14.4 \text{ kips} \ (4 \times 53 \text{ kN})$$

$$= 57.6 \text{ kips} \ (212 \text{ kN})$$
Concrete Pullout Strength

- Provisions in ACI 318-08, Section D5.3
- Design pullout strength of headed anchor rod or anchor rod with nut:
  \[ \phi N_p = \phi \psi_4 A_{brg} 8f'_c \]
  where \( \phi = 0.70 \)
  \[ \psi_4 = 1.4 \text{ for no cracking, } 1.0 \text{ if cracking exists} \]
  \( A_{brg} = \text{net bearing area of the anchor rod head or nut, in}^2 \)
  \( f'_c = \text{specified compression strength of concrete, psi} \)

Notes: Hooked anchor rods are not recommended with tensile loadings.
Design for Tensile (Uplift) Forces

Concrete Pullout Strength

- AISC Design Guide 1 Table for Strengths with Heavy Hex Nuts

<table>
<thead>
<tr>
<th>Rod Diameter, in.</th>
<th>Rod Area, $A_b$, in.²</th>
<th>Bearing Area, $A_{brg}$, in.²</th>
<th>Concrete Pullout Strength, $f_N$</th>
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<td></td>
<td>$f_c' = 3,000$ psi</td>
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<td>$f_c' = 4,000$ psi</td>
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<td>$f_c' = 5,000$ psi</td>
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<tr>
<td>5/8</td>
<td>0.307</td>
<td>0.689</td>
<td>11.6</td>
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<td>¾</td>
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Note: kN = 4.448 x kips  \( \text{N/mm}^2 = 6.895 \times 10^{-3} \times \text{psi} \)
Concrete Breakout Strength

- Provisions in ACI 318-08, Section D4.2.2

**Full breakout cone**

- $f_t = \text{Tensile stress in concrete along surface of stress cone.}$

**Breakout cone for group anchors**

- $x = a - 3(h-h_{ef})$

**Breakout cone near edge**

- $P_{UL} = 56k \text{ psi}$
- $f'_c = 4000 \text{ psi}$
Design for Tensile (Uplift) Forces

Base Plate Bending Strength
• AISC Design Guide 1 recommended bend lines.

Alternate Critical Section is the full width of the base plate.
Design for Tensile (Uplift) Forces

**Base Plate Bending Strength**
- Other possible bend lines.

For all cases:

Define: 
- \( x \) = distance from center of anchor bolt to critical section
- \( w \) = width of critical section
- \( T_u \) = force in anchor bolt

\[
\phi M_n = 0.9F_y t_p w t_p^2 / 4 = M_u = T_u x \quad \Rightarrow \quad t_{p,\text{min}} = \sqrt{\frac{4T_u x}{0.9F_y w}}
\]
Base Plates for Axial Compression and Moment
Design for Axial Compression and Moment

Connection Limit States

- Concrete Crushing
- Anchor Rod Tensile Strength
- Concrete Pull-out Strength
- Concrete Anchorage Tensile Strength
- Base Plate Bending Strength

Cases

- $T = 0$ (Relatively small moment)
- $T > 0$ (Relatively large moment)
Design for Axial Compression and Moment

**Limit for T = 0**

\[ \Sigma F_y = 0 \text{ with } T=0 \]

Base Plate is B by N in plan

\[ P_r = qY = f_p BY \]

\[ \Sigma M_o = 0 \]

\[ P_re = qY^2/2 - P_rN/2 \]

Then

\[ e = N/2 - Y/2 \text{ if } f_p \leq f_{p,max} \]

with

\[ f_{p,max} = 0.65x0.85f'_c \sqrt{A_2/A_1} \leq 0.65x 1.7f'_c \]

then

\[ e_{\text{crit}} = N/2 - P_r/(2Bf_{p,max}) \]

Therefore

If \( e \leq e_{\text{crit}} \), \( T = 0 \) and \( Y = N - 2e \)

\[ e_{\text{crit}} = N/2 - P_r/(2Bf_{p,max}) \]
Design for Axial Compression and Moment

For $T > 0$

$e > e_{\text{crit}}$ and $f_p = f_{p,\text{max}}$

$\Sigma F_y = 0$

$P_r - T - f_{p,\text{max}}BY = 0$

$\Sigma M_o = 0$

$T(N/2 + f) + P_r(N/2) - P_re - f_{p,\text{max}}BY^2/2 = 0$

Solving the resulting quadratic equation

Note: If the quantity in the radical is less than zero, a larger base plate is required.
Ex. 1. Determine required plate thickness and anchor rod diameter.

Given:  \( P_u = 376 \text{ kips} \quad M_u = 940 \text{ in-kips} \quad W12x96 \ A992 \)

\( N = 19 \text{ in.} \quad B = 19 \text{ in.} \quad A_2/A_1 = 1 < 4 \quad b_f = 12.2 \text{ in.} \quad d = 12.7 \text{ in.} \)

\( f_c' = 4.0 \text{ ksi} \quad F_y = 36 \text{ ksi} \quad f = 8 \text{ in.} \)

Solution:

\[
f_{p,\text{max}} = 0.65 \times 0.85 f_c' \sqrt{A_2 / A_1}
\]

\[
= 0.65 \times 0.85 \times 4.0 \times \sqrt{1.0} = 2.21 \text{ksi}
\]

\( e = M_u / P_u = 970 / 376 = 2.50 \)

\( e_{\text{crit}} = N/2 - P_r / (2Bf_{p,\text{max}}) \)

\[
= 19.0 / 2 - 376 / (2 \times 19.0 \times 2.21)
\]

\( = 5.02 \text{ in.} \)

\( e < e_{\text{crit}} \rightarrow T = 0 \text{ and } Y = N - 2e = 19.0 - 2 \times 2.50 \)

\( = 14.0 \text{ in.} \)
Ex. 1. Determine required plate thickness and anchor rod diameter.

Given:
- \( P_u = 376 \text{ kips} \)
- \( M_u = 940 \text{ in-kips} \)
- \( W12\times96 \text{ A992} \)
- \( N = 19 \text{ in.} \)
- \( B = 19 \text{ in.} \)
- \( \frac{A_2}{A_1} = 1 < 4 \)
- \( b_f = 12.2 \text{ in.} \)
- \( d = 12.7 \text{ in.} \)
- \( f_c' = 4.0 \text{ ksi} \)
- \( F_y = 36 \text{ ksi} \)
- \( f = 8 \text{ in.} \)

Solution Continued:

\[ f_p = \frac{P_u}{NY} = \frac{376}{(19.0 \times 14.0)} = 1.41 \text{ ksi} \]

\[ m = \frac{(N-0.95d)}{2} = \frac{(19.0-0.95 \times 12.7)}{2} = 3.47 \text{ in.} \]

\[ m = \frac{(B-0.80b_f)}{2} = \frac{(19.0-0.80 \times 12.2)}{2} = 4.62 \text{ in.} \]

\[ t_p = \sqrt{\frac{2f_{pu}n^2}{0.9F_y}} = \sqrt{\frac{2 \times 1.41 \times 4.62^2}{0.9 \times 36}} = 1.36 \text{ in.} \]

Use PL 1½ x 19 x 1ft 7 in. A36
4 – ¾ in. Anchor Rods x 12 in. F1554 Gr 36
w/ heavy hex nuts at bottom.
Ex. 2. Determine required plate thickness and anchor rod diameter.

Given: \( P_u = 376 \text{ kips} \quad M_u = 2500 \text{ in-kips} \quad \text{W12x96 A992} \)
\( N = 19 \text{ in.} \quad B = 19 \text{ in.} \quad A_2/A_1 = 1 < 4 \quad b_f = 12.2 \text{ in.} \quad d = 12.7 \text{ in.} \)
\( f_c' = 4.0 \text{ ksi} \quad F_y = 36 \text{ ksi} \quad f = 8 \text{ in.} \)

Solution:

\[
 f_{p,\text{max}} = 0.65 \times 0.85 f_c' \sqrt{\frac{A_2}{A_1}} \\
= 0.65 \times 0.85 \times 4.0 \times \sqrt{1.0} = 2.21 \text{ ksi} \\
\]

\( e = \frac{M_u}{P_u} = \frac{2500}{376} = 6.65 \)

\( e_{\text{crit}} = \frac{N}{2} - \frac{P_r}{(2Bf_{p,\text{max}})} \)
\( = 19.0/2 - 376/(2 \times 19.0 \times 2.21) \)
\( = 5.02 \text{ in.} \)

\( e > e_{\text{crit}} \rightarrow T > 0 \text{ and } Y = (f + N/2) - \sqrt{(f + \frac{N}{2})^2 - \frac{2P_r(e + f)}{f_{p,\text{max}}B}} \)
Design for Axial Compression and Moment

Ex. 2. Determine required plate thickness and anchor rod diameter.

Given:  \( P_u = 376 \text{ kips} \quad M_u = 2500 \text{ in-kips} \quad W12\times96 \text{ A992} \)

\( N = 19 \text{ in.} \quad B = 19 \text{ in.} \quad A_2/A_1 = 1 < 4 \quad b_f = 12.2 \text{ in.} \quad d = 12.7 \text{ in.} \)

\( f_c' = 4.0 \text{ ksi} \quad F_y = 36 \text{ ksi} \quad f = 8 \text{ in.} \)

Solution Continued:

\[
Y = \left( f + \frac{N}{2} \right) - \sqrt{\left( f + \frac{N}{2} \right)^2 - \frac{2P_r(e+f)}{f_{p,\text{max}}B}}
\]

\[
= \left( 8.0 + \frac{19.0}{2} \right) - \sqrt{\left( 8.0 + \frac{19.0}{2} \right)^2 - \frac{2\times376(6.65+8.0)}{2.21\times19.0}}
\]

\[
= 10.9 \text{ in.}
\]

\( f_p = \frac{P_u}{(NY)} \)

\[
= \frac{376}{(19.0\times10.9)} = 1.82 \text{ ksi}
\]
Ex. 2. Determine required plate thickness and anchor rod diameter.

Given:  \( P_u = 376 \) kips  \( M_u = 2500 \) in-kips  \( W12\times96\) A992

\( N = 19 \) in.  \( B = 19 \) in.  \( A_2/A_1 = 1 \leq 4 \)

\( f_c' = 4.0 \) ksi  \( F_y = 36 \) ksi  \( f = 8 \) in.

Solution Continued:

\[
m = \frac{(N - 0.95d)}{2} = \frac{(19.0 - 0.95 \times 12.7)}{2} = 3.47 \text{ in.}
\]

\[
n = \frac{(B - 0.80b_f)}{2} = \frac{(19.0 - 0.80 \times 12.2)}{2} = 4.62 \text{ in.}
\]

\[
t_p = \sqrt{\frac{2f_{pu}m^2}{0.9F_y}} = \sqrt{\frac{2 \times 1.82 \times 4.62^2}{0.9 \times 36}} = 1.54 \text{ in.}
\]

Need to check tensions side.
Ex. 2. Determine required plate thickness and anchor rod diameter.

Given:  \( P_u = 376 \text{ kips} \)  \( M_u = 2500 \text{ in-kips} \)  \( W12x96 \)  \( A992 \)
\( N = 19 \text{ in} \)  \( B = 19 \text{ in} \)  \( A_2/A_1 = 1 < 4 \)
\( f_c' = 4.0 \text{ ksi} \)  \( F_y = 36 \text{ ksi} \)
\( b_f = 12.2 \text{ in} \)  \( d = 12.7 \text{ in} \)
\( f = 8 \text{ in} \)

Solution Continued:
\[ T = f_{p,\text{max}} BY - P_u \]
\[ = 2.21 \times 19.0 \times 10.9 - 376 = 80.4 \text{ kips} \]

Try 2 – Anchor Rods each Side

Required plate thickness:
\[ X = f - 0.95d/2 = 8.0 - 0.95 \times 12.7/2 \]
\[ = 1.96 \text{ in} \]
\[ w = b_f + 1.0 = 12.2 + 1.0 = 13.0 \text{ in} \]

\[ t_{p,\text{min}} = \sqrt{\frac{4T x}{0.9F_y w}} = \sqrt{\frac{4 \times 80.4 \times 1.96}{0.9 \times 36 \times 13.0}} = 1.22 \text{ in} \]

Use PL 1½ x 19 x 1ft 7 in. A36
Ex. 2. Determine required plate thickness and anchor rod diameter.

Given: \( P_u = 376 \) kips \( M_u = 2500 \) in-kips \( W12x96 \) A992

\( N = 19 \) in. \( B = 19 \) in. \( A_2/A_1 = 1 < 4 \)

\( f_c' = 4.0 \) ksi \( F_y = 36 \) ksi

Solution Continued:

\( T_{rod} = 80.4/2 = 40.2 \) kips per anchor rod

Try 1 -1/4 in. diameter

\( \phi T_n = 0.75 (0.75F_u)A_b \)

\( = 0.75 (0.75 \times 58)(\pi 1.25^2/4) \)

\( = 40.0 \) kips \( \approx 40.2 \) kips Say OK

Check Pullout:

From AISC Design Guide 1, Table 3.2, \( \phi T_n = 50.2 \) kips OK
Shear Anchorage of Base Plates
Shear Anchorage of Base Plates

Transferring Shear Forces (ACI 318-08 and ACI 349-06)

- Friction between base plate and grout or concrete surface.
  \[ \phi V_n = \phi \mu P_u \leq \phi 0.2f_c'A_c \text{ or } \phi 800A_c \]
  where \( \phi = 0.75 \)
  \( \mu = \) coefficient of friction = 0.4
  \( P_u = \) factored compressive axial force
  \( A_c = \) plan area of base plate, BN

- Bearing of the column and base plate and/or shear lug against concrete.

  \[ \phi P_{u,brg} = 0.55f_c'A_{brg} \]
  where \( A_{brg} = \) vertical bearing area
Shear Anchorage of Base Plates

Transferring Shear Forces (ACI 318-08 and ACI 349-06)

- Shear strength of the anchor rods.
  Not recommended because of oversize holes in base plate.

- Hairpins and Tie Rods
Column Erection Procedures
Anchor rods are positioned and placed in the concrete before it cures. Plastic caps are placed over the anchor bolts to protect laborers.
Concrete block-outs may be made so that the base plate and anchor bolts are recessed below floor level for safety and aesthetics.
Column Erection Procedures

Slotted holes are allow for difference in standard field tolerances between concrete and steel.
The column is leveled by adjusting the anchor bolt nuts below the plate. Grout will be placed under and around the base plate to transfer axial forces to the concrete below.
Grout will be placed under and around the base plate to transfer axial forces to the concrete below. At least it should be.
Result of Poor Anchor Rod Placement

The following slides are courtesy of Fisher & Kloiber- AISC Field Fixes presentation.
Anchor Rod Placement

Anchor rods in the wrong location.
Anchor Rod Placement

Anchor rods in the wrong location.
Anchor Rod Placement

Anchor rods in the wrong location.
Anchor Rod Placement

Anchor rods too short.
Anchor Rod Placement

Anchor rods too long.
Anchor Rod Placement

Shop rework for column and base plate.
Anchor Rod Placement

Anchor rods
Poor Anchor Rod Placement

Anchor bolts run over by a crane.
Poor Anchor Rod Placement

Anchor bolts run over by something.
Our next IMCA Manual, due to come out shortly, will state in the Code of Standard Practice, that in addition to the requirement that the contractor responsible for placing the anchors in site, present a drawing showing the as-placed location of the anchors, that the supplier of the structure provide the necessary templates for this purpose. They are to be so designed as to insure the correct position, both vertically (including the length of the anchor extending above the concrete surface) and horizontally, show the location of the building axis relative to the anchor group and leave permanent marks of the axis in the concrete surface. The price of the templates is recommended to be the average price of the steel structure. (We save so much on the cost of erection that we would be glad to give the templates away free, but don't tell my clients.)

We have been using this method over the past 5 years in all of our jobs. We are delighted in not having had a single problem in placing the columns, the structures are all self-plumbing, the bolts all easily inserted and the time for erection greatly shortened. On a job we are now doing, from the date our bid was accepted, it took 7 weeks to design, fabricate, erect the steel structure and install 20,000 sq. ft. of decking, with shear anchors hand welded, for a three story school building, working one 11 hr shift both at the shop and the site. A second similar 30,000