Steel Column Base Plate Design

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The design of base plates of columns in steel frame buildings is simple but time consuming. The AISC Manual of Steel Construction contains tables of base plate sizes and thickness for maximum loads on columns of short lengths. However, in actual practice the column loads for various column sizes are seldom maximum as tabulated in the AISC Manual. Therefore, the size and thickness of base plate have to be calculated following the procedure given on pg. 3-95 of the AISC Manual of Steel Construction, 7th Edition. The writer has developed an alignment chart for the design of base plates of axially loaded columns using the AISC method.

The plate thickness \( t \), in inches, is given by the larger value of the following:

\[
t = \frac{\sqrt{3F_p m^2}}{F_b} \quad (1)
\]

or

\[
t = \frac{\sqrt{3F_p n^2}}{F_b} \quad (2)
\]

where

\[
F_p = \text{allowable concrete bearing pressure, psi}
\]

\[
F_b = \text{allowable plate bending stress, psi}
\]

\[
m = \frac{(L - 0.95d)}{2}
\]

\[
n = \frac{(B - 0.8b)}{2}
\]

\[
L = \text{base plate length, in.}
\]

\[
B = \text{base plate width, in.}
\]

\[
d = \text{column depth, in.}
\]

\[
b = \text{column flange width, in.}
\]

For economical design, the dimensions of a base plate should be such that \( m \) and \( n \) are approximately equal. If base plate dimensions are so chosen that \( m \) is slightly larger than \( n \), Eq. (1) will always control the plate thickness.

From the AISC Specification Sect. 1.5.5:

\[
F_p = 0.25f'_c \text{ on full area of concrete support}
\]

\[
F_p = 0.375f'_c \text{ on loaded concrete area equal to one-third or less of the total concrete support area}
\]

Also, from AISC Specification Sect. 1.5.1.4.3:

\[
F_b = 0.75F_y
\]

where \( f'_c \) and \( F_y \) are compressive strength of concrete and yield stress of steel, respectively.

Substituting the values of \( F_p, F_b \) and \( m \) in Eq. (1), the plate thickness is given as:

On full support area: \[
t = \frac{(L - 0.95d)}{6} \sqrt{\frac{9f'_c}{F_y}} \quad (3)
\]

On one-third or less of support area:

\[
t = 1.225 \frac{(L - 0.95d)}{6} \sqrt{\frac{9f'_c}{F_y}} \quad (4)
\]

The alignment chart is drawn for:

\[
f'_c = 4000 \text{ psi}
\]

\[
F_y = 36000 \text{ psi}
\]

Substituting these values in Eqs. (3) and (4):

On full support area: \[
t = \frac{(L - 0.95d)}{6} \quad (5)
\]

On one-third or less of support area:

\[
t = 1.225 \frac{(L - 0.95d)}{6} \quad (6)
\]

Equations (5) and (6) are linear in \( L, d \) and \( t \). An alignment chart, Fig. 1, is drawn for a wide range of column loads and common column sections. The base plate width \( B \) and length \( L \) are so proportioned that \( (L - 0.95d) \) is always larger than \( (B - 0.8b) \) and therefore controls the design thickness.

The use of the alignment chart is illustrated by the following examples:

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ALIGNMENT CHART
COLUMN BASEPLATE DESIGN
Concrete Strength $f'_c = 4000$ psi
Steel Yield Stress $F_y = 36,000$ psi

Allowable Concrete Bearing Pressure:
- On full area $F_p = .25 f'_c = 1000$ psi
- On one-third area or less $F_p = .375 f'_c = 1500$ psi

<table>
<thead>
<tr>
<th>Plate Thickness $t$ (in.)</th>
<th>0.95d</th>
<th>Column Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_b = .25 f'_c$</td>
<td>0.5</td>
<td>W 14 x 605, W 14 x 665, W 14 x 730</td>
</tr>
<tr>
<td>$F_b = .375 f'_c$</td>
<td>0.5</td>
<td>W 14 x 426, W 14 x 455, W 14 x 500, W 14 x 550</td>
</tr>
</tbody>
</table>

1. Design Load = (DL + LL) or .75 (DL + LL + Wind Load), whichever is greater.
2. Select baseplate size from table of allowable loads.
3. Align the length (L) of plate and the column size and read plate thickness ($t$) for appropriate concrete bearing.

Figure 1

$F_p = .25 f'_c = 1000$ psi
$F_p = .375 f'_c = 1500$ psi

use minimum $t = \frac{3}{4}$"
Example 1:

Given:
Design the base plate.

Column: W14×87
Axial load = 240 kips
Concrete $f_c = 4000$ psi
Allowable concrete bearing $F_v = 0.25f'_c$
Steel $F_y = 36000$ psi
Full area of concrete support loaded.

Solution:
From the column of allowable loads on base plates, the plate dimensions are $B = 14$ in. and $L = 18$ in.
Align $L = 18$ in. and column size W14×87, and determine plate thickness $t$ for $F_v = 0.25f'_c$, which is 1.0 in.

Base plate required is 14 x 1 x 1'-6".

The alignment chart can also be used for values of $f'_c$ and $F_y$ other than 4000 psi and 36000 psi, respectively, as in the following example.

Example 2:

Given:
Column W14×127
Axial load = 400 kips
Loaded area of concrete support less than one-third of total support area, i.e.:
$F_v = 0.375f'_c$
Concrete $f'_c = 3000$ psi
Steel $F_y = 42000$ psi

Solution:
The base plate dimensions can be determined using equivalent column load for concrete support of $f'_c = 4000$ psi and then multiplying the thickness $t$ obtained from the alignment chart by the correction factor $\sqrt{9f'_c/F_y}$.

Equivalent load for 4000 psi concrete

\[
= 400 \times \frac{4000}{3000} = 534 \text{ kips}
\]

Base plate dimensions from table of allowable load for concrete bearing $F_v = 0.375f'_c$ are:
$B = 17.0$ in.
$L = 21.0$ in.

From alignment chart $t = 1.53$ in.

Corrected thickness

\[
= 1.53 \times \frac{3000}{42000} = 1.53 \times 0.8 = 1.23 \text{ in.}, \text{ say } 1\frac{1}{4} \text{ in.}
\]

Hence, base plate required is 17 x 1\frac{1}{4} x 1'-9".

The chart is applicable for bases with direct load only. The base plates with overturning moment or uplift due to seismic or wind load are to be specially designed.

For column sizes other than those shown on the alignment chart, the chart can still be used by proportioning the base plate length $L$ and $B$ such that $(L - 0.95d)$ is larger than $(B - 0.806)$. Then align 0.95$d$ of column and $L$ to determine plate thickness $t$. 