Inconsistencies in Column Base Plate Design in the New AISC ASD Manual

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The new AISC steel design manual (ninth edition)[1] suggests a new procedure for computing the thicknesses of column base plates to rectify problems associated with the somewhat conservative design approach adapted in its earlier version. However, a close scrutiny of the suggested method reveals that the new approach is sometimes overly conservative and even inconsistent.

Referring to Fig. 1 (pg. 3-106 of the AISC Manual),

P = Total column load, kips
A_1 = $B \times N$ = Area of plate, in.^{2}
A_2 = Full cross-sectional area of concrete support, in.^{2}
F_b = Allowable bending stress in base plate, ksi
F_p = Allowable bearing stress in support, ksi
f_p = actual bearing pressure, ksi
f'_c = Compressive strength of concrete, ksi
t_p = Thickness of plate, in.

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Referring to page 3-108 of the Manual, the following procedure is followed to compute base plate size:

For a given P, f'_c and A_2, minimum area of base plate is computed and reasonable values of B and N are selected. Based on the column dimensions and selected B and N, quantities m and n are computed and the larger of the two controls. In the next step, the value of L (Fig. 2) is computed from the following expression, $F_p = P/(2 + d + b - 2L)/L$, which is quadratic in L. Solving for L,

$$L = [(d + b) \pm \sqrt{((d + b)^2 - 4P/F_p)}]/4$$

The Manual is silent as to which of the two solutions should be used in further computation. However, a careful study of the equation reveals that the smaller of the two L values should be used. The required base plate thickness is then computed based on the larger of m and n calculated and the value of L, as described in the Manual.

The quantity L is computed based on an area with a pressure of F_p and not f_p. Thus it is not clear why f_p is used in the expression $t = L\sqrt{(3f_p/F_b)}$ (pg. 3-107 of the Manual).

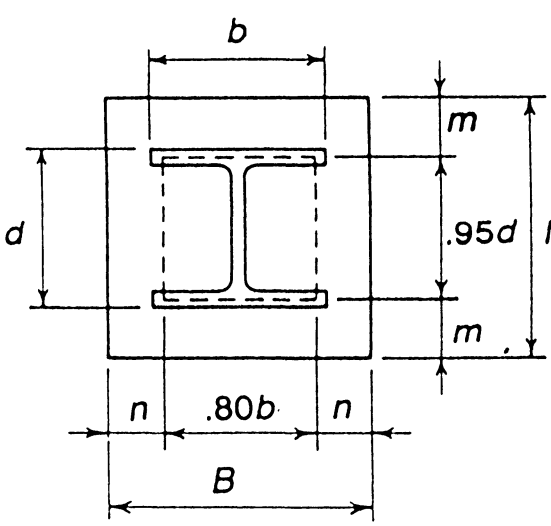

Figure 1

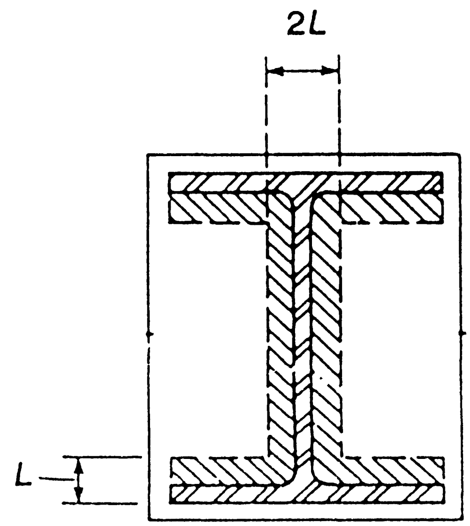

Figure 2

Example

Let

$P = 331$ kips
Column W12×106 ($d = 12.89$, $b = 12.22$)
$f'_c = 3$ ksi
$F_y = 36$ ksi
Pier: 34 in. × 34 in.

1. $A_1 = (1/(34 \times 34))(331/(.35 \times 3))^2 = 86$
   $A_1 = 331/(.7 \times 3) = 158$ **Controls**
2. $\Delta = .5[.95 \times 12.89 - .8 \times 12.22] = 1.235$
   $N = \sqrt{158} + 1.235 = 13.8$, use 14 in.
   $B = 158/14 = 11.3$, use 13 in.
   $A_1 = 14 \times 13 = 182$ in.^{2}
3. $f_p = 331/182 = 1.82$ ksi
4. $m = [14 - 0.95 \times 12.89]/2 = 0.88$ in.
   $n = [13 - 0.80 \times 12.22]/2 = 1.61$ in. **Controls**

$F_p = .35 \times 3 \times (34 \times 34/182) = 2.65 \text{ ksi} > 2.1$ ksi, use 2.1 ksi
$L = [12.89+12.22-\sqrt{((12.89+12.22)^2-4\times331/2.1)}]/4$
$= (25.11 - \sqrt{0.036})/4 = 6.23$ in.
$t_p = 1.61 \times \sqrt{(1.82/(.25\times36))} = 0.72$ in.
$t_p = 6.23 \times \sqrt{(3\times1.82/27)} = 2.80$ in. **Controls**

It may be noted that the thickness of 2.80 in. is greater than what would be obtained according to the eighth edition AISC Manual.

Now if one repeated the same calculations with a load of 332 kips, L would become imaginary and as per the manual would be ignored. As a result the required thickness would be 0.72 in., less than that required for a lighter load.

Therefore the authors feel that the new way of computing L is basically inconsistent and likely to result in too thick a base plate when L controls and too thin a base plate when L is imaginary and thus ignored.

SUGGESTED METHOD OF ANALYSIS

Let us assume that the pressure under the base plate is uniform and is equal to P/A_1. Let us also assume that the plate is essentially fixed at the web and flanges of the column. Thus what we have here is a plate with one long and two short edges fixed and the fourth edge free with a uniform load. One can go back to various moment coefficients available in the literature to compute maximum moment in the plate. Considering the width to length ratios of usual column sections, the authors suggest a moment coefficient of 0.022 so that the maximum moment in the plate is $0.022 \times f_p \times d^2$ kip-in./in., where d is the depth of the column.

$$S_{reqd.} = 0.022 \times f_p \times d^2/F_b$$
$$t = \sqrt{(6S_{reqd.})} = \sqrt{(0.132 f_p d^2/F_b)} \qquad (1)$$

Therefore, to compute the base plate thickness,

a) Compute m and n as discussed in the Manual and select a thickness based on the larger of the two.
b) Use the larger of the two thicknesses obtained in step (a) and by Eq. 1.

Applying this method to the example above,

a) Compute thickness to be 0.72 in. for the larger of m and n.
b) Use Eq. 1 for $t = \sqrt{(0.132 \times 1.82 \times 12.89^2/27)}$
   $= 1.22$ in. **Controls**

REFERENCES

1. American Institute of Steel Construction, Inc., *Manual of Steel Construction, Allowable Stress Design,* ninth edition, Chicago, IL, July 1989.
2. Winter, Urquhart, O'Rourke, Nilson, *Design of Concrete Structures,* seventh edition, McGraw-Hill Book Company, New York.