Fast Check for Ponding

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FOR A FLAT or near flat roof, it is necessary that the roof framing be sufficiently stiff to prevent ponding of water. Without sufficient stiffness, deflection of the roof may cause successive ponding and deflection until the accumulated weight could conceivably cause failure.

The AISC Specification provides formulas by which the stiffness of a roof system may be checked. Section 1.13.3 states that "The roof system shall be considered stable and no further investigation will be needed if

$$C_p + 0.9C_s \leq 0.25 \quad \text{and} \quad I_d \geq \frac{25S^4}{10^6}$$

$$\text{where } C_p = \frac{32L_sL_p^4}{10^7 I_p} \quad \text{and} \quad C_s = \frac{32SL_s^4}{10^7 I_s} \ldots"$$

If these requirements are not satisfied, the stiffness investigation procedure outlined in the AISC Commentary should be followed.

To speed up checking for ponding and to simplify locating the decimal point, the formulas for C_p and C_s may be rewritten as follows:

$$C_p = \frac{32L_sL_p^4}{10^7 I_p} = \frac{1}{I_p}\left(\frac{32L_sL_p^4}{10^7}\right) = \frac{P_1}{I_p}$$

$$C_s = \frac{32SL_s^4}{10^7 I_s} = \frac{1}{I_s}\left(\frac{32SL_s^4}{10^7}\right)$$

$$\text{and } 0.9C_s = \frac{1}{I_s}\left(\frac{28.8SL_s^4}{10^7}\right) = \frac{P_2}{I_s}$$

Using these values, the Ponding Equation becomes:

$$\frac{P_1}{I_p} + \frac{P_2}{I_s} \leq 0.25$$

The values of P_1 and P_2 indicate the degree of stiffness required for beams whose lengths are L_p and L_s, respectively (see Fig. 1). The relationships of P_1 and P_2 to L_s, L_p, and S are shown on Graphs I and II, Fig. 2, which illustrate how ponding becomes increasingly critical as the lengths of supporting members increase. The engineer must be particularly attentive to the possibility of ponding when bay sizes are large. For instance, if $L_s = 30$ ft, it may be seen from Graph I that P_1 increases 70% when L_p is increased from 35 to 40 ft, an increase of only 14%. The same effect is apparent in Graph II as L_s is increased.

To check for ponding:

a. In Graph I, with L_s and L_p known, select P_1.
b. In Graph II, with S and L_s known, select P_2.
c. Substitute P_1 and P_2, along with I_p and I_s, into the rewritten Ponding Equation.

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Example 1

Given:
Check the roof structure shown in Fig. 3 for ponding.

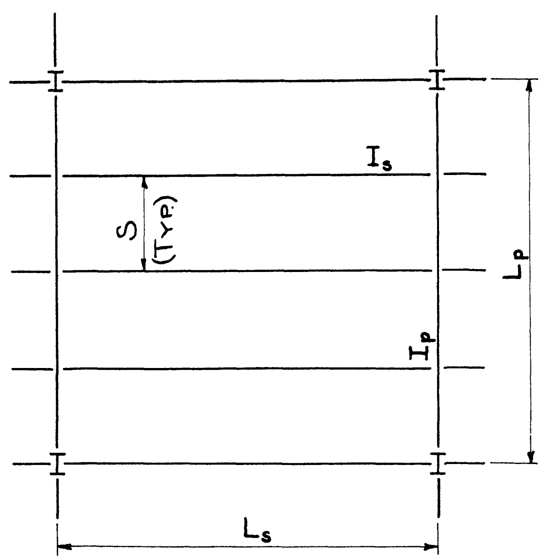

Figure 1

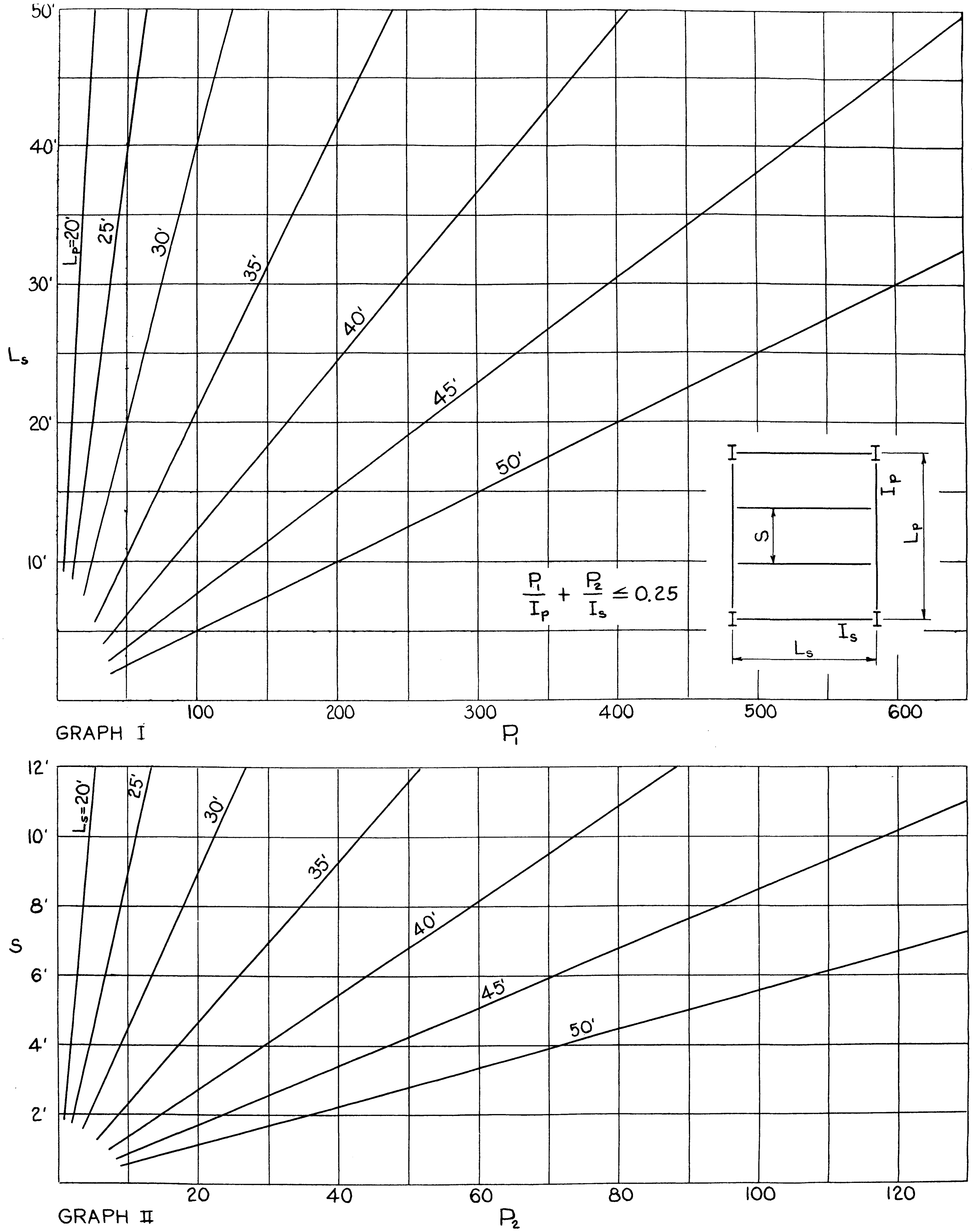
50'
40'
30'
20'
10'
L_s
L_p=20'
25'
30'
35'
40'
45'
50'
$\frac{P_1}{I_p} + \frac{P_2}{I_s} \leq 0.25$
I_p
L_p
S
I_s
L_s
100
200
300
400
500
600
GRAPH I
P_1
12'
10'
8'
6'
4'
2'
S
L_s=20'
25'
30'
35'
40'
45'
50'
20
40
60
80
100
120
GRAPH II
P_2

Figure 2

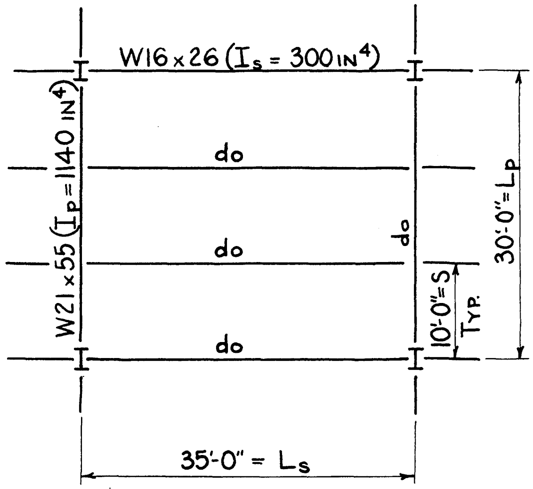

Figure 3

Solution:
Enter Graph I with L_s = 35.0 ft. Project a line horizontally until it intersects the diagonal line, L_p = 30.0 ft. Project vertically downward and read P_1 = 85.

Enter Graph II with S = 10.0 ft. Project a line horizontally until it intersects the diagonal L_s = 35.0 ft. Project vertically downward and read P_2 = 44.

Substituting into the rewritten Ponding Equation:

$$\frac{P_1}{I_p} + \frac{P_2}{I_s} \leq 0.25$$

$$\frac{85}{1140} + \frac{44}{300} = 0.075 + 0.147 = 0.222 < 0.25 \quad \textbf{ok}$$

Example 2—

Given:
Examine the end bay of the structure of Example 1 (see Fig. 4).

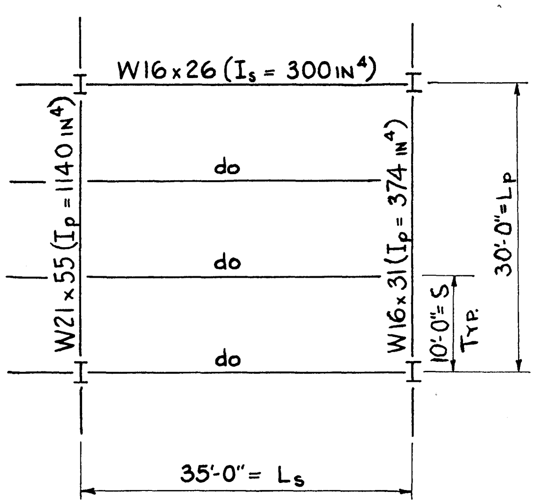

Figure 4

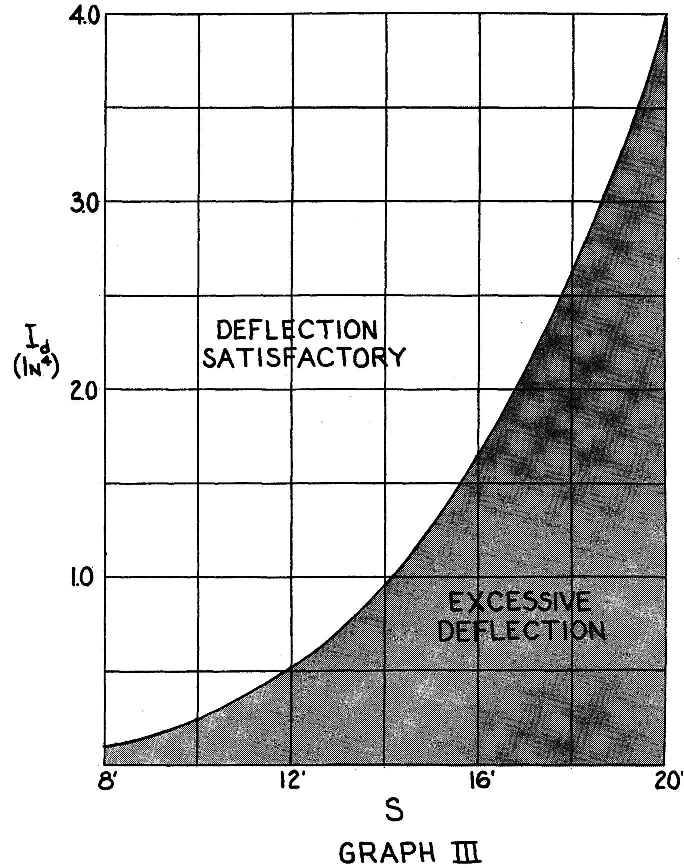

Figure 5

Solution:
In this case, where a loaded bay is on one side of the girder only, use half the value of P_1.

Then

$$\frac{P_1}{I_p} + \frac{P_2}{I_s} = \frac{(85/2)}{374} + \frac{44}{300} = 0.114 + 0.147$$
$$= 0.261, > 0.25 \quad \textbf{ng}$$

Change the W16×31 to W18×35 (I = 513 in.^{4}) and check.

$$\frac{P_1}{I_p} + \frac{P_2}{I_s} = \frac{42.5}{513} + \frac{43}{300} = 0.083 + 0.147$$
$$= 0.230 < 0.25 \quad \textbf{ok}$$

Rather than change the size of the W16×31, the framing system might have been investigated using the more refined method given in the Commentary on the AISC Specification.

To complete the graphical investigation of ponding, Graph III (Fig. 5) may be used to check the stiffness of the steel deck. Plotting the intersection of the moment of inertia of the deck (I_d) and the spacing of the secondary members (S) in Graph III, the deflection is satisfactory so long as the intersecting point lies outside the shaded area.