One Engineer's Opinion

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T. V. Galambos has developed a formula for the area of the diagonal brace required to stabilize a frame subject only to vertical loads (AISC Engineering Journal, January, 1964). Referring to Fig. 1, the formula can also be written as:

$$A_b = \frac{\Sigma P L_b}{E h \cos^2\theta}$$

where:

A_b = area of the brace, in.^{2}
ΣP = total of all the vertical loads which depend on the brace for stability, kips
L_b = length of brace, in.
h = story height, in.
θ = angle of brace to the horizontal

In most real buildings, the Galambos formula results in very small required bracing areas. The size of the bracing would usually be governed by the lateral loading, such as wind or seismic, or by the minimum slenderness ratio criterion. Nevertheless, the formula is useful because it assures the designer that his structure is also safe from instability under gravity loads only.

The Galambos formula may be questioned as being unconservative when used in high rise buildings. It could be theorized that the formula does not consider the force in the brace resulting from unsymmetrical loading, such as might result from an initial out-of-plumbness. In effect, the formula ignores the "$P\Delta$ effect."

In this engineer's opinion, any forces induced in the diagonal bracing system of a high rise building due to out-of-plumbness are insignificant. In other words, the $P\Delta$ effect in a braced frame can be ignored in real structures. This can be seen by examining the $P\Delta$ effect for a braced frame in an unrealistically severe design condition under very conservative assumptions. For the frame in Fig. 2:

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1. Vertical loads are of a magnitude that can be carried only by the heaviest sections rolled.
2. The frame is erected out-of-plumb to the limit specified by AISC, which permits out-of-plumbness of 1/500 up to a maximum of 2 in. It should be noted that in a real building, out-of-plumbness would have a random direction resulting in a considerably less average Δ.
3. The truss is considered as pin-ended, disregarding the stiffening effect of the frame action.
4. No stiffening is accorded the collateral building elements such as partitions and walls.

The hypothetical $P\Delta$ force $H_{P\Delta}$ applied to the top of the structure is computed as:

$$H_{P\Delta} = \frac{6000 \times 2}{80 \times 12} = 12.5 \text{ kips}$$

The resulting force in the diagonal brace, F_b, using a factor of safety of 2, is:

$$F_b = 2(12.5) \times \frac{\sqrt{20^2 + 10^2}}{20} = 27.8 \text{ kips}$$

Assuming an A36 brace in tension, this results in additional required area of only:

$$A_b = \frac{27.8}{22.0} = 1.2 \text{ in.}^2$$

The additional force on the column, $P_{P\Delta}$, is also small:

$$P_{P\Delta} = 2 \times 12.5 \times \frac{80}{20} = 100 \text{ kips}$$

Even if the brace were required to stabilize several adjacent unbraced bents, it is hard to imagine the $P\Delta$ effect as having an effect on the design of either the bracing system or columns in a braced multistory building. For this reason, engineering practice justifiably has never included the consideration of the $P\Delta$ effect in the design of braced structures.

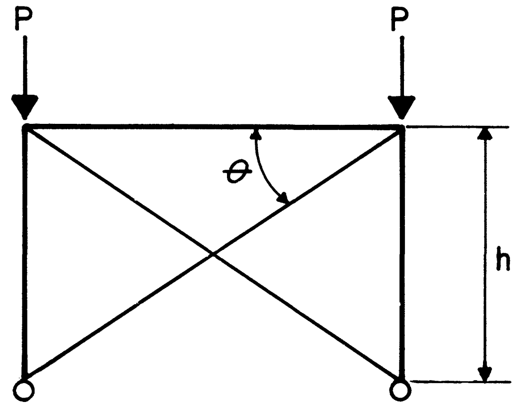

Figure 1

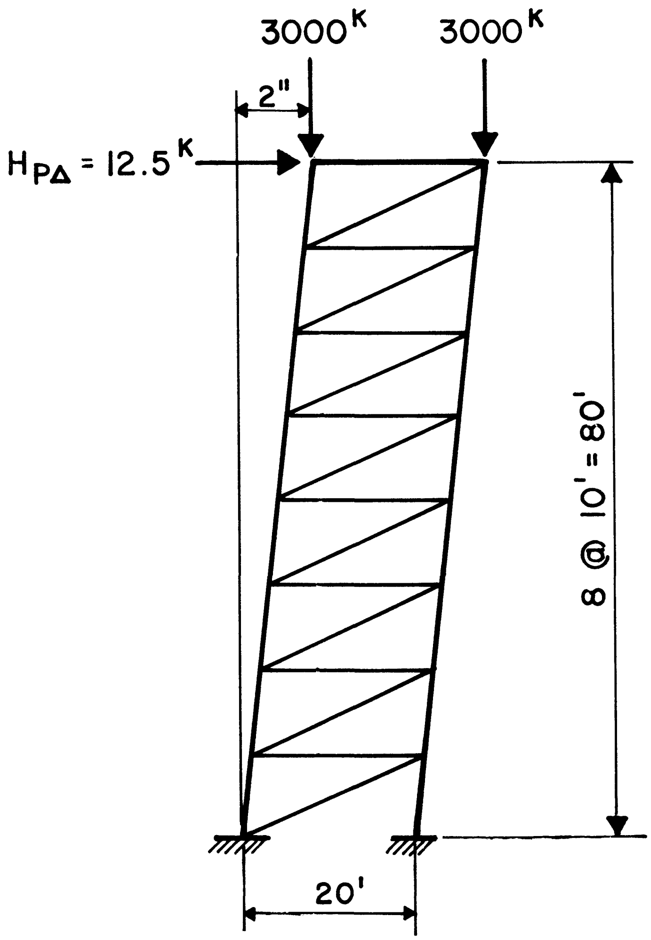

Figure 2