(3) Accommodation of Brace Buckling

Braces in SCBF are expected to undergo cyclic buckling under severe ground motions, forming plastic hinges at their center and at each end. To prevent fracture resulting from brace rotations, bracing connections must either have sufficient strength to confine inelastic rotation to the bracing member or sufficient ductility to accommodate brace end rotations.

For brace buckling in the plane of the gusset plates, the end connections should be designed to resist the expected compressive strength and the expected flexural strength of the brace as it transitions from pure compression to pure flexure (Astaneh-Asl et al., 1986). Note that a realistic value of K should be used to represent the connection fixity.

For brace buckling out of the plane of single plate gussets, weak-axis bending in the gusset is induced by member end rotations. This results in flexible end conditions with plastic hinges at midspan in addition to the hinges that form in the gusset plate. Satisfactory performance can be ensured by allowing the gusset plate to develop restraint-free plastic rotations. This requires that the free length between the end of the brace and the assumed line of restraint for the gusset be sufficiently long to permit plastic rotations, yet short enough to preclude the occurrence of plate buckling prior to member buckling. A length of two times the plate thickness is recommended (Astaneh-Asl et al., 1986). Note that this free distance is measured from the end of the brace to a line that is perpendicular to the brace centerline, drawn from the point on the gusset plate nearest to the brace end that is constrained from out-of-plane rotation.

This condition is illustrated in Figure C-F2.9 and provides hysteretic behavior as illustrated in Figure C-F2.10. The distance of $2t$ shown in Figure C-F2.9 should be considered the minimum offset distance. In practice, it may be advisable to specify a slightly larger distance (for example, $2t + 1$ in.) on construction documents to provide for erection tolerances. More information on seismic design of gusset plates can be obtained from Astaneh-Asl (1998).

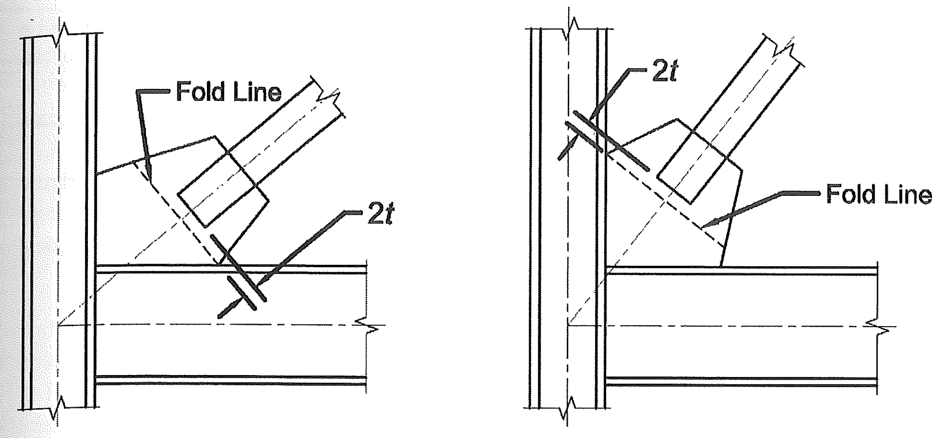
Alternatively, connections with stiffness in two directions, such as cross gusset plates, can be detailed. Test results indicate that forcing the plastic hinge to occur in the brace rather than the connection plate results in greater energy dissipation capacity (Lee and Goel, 1987).

Where fixed end connections are used in one axis with pinned connections in the other axis, the effect of the fixity should be considered in determining the critical buckling axis.

6d. Column Splices

In the event of a major earthquake, columns in concentrically braced frames can undergo significant bending beyond the elastic range after buckling and yielding of the braces. Even though their bending strength is not utilized in the design process when elastic design methods are used, columns in SCBF are required to have adequate compactness and shear and flexural strength in order to maintain their lateral strength during large cyclic deformations of the frame. In addition, column splices

are required to have sufficient strength to prevent failure under expected post-elastic forces. Analytical studies on SCBF that are not part of a dual system have shown that columns can carry as much as 40% of the story shear (Tang and Goel, 1987; Hassan and Goel, 1991). When columns are common to both SCBF and special moment frames (SMF) in a dual system, their contribution to story shear may be as high as 50%. This feature of SCBF greatly helps in making the overall frame hysteretic loops



t = thickness of gusset plate

Fig. C-F2.9. Brace-to-gusset plate requirement for buckling out-of-plane bracing system.

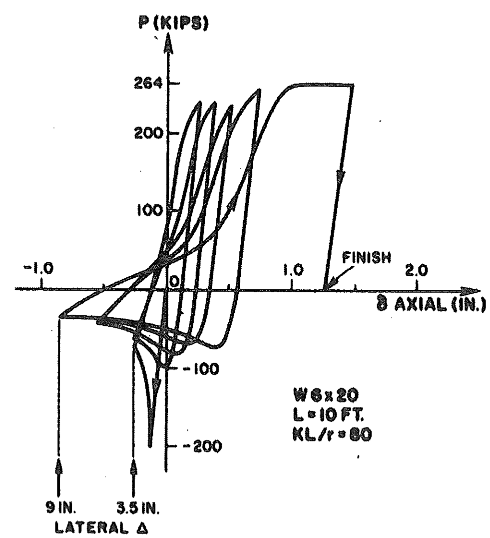


Fig. C-F2.10. P-δ diagram for a strut.