The Fundamental Flaw in the "pre-Northridge" Moment Frame Connection

The popular field welded–field bolted beam-to-column moment frame connection, shown in both of the current AISC LRFD and ASD steel design manuals, has become known as the "pre-Northridge" connection. As a result of surveys of damaged buildings made subsequent to the 1994 Northridge, CA earthquake, it was concluded by the Structural Engineers Association of California (1996 SEAOC Blue Book Commentary) that the pre-Northridge connection is ***fundamentally flawed*** and should not be used in the construction of new seismic moment frames. This conclusion was based upon (1) this connection's modes of fracture, (2) an historic review of the 1960 - 1990 tests made at the University of California and Lehigh University that led to this connection's design rationale, and (3) ATC-24 protocol tests in the SAC/FEMA research program.

Extensive finite element analyses and strain gage data from ATC-24 tests by Seismic Structural Design Associates, Inc. (SSDA) of this pre-Northridge connection made in 1994 and 1995 showed large stress and strain gradients horizontally across and vertically through the beam flanges and welds at the face of the column. ***These large flange stress and strain gradients are caused by a very large component of the seismic shear, typically 50% or more, that is carried by the beam flanges***. It is these flange shear forces that produce a prying moment in the welds and flanges at the face of the column and at the weld access holes that led to the weld and flange fractures and to the column flange divot modes of connection fracture. Moreover, the large plastic strains associated with these prying moments significantly reduce the fatigue life of the connection. A failure analysis of the SAC ATC-24 test specimens at the University of Michigan and at Lehigh University demonstrated that fatigue cracks initiated and propagated in all the tested specimens (John M. Barsom, "SAC Steel Project 7.1.3", May, 2000).

At the August, 2000, conclusion of a $12M research program by SAC (a consortium of three organizations, SEAOC, the Applied Technology Council, and the Consortium of Universities for Research in Earthquake Engineering), which was funded by the Federal Emergency Management Agency (FEMA), the American Institute of Steel Construction (AISC), and the National Science Foundation (NSF), a series of seismic connection design seminars were given that were funded by FEMA. Attendees were provided with a set of notes entitled "New Recommended Seismic Design Criteria for Steel Moment Frame Buildings: Speakers Slide's". In these notes it is stated that the large component of seismic shear, typically 50%, and its prying effects still exist in the beam flanges and welds of the SAC pre-qualified Reduced Beam Section (RBS) connection, which uses the unreinforced flange connection (James Malley, p. 5-19; Stephen Mahin, p. 3-14,15). ***However, the published FEMA-350 design rationale for the RBS, WUF-W, and WUF-B connections does not account for these large flange shears wherein all of the shear is assumed to be resisted by the beam web connection*** (FEMA-350, p. 3-41, RBS design steps 4 and 5; p. 3-28 WUF-W designs; p. 3-28 WUF-B design steps 5 and 6).

An alternative connection design using vertical beam flange fins to account for the flange shear has been tested successfully by SAC (AISC Engineering Jr., p. 43, 2nd Qtr, 1997). SAC apparently has not recommended it because of its increased cost of fabrication.