STRESS REVERSAL WITHIN SAME FLANGE OF PRE-NORTHRIDGE MOMENT FRAME CONNECTION

James E. Partridge
Smith-Emery Company
Los Angeles, California

During the conduct of some recently run cantilever beam/column seismic connection tests utilizing ATC-24 test criteria and post-yield strain gauges which were applied directly to the weld filler metal upper and lower horizontal surfaces, the presence of an accumulation of strain was detected. The subject of our presentation is to explore this phenomenon which has never been measured before or never been the subject of a technical paper. The importance of this phenomenon, if confirmed by testing, would indicate that the principal failure mode of the pre-Northridge connection detail was the result of fatigue in the weldment.

Previously, we have reported two results, which have now been widely accepted:

1. Stress Concentration Factor

   The presence of a very high stress concentration factor (SCF) in the center of the girder flange weld at the column flange face. This SCF is known to be of a magnitude 4 to 5 times the nominal design stress in the girder flange and occurs at the extreme fibre in bending of the tension flange center.

2. Stress Reversal in Same Flange

   The presence of compressive stress in the pre-Northridge flange weld metal at the column face in the center of the tension flange side which is opposite the extreme fiber in bending, i.e., the underside of the top flange or the top side of the bottom flange of the horizontal girder when the respective flange is in a tension loaded state.

Both of the above two phenomenons are now widely known to be present in the pre-Northridge connection and were confirmed by both physical test and strain gauge measurement (accuracy 1x10-6 m/in) as well as the finite element method. Analysis for both elastic and plastic states of strain were accomplished using both plate element and solid element in Finite Element Models. These results have been published in several technical papers and acknowledged in SAC publications and the Structural Engineers Handbook for Seismic Design.

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To date we have accomplished a literature search to determine the number of post yield cycles prior to failure in historical ATC-24 tests. We have also reviewed the historical literature to determine any mention or consideration given to the phenomenon of fatigue in the pre-Northridge connection.

In our studies we will conduct ATC-24 tests with extensive post-yield strain gauges. In this way we can maintain observation of the strains up to approximately 3% strain levels. This will allow for measurement of accumulated strains on each cycle of post yield loading. This accumulation of strains is the manifestation of fatigue loading and is commonly referred to as the "ratchet effect" by those familiar with fatigue studies.

We will accomplish several tests as follows:

1. Single beam flange to column flange tests in cyclic loading to failure with instrumentation.

2. Typical pre-Northridge connection tests with the same flange size as the single beam flange/column flange size as in the above described beam flange only test. ATC-24 load criteria will be utilized and extensive instrumentation will be utilized.

It is the second above-listed phenomenon, which we are concerned with in this current study. It is acknowledged by metallurgical, engineering mechanics, and fracture mechanics studies that when there is a reversal in stress or a high SCF present within the same member, that these factors can produce a fatigue failure upon repeated cycles of loading and unloading. The transition between high cycle fatigue and low cycle fatigue loading may be fewer than 100 cycles of loading.

If the mode of failure by fatigue is found, it will manifest itself as an accumulation of strain during cyclic loading. That is, the tension flange strain gauges will display elongation during the tension loading cycle but will not display a return to zero strain upon the subsequent compression cycle of loading. Each successive cycle of tension loading in a flange, if fatigue is a failure mode, will show greater levels of strain accumulation.

A sufficient number of tests will be run to plot fatigue curves or number of cycles vs. load or so called S-N curves, should the data prove indicative of a fatigue failure.