ABSTRACT

Following the Northridge Earthquake (1994), the SAC steel project was initiated to investigate the causes of widespread damage observed in the connections of steel moment frame buildings. The published results of these studies concentrated on local connection defects that potentially initiated the observed cracks. However, damage to some buildings could not be reconciled by use of this failure mechanism. This led to renewed interest in the effects of low-cycle fatigue combined with the higher modes of vibration increasing the cumulative fatigue at critical connections and consequently creating the observed connection failures.

The current study is focused on the effect of low-cycle fatigue in the connection damage observed in steel moment frames and the contribution of the higher modes of vibration to these failures. A comprehensive fatigue analysis procedure is developed based on the Palmgren-Miner method. Low-cycle fatigue behavior of Pre-Northridge connections are studied, and S-N curves established for the high-cycle fatigue range are extended to the low-cycle region using the limited test results that are available.

A series of linear and non-linear time-history analyses are performed on two buildings damaged by the Northridge Earthquake. These buildings have two and ten stories, respectively, and used steel moment frames as the lateral load resisting system in both directions. Fatigue analyses are performed at critical locations of the moment frames using the established procedure, and the contribution of higher
modes in cumulative fatigue is evaluated. Finally, the pattern of cumulative fatigue at critical connections and the observed damage are compared.

Results of this analytical study indicate that the effect of low-cycle fatigue and higher modes of vibration can be significant in the connection damage resulting from the Northridge Earthquake. Although the first mode created a high percentage of cumulative fatigue in the connections of the two-story building, the cumulative fatigue and damage pattern in the ten-story building shows that the contribution of higher modes in the beam and column stress histories significantly increased the cumulative fatigue relative to the first mode. This results in various types of connection damage similar to that observed in the steel moment frames during the Northridge Earthquake.