Published by Elsevier Science Ltd 1996
Paper No.2139. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

DAMAGE TO STEEL MOMENT FRAMES OBSERVED IN THE 1994 NORTHRIDGE EARTHQUAKE

MICHAEL D. ENGELHARDT

Ferguson Laboratory, The University of Texas at Austin, Austin, Texas 78758 U.S.A.

ABSTRACT

The 1994 Northridge Earthquake caused unprecedented damage at welded beam-to-column connections in modern steel moment resisting frames in the Los Angeles area. Prior to the Northridge Earthquake, steel moment frames were held in high regard in the US as being among the most ductile of structural systems for resisting strong earthquake ground motions. Because of this preconceived notion, the discovery of significant connection damage was particularly astounding to much of the structural engineering profession.

The majority of damage to steel moment frames in the Northridge Earthquake occurred at the typical welded flange - bolted web moment connection detail, widely used in west coast US construction since the early 1970's. The most common type of damage observed at these connections were a variety of fractures in the vicinity of the beam flange groove welds. Many of the fractures occurred at the beam bottom flange groove weld, often near the interface of the weld and the face of the column. In a number of cases, fractures occurred within columns, often apparently initiating at or near a beam flange groove weld. Even though connection damage occurred in a large number of buildings, no steel moment frame building collapsed. Remarkably, many of the buildings with extensive connection damage showed no outward signs of distress.

As of yet, a complete understanding has not been achieved as to the causes of the moment connection damage. However, a number of factors related to welding, connection design, and material properties have been suggested as possible contributors. Welding related factors that may have contributed to the damage include inadequate workmanship and inspection, the use of low toughness weld metal, and the practice of leaving backup bars and weld tabs in place. Design related factors include overstress of beam flanges due to inadequate flexural participation of the bolted web, the presence of large stress concentrations within the groove weld, the development of triaxial states of tension in the vicinity of the groove welds, and excessive column panel zone deformations. A number of steel material related factors may also have contributed to the damage. These include elevated yield stress values in beams, high values of yield-to-tensile strength ratio, and questions regarding material toughness and column flange through-thickness properties. No single factor has emerged as the primary culprit of the moment connection damage. Rather, it appears that quite a large number of interrelated factors played a role.

KEYWORDS

Northridge Earthquake; steel moment frames; damage; connections; fracture; welding