Investigation of seismic behavior of drilled flange connection with inclined arrangement of holes

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ABSTRACT

Since unreinforced welded connections were brittle and prematurely fractured in the connections of the beam-to-column penetration welds in the 1994 Northridge earthquake, the researchers proposed radius-cut flange reduction connections to improve the seismic behavior of rigid connections. The brittle failure of weld in the beam-to-column connection and the lateral buckling of the beam flange in the reduced sections of the beam flange led to propose the modified forms of this type of connection. The new type of connection includes drilled flange connection with parallel rows of holes. In order to improve the performance of these drilled flange connections, in this study, beam flange drilling arrangements were used with an inclined arrangement of holes with different hole diameters. The study showed that in the inclined arrangement of a hole, the amount of plastic rotation is 0.059 radians, which is 7.3% more than the plastic rotation of the same radius-cut flange reduction connection. Also, in the best connection sample with the most suitable oblique drilling arrangement, the equivalent plastic strain index in the center and corner of the complete joint penetration weld line decreased to 92.3% and 87.7%, respectively, compared to conventional radius-cut flange reduction connections. Mises index in this connection in the center and corner of the complete joint penetration weld line decreased to 45.5% and 39.9% compared to radius-cut flange reduction connections, respectively. This indicate better performance and less sensitivity of this type of connection to the problems of the complete joint penetration weld line of the beam-to-column connection compared with conventional radius-cut flange reduction connections and these drilled flange connections with the parallel arrangement.

KEYWORDS

Drilled Flange Connection (DFC) with inclined arrangement of holes, Cyclic Behavior, Equivalent Plastic Strain Index (EPEQI), Pressure Index (PI), Mises Index (MI)

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1. Introduction

Steel buildings with rigid connections were severely damaged in the 1994 Northridge earthquake. Many researchers identified these damages caused the brittle weld behavior of steel moment frame connections due to multiaxial stresses in the near area of the beam-to-column connection [1, 2]. Han et al. [3] investigated the cyclic behavior of a direct beam-to-column connection with bolt connection. Yang and Popov [4] used the circular holes in the beam flange to reduce the stress in the beam-to-column connection by reducing the cross-section of the beam flange. Farrokhi et al. [5] tested rigid connections with drilled cover plates. They used 30 analytical models as well as three experimental specimens. They considered I shaped built-up columns in analytical models. Vetr [6, 7] et al. tested the seismic performance of drilled beam flange connection with regular two parallel rows under cyclic load. Lee et al. [8] investigated the seismic behavior of reduced cross-section connections by four full-scale laboratory samples and proposed four different drilling beam flange patterns. Atashzaban et al. [9] investigated damage parameters such as equivalent plastic strain, triaxiality index, and rupture index in the numerical FEM for direct beam-to-column connection with two parallel rows circular hole in beam flange. Rahnavard et al. [10] studied the nonlinear behavior of the drilling beam flange connections with numerical analysis of eight finite element models with two row arrangement of holes in beam flange connections. Ahmady Jazani [11] showed that the drilling beam flange connection with different holes diameters can absorb more energy compared to the connection with similar holes diameter. Shadman Heidari et al. [12] presented new drilled flange connections with combined arrangements of holes and notches. They studied two experimental specimens and 24 numerical models. Among the studied arrangements (i.e., WUF, RBS, DFCs with inclined, parallel, and combined notches and holes drilling patterns), CDFC with combined notches and holes drilling patterns performed better than the other connections, remarkable reductions of damage indexes were observed in connection. In this research, to improve the seismic performance of reduced beam section connections used hole drilling in two parallel rows. The cyclic behavior of the connection improved by preventing local buckling and premature failure in the distance between the holes and the proper arrangement of the beam flange holes. For this purpose, beam flange drilling arrangements were used with an inclined arrangement of holes with different hole diameters. The plastic strains are distributed extensively in the beam flange with an inclined arrangement of holes and prevent the concentration of stress and premature failure of the areas between the holes.

2. Methodology

In this study, the seismic behavior and damage index was studied for parallel and inclined arrangement of holes in beam flange connections. The plastic strain distribution in the beam flange can be changed appropriately by changing the beam flange drilling arrangement. In drilling patterns used two parallel and inclined drilling rows in the longitudinal direction of beam flanges with diameters of 20, 25, 30, 40, 45, 50, and 55 mm which are 18%, 23%, 27%, 36%, 41%, 45%, and 50% decrease in cross-sectional of the beam flange respectively. The distance of the nearest hole to column face (a) and the length of the reduced section (b) were met the following provisions per the American national standard of AISC358-16 [13]:

$$0.5b_{bf} \le a \le 0.75b_{bf} \quad (1)$$

$$0.65d_b \le b \le 0.85d_b \quad (2)$$

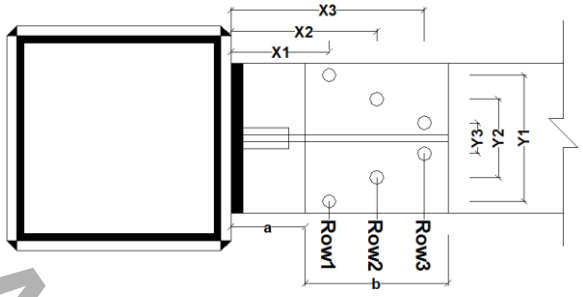

Figure 1. Determination of the location of holes and their diameters

The important damage indexes for evaluating the performance of moment resisting frame connections including equivalent plastic strain index (EPEQI), Pressure index (PI), and Mises index (MI) have been proposed by EL-Tawil et al [14].

3. Results and Discussion

The amount of cross-sectional plastic rotation in the proposed connection DFC7 sample is equal to 0.059 radians, which is 7.3% higher than the conventional RBS connection plastic rotation. The maximum resistance increase of 22.2% occurred in the connection of the DFC7 sample compared to the equivalent RBS connection. The maximum and minimum stiffness values are calculated for WUF and RBS samples, respectively. Also, the highest and lowest values of ductility coefficient are obtained for RBS and DFC3 samples, respectively. In the connection of the DFC7

sample decreased the equivalent plastic strain index occurred in the center and the corner of the complete joint penetration weld line compared to other connections. The highest and lowest values of the equivalent plastic strain index around the hole occurred in DFC8 and DFC1 samples, respectively. The proposed connection of the DFC7 sample has the highest value of 0.43 for the Pressure index in the corner of the weld line of the beam-to-column connection, which indicates the proper ductility of this connection compared to other proposed DFC connections. In the connection of the DFC7 sample, the largest decrease in the Mises index occurred in the center and the corner of the complete joint penetration weld line compared to other connections. Also, the Mises index decreased in the center of the weld line 45.5% and in the corner weld line 39.9% conventional RBS connection.

4. Conclusions

A significant reduction in equivalent plastic strain occurred in the center and corner of the complete joint penetration weld line of the beam-to-column connection in the DFC connections compared to the RBS connection. The proposed connection DFC7 sample with the inclined arrangement of holes in beam flange from a small diameter to a large diameter above the face column occurred a significant reduction of the equivalent plastic strain index on the weld line, also appropriate distribution of plastic strains happened between the beam flange holes due to the creation of diagonal paths between the holes compared to other connections. Increasing the values of Pressure index in the complete joint penetration weld line of the beam-to-column connection indicated the increase of local ductility of the weld line in the DFC7connection compared to the conventional RBS connection. Also in the DFC7 sample connection significantly reduced Mises index on the center and corner of the complete joint penetration weld line of the beam-to-column connection.

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