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Study of Seismic Behavior of Drilled Flange Connection with Slot Hole

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ABSTRACT: Extensive damages in welded unreinforced flange (WUF) connections in 1994 Northridge earthquakes has led to the idea of using reduced beam section (RBS) connections and Drilled Flange (DF) connection to prevent brittle failure modes in welded joints. In this paper, the seismic behavior of DF moment-resisting connection with slot holes as an easy-to-construct method for DF connection in seismic regions was investigated. DF connection is made by drilling at top and bottom beam flange along beam main axis to establish an intentional weak point to reduce stress concentration at the beam to column flange welded connection. In this investigation, Finite Element models which were validated with previous experiments were utilized to consider the effect of slot holes in DF connection compared to circular holes on rupture potential of the beam to column welded connection. The utilized FE models of DF connection with various geometric properties and different panel zone strength ratios were developed to investigate the optimum slot hole configuration and reduce the rupture potential at CJP groove weld. The results showed that the optimum drilled slot holes can shift the plastic strain at the beam to column welded connection having the ratio of slot hole length to hole diameter (L/D) by up to 2. Using the configuration of the latter holes, the plastic strain at the beam to column weld connection and around the holes decreases approximately by up to, on average, 28 and 70% respectively compared to corresponding values of DF connection with circular holes.

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1. INTRODUCTION

The 1994 Northridge earthquake was a turning point in the design and construction of welded steel beam-to-column moment connection [1,2].

Reduced Beam Section (RBS) connections were developed to find a reliable and practical solution for eliminating the CJP groove weld line fracture at beam-to-column welded connection [3]. The fabrication of RBS connections is difficult although it is categorized as a prequalified connection for use in special moment resisting frames (SMRFs) [1]. As an alternative for RBS connection, Drilled Flange (DF) moment-resisting connection was proposed by some researchers [4-5]. Some researchers proved that the DF connection is capable of accommodating the required seismic performance as desired by AISC [1-2]. Alibakhshi et al. [6] and Atashzaban et al. [7-8] find the optimum configuration of drilled holes to provide satisfactory seismic performance for DF connections. Ahmady Jazany [9] propose a design method for DF connections to improve the seismic performance of DF connection and estimate the seismic capacity of DF connection. More recently Maleki et al. [10] probabilistically evaluate the influences of drilled flange (DF) connection on seismic performance of steel moment frames (SMFs) incorporating near-field ground motions. They showed that DF connections can sustain the acceptable seismic performance similar to RBS connections.

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Table 1. Reference experiment specification

Column section	Beam section	Doublers Plate thickness	material		weld
			column	Beam	d/e/f
H220* 220*10*15	IPE270	8 (mm)	SM400	ST37	E7018 35/20

2. EXPERIMENTAL

To study the seismic behavior of the DF connection, some experimental tests conducted by Vetr and Haddad [5] were selected for experimental validation of finite element models (FEMs). Table 1 presents a summary of the test specimen's specifications.

2.1. Verification of developed FE models

The FE models are validated by using the hysteretic responses and experimental observations of reference test specimens. The cyclic responses of FE models of reference test specimens agree well with the experimental load-

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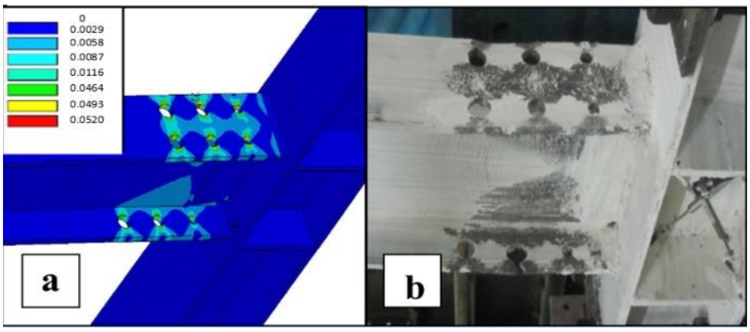

Fig. 1. Comparison between flaking off the whitewashed area on the test specimen and equivalent plastic strain distribution in the FE model of the test specimen.

displacement responses with less than 8% errors in peak strength points obtained at a story drift angle of 0.05 radians. The ultimate strength obtained from the inelastic FE analysis is well-correlated. As it is evident from Fig. 1, there is a good agreement between the flaking off the whitewashed area and EPEQ distribution for the analytical models of the reference experimental test with the experimental results from the test specimens.

2.2. Rupture index

In the present analytical study, the crack itself is not modeled explicitly but some analytical indices are employed to predict and monitor the crack initiation, related to the test observations and results. Rupture Index (RI) is one of the useful analytical indices utilized by many researchers [6-9] to evaluate the fracture potential of the connections. The Equivalent Plastic Strain (EPEQ) represents the local inelastic strain demand, used for comparing the rupture potential of different configurations of a connection. Triaxiality Ratio (TR) is the ratio of the hydrostatic stress to Von-Mises stress which is utilized to evaluate the seismic performance of DF connections.

Based on the cyclic void growth model (CVGM) developed by Kanvinde and Deierlein [11], EPEQ obtained from FEM can predict the initiation of cracking by defining the thresholds concerning the test observation; while, RI and TI are two measures that provide the potential of rupture in a structure. In other words, EPEQ can estimate the beginning of the rupture whereas RI and TR indices can compare the likelihood of rupture between different FE models. In this study EPEQ, RI and TI are employed for evaluating the seismic performance of DF connections.

2.3. Parametric FE analysis

In the present study, three important design parameters which play a pivotal role in the seismic performance of DF connection were considered including the ratio of hole slot length to hole diameter, panel zone strength ratio, and the row number of slot holes. These design parameters were not studied in the previous research studies despite their considerable effects on the seismic performance of DF connections. Some critical points are considered to compare the rupture index. These critical points are located around the slot holes and vicinity of the CJP groove weld. These critical points affect considerably the seismic performance of DF connection concerning the previous experimental study [5].

3. CONCLUSIONS

The present detailed analytical study was performed to improve the seismic performance of drilled flange (DF) moment-resisting connections. The detailed FE models were developed to investigate DF connection with slot holes. Based on the results of this study, the following conclusions can be drawn:

1-The FE analyses showed that DF connection with slot holes can reduce the EPEQ around the holes and beam to column weld connection by up to, on average, 28 and 70% compared

2-The optimum ratio of slot length to hole diameter is the approximate value of 2. Using this ratio can lead to the minimum RI and EPEQ value around the holes and beam to column weld connection for DF connection with slot holes.

3-The FE analyses revealed that using DF connection with a ratio of hole slot length to hole diameter equal to 0.5 results in maximum strength degradation of cyclic response by up to 18.8%.

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