Connection Behavior Analysis of Drilled Reduced Beam Flange and Reinforced Concrete Column

Ali Parvari[1*], Hamed Baratali[2], Fatemeh Shahrokhi[3]

[1] Assistant Professor, Department of Civil Engineering, Khomein Branch, Islamic Azad University, Khomein, Iran
[2] M.Sc., Department of Civil Engineering, Khomein Branch, Islamic Azad University, Khomein, Iran
[3] M.Sc., Department of Civil Engineering, Khomein Branch, Islamic Azad University, Khomein, Iran

ABSTRACT

Composite special moment frames represent a novel type of special moment frames (SMFs) where a combination of concrete columns and steel beams is used. This paper evaluates the modeling of composite special moment frames and the behavior of the steel beam-concrete column connection. Due to the focus on hinge formation, the behavior of the connection with a hole drilled on the beam flange was analyzed. Numerical simulations were carried out in ABAQUS. The beam-column connection was subjected to one-five rows of holes. It was observed that the beam-column connection with three rows of holes had the optimal hinge formation behavior, stress distribution, and load. The connection with five rows of holes showed plastic strains in the first four rows, while the fifth row had no plastic strain. This suggests an increased drilling space since the fifth hole row did not contribute to the improvement of stress distribution uniformity. It was numerically found that the bending moment change varied from 8% to 46%; the model with three rows of holes had the lowest bending moment change, whereas the model with a single hole row showed the highest change in the bending moment. Moreover, energy absorption changed by 4-20%.

KEYWORDS

Steel connection, ABAQUS, Circular hole, Nonlinear static time-history analysis, Shear capacity.

* Corresponding Author: Email: ali.parvari@iau.ac.ir

1. Introduction

Composite special moment frames are a combination of concrete columns and steel beams. These frames exploit the compressive strength of concrete in the columns and the tensile strength of the beams, reducing member sections. A reduced section would reduce the building weight and lowers the construction cost.

Plumier (1990) proposed the reduced beam section (RBS) when steel was considered to be a major reinforcement material [1]. Arbed (1992) analyzed and introduced the RBS in the United States; however, it was not franchised in the 1994 Northridge earthquake [2, 3].

To reduce construction costs and facilitate the implementation of reduced beam flange connections, Yang et al. [4] proposed the exploitation of holes in the beam flange to reduce the beam section. A number of studies demonstrated that holes of the same diameter could not meet SMF requirements [5, 6]. Later, a new methodology was proposed based on using holes of unequal diameters in a specific configuration. It was found that such connections could meet the requirements [7, 8].

2. Methodology

To validate the numerical models, a steel beam-concrete column connection investigated by Cheng and Chen [9] was simulated in ABAQUS (the validation specimen). The specimens were analyzed under incremental cyclic loading, comparing the numerical results to the experimental data. Figure 1 compares the numerical and experimental load-displacement curves.

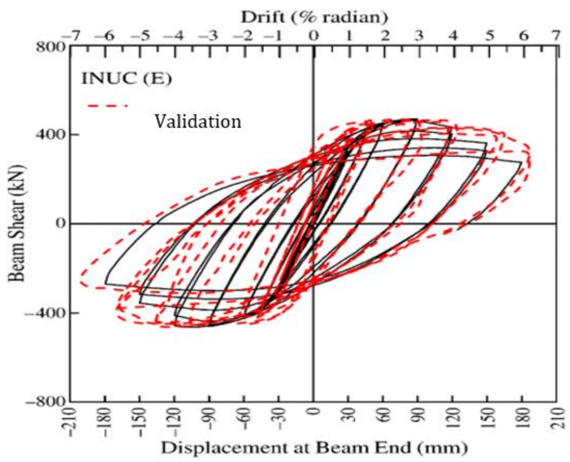

Figure 1. Numerical versus experimental load-displacement curves

This paper evaluated the behavior of a beam-column connection under two hole patterns. The first pattern consisted of holes configured in ascending size order to the middle and in descending order after the middle (symmetric configuration). The second hole pattern, however, consisted of holes of the same diameter, with a variable number of holes. The flange-web thickness was set to 1.5, 2.0, and 2.5. Nonlinear static time-history analysis was carried out. The models were subjected to cyclic loading in ABAQUS. The column had a concrete section and a column beam. Three seismic records were applied to a single-story frame with a span length of 6 m, according to model CFD-1.

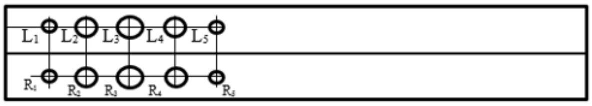

Figure 2. A flange drilling model

Table 1 reports the parameters of some of the twenty-seven models.

Table 1. Model parameters

Model	R1 (mm)	R2 (mm)	R3 (mm)	R4 (mm)	R5 (mm)
CDF-1	20				
CDF-5	20	20	20	20	20
CDF-27	15	25	30	25	15

Model	L1 (mm)	L2 (mm)	L3 (mm)	L4 (mm)	L5 (mm)	t/tw
CDF-1	100					1.5
CDF-5	100	100	100	100	100	1.5
CDF-27	100	100	100	100	100	2.5

3. Results and discussion

Figure 3 illustrates the von Mises stresses of some models.

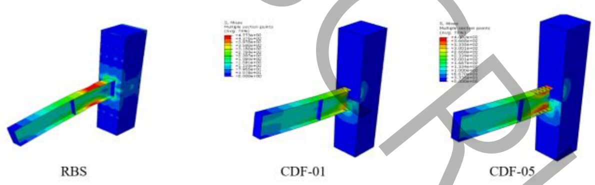

Figure 3. von Mises stress

According to Fig. 3, the drilled-flange models had stresses in the beam-column connection, which is satisfactory behavior. The base model without beam holes, however, experienced maximum stresses in the connection area near the column, which is unsatisfactory. Table 2 reports the numerical parameters based on the hysteresis loops for some of the models.

Table 2. Numerical parameters from hysteresis loops

Model	Max. Moment (kN.mm)	Stiffness (kN.mm/rad)	Ductility	Energy Absorption (kN.m.rad)
CDF-1	680.2	164519	0.6	2.35
CDF-5	681.4	157613	0.6	2.51
CDF-19	921.8	216984	0.6	3.07
CDF-27	690.9	197774	0.5	2.97
RBS	566.8	144519	0.5	1.88

Table 3 summarizes the displacement and base shear results under the seismic records.

Table 3. Displacement and base shear under seismic records

Record	Displacement (m)	Base shear (kN)
1992 Cape Mendocino	0.104	395
1979 Imperial Valley	0.089	370
1994 Northridge	0.097	340

4. Conclusions

The results can be summarized as:

- The symmetrically drilled models had mostly a uniform stress distribution between the holes. The symmetric configuration of holes in size-based order enabled such a uniform distribution of stresses between the holes.
- The minimum bending moment change varied from 8% to 46%.
- The minimum energy absorption change varied from 4% to 20%.
- The minimum ductility change varied from 10% to 25%.
- A rise in the middle hole reduced the load and moment capacities in all the models, partially due to the reduced section.
- A rise in the middle diameter reduced the moment capacity, and the incorporation of concrete into the model raised the moment capacity. An increase in the flange-web thickness ratio led to a 12-28% increase in the bending moment capacity of the connection.
- The model with three hole rows had nearly a 25-37% higher moment capacity than the one with five hole rows.
- The RBS model showed a 10% lower load capacity than the drilled models.

5. References

[1] A. Plumier, The dog bone: back to the future, Engineering Journal-American Institute of Steel Construction, 34 (1997) 61-67.

[2] M.D. Engelhardt, T. Winneberger, A.J. Zekany, T.J. Potyraj, The dogbone connection: Part II, Modern Steel Construction, 36(8) (1996) 46-55.

[3] R. KANNNO, Strength, deformation, and seismic resistance of joints between steel beams and reinforced concrete columns, Doctor Dissertation presented to the Faculty of Graduate School of Cornell University, ۱۹۹۳.

[4] C.M. Uang, Q.S.K. Yu, S. Noel, J. Gross, Cyclic testing of steel moment connections rehabilitated with RBS or welded haunch, Journal of Structural Engineering, 126(1) (2000) 57-68.

[5] J. Qian, H. Yu, F. Yan, H. Dong, J. Li, Y. Liu, Experimental study on full-scale steel beam-to-column moment connections, Earthquake Engineering and Engineering Vibration, 4(2) (2005) 311-323.

[6] K. Tsai, C.-Y. Chen, Performance of ductile steel beam-column moment connections, in: Eleventh World Conference on Earthquake Engineering, 1996.

[7] S.J. Lee, S.E. Han, S.Y. Noh, S.-W. Shin, Deformation capacity of reduced beam section moment connection by staggered holes, in: International conference on sustainable building, Seoul, Korea, 2007.

[8] M. Vetr, M. Miri, A. Haddad, Seismic behavior of a new reduced beam section connection by drilled holes arrangement (RBS_DHA) on the beam flanges through experimental studies, in: 15th world conference of earthquake engineering, Lisbon, Portugal, 2012.

[9] C.-T. Cheng, C.-C. Chen, Seismic behavior of steel beam and reinforced concrete column connections, Journal of constructional steel research, 61(5) (2005) 587-606