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EXTENDED ABSTRACT

Numerical Investigation on Seismic Behavior of Novel Moment Connections with Heat-Treated Beam Sections

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Moment connection, Reduced beam section, Heat-treated beam section, Seismic performance, Near-fault.

1. Introduction

Morrison et al. (2015) proposed a controlled heating process for steel in which every property of steel remains constant except its strength (i.e. yielding strength). This novel idea is used for the weakening of beam sections as reduced beam section (RBS) moment connections do. Therefore, plastic hinges develop away from the column face. In this paper, in addition to study the near-fault effects on this type of moment connections, parametric analyses are performed. Moreover, the seismic performance of this new weakened connection is evaluated using nonlinear static analyses. With regards to the obtained results, the best region of beam for heating is determined and seismic performance factors are proposed.

2. Methodology

2.1. Parametric analyses

In this study, the finite element modeling was verified based on an experimental specimen (Morrison et al., 2015). The modeling process was performed by ABAQUS software using reduced integration 4-node general-purpose shell elements with hourglass control which considers finite membrane strains. As the purpose is to overcome disadvantages of common RBS connection by substitution of this new heat-treated beam section (HBS), regarding to the recommended ranges of building codes for geometrical properties of the weakened zone, 3 different statuses were selected. The selected statuses were studied on W6x16, W14x48, and W21x73 cross-sections with only flange (F_HBS), only web (W_HBS) along with both flange and web (WF_HBS) heat-treatments.

2.2. Study on the effects of near-fault loading history

Due to the importance of near-fault ground motions and their destructive effects, the proposed cyclic loading history by Krawinkler et al. (2000) was used for the evaluation of seismic behavior of HBS connections. In this section, the model had 2 beams that were connected to the column and they were modeled in ABAQUS in the same way as mentioned in section 2.1.

2.3. Seismic Performance factors

To estimate seismic performance factors, 2 dimensional 5-, 10- and 15-story building models were analyzed by the nonlinear static procedure in SAP2000. For the definition of bending plastic hinge behavior in beams, the envelop curve of the obtained hysteretic curves was used. Finally, response modification factor, overstrength factor and displacement amplification factor were estimated using the ATC19 approach.

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3. Results and discussion

The hysteretic curve of bending moment against drift ratio at column face for W14_F_HBS, W14_W_HBS, and W14_WF_HBS is shown in Fig. 1. Regarding to Fig. 1, there is no significant strength reduction until 4% drift ratio which is an acceptable ductility limit for special moment-resisting frames. At last steps of loading, due to some minor local buckling in flange or web of models, strength degradation is observed; however, up to 6% drift ratio, moment strength is not less than 80% of the plastic moment of section.

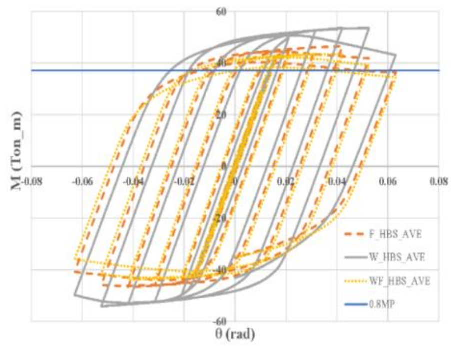


Fig. 1. Hysteretic curve of M- θ for W14

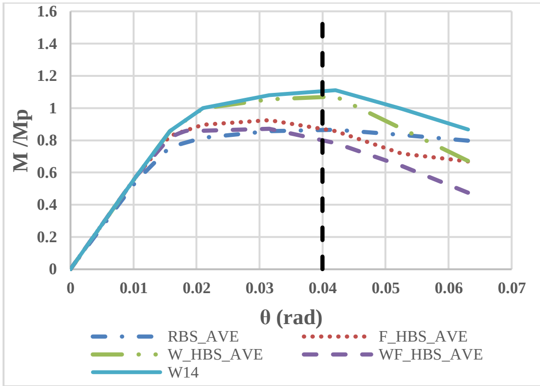
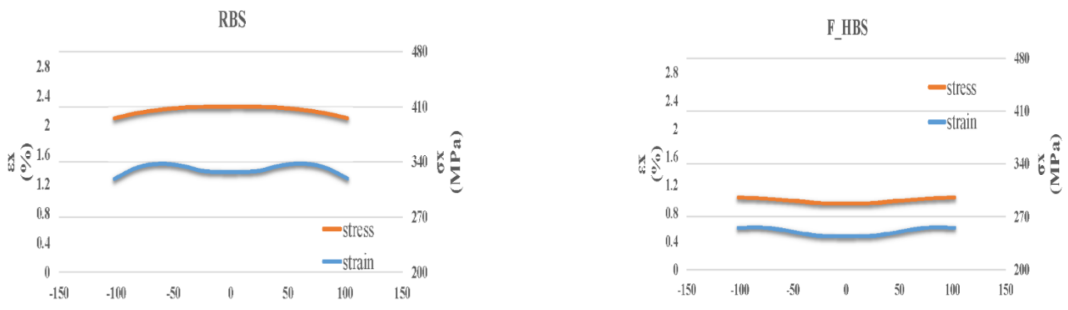


Fig. 2. Comparison of envelop curves at column face for W14, W14_RBS and W14_HBS

With respect to Fig. 2, it is shown that M/M_p for W14, and W14_W_HBS is more than 1 which means plastic hinge develops at column face that in turn causes brittle fracture at connection. In contrast, 3 models of W14_RBS, W14_F_HBS and W14_WF_HBS have a value less than 1 for M/M_p. Moreover, it is concluded that the models in which only flange or both flange and web are heat-treated, there is a similar strength, stiffness, and ductility values with respect to RBS.

However, in both of the weakening methods, the material inelasticity is developed at the desired location, but there are differences in the distribution and amount of stress and strain (Fig. 3). In the case of F_HBS, due to the reduced yielding strength of the beam flange along with not area reduction in the flange, the amount of stress decreased. Moreover, the extension of inelasticity along the heat-treated region caused the strain values to decrease. Also, due to the fact that in this novel method, in contrast to the RBS, the flange area is not variable, the distribution of stress and strain is almost uniform and linear. This stress reduction along with no area change in the HBS cross-section increase resistance to buckling. In addition, it can be noted that the performance of F_HBS beams has been extended over the entire heat-treated region, but for the RBS beams, it is more concentrated in the center of the reduced area.



(a) (b)

Fig. 3. Stress and strain distribution across beam flange at the center of the weakened region for W14_Ave at 2% drift ratio

The obtained hysteresis curve for applied near-fault loading history (Fig. 4), indicates the acceptable seismic performance of these connections without any strength degradation in both near and far fault zones. For evaluation of the global behavior of HBS connections, seismic performance factors have been estimated by ATC 19 approach. In this study, two kinds of triangular and uniform lateral loading distribution have been considered and ductility reduction factors were calculated based on two approaches of Newmark-Hall and Nassar-Krawinkler. Table 1 shows the estimated values.

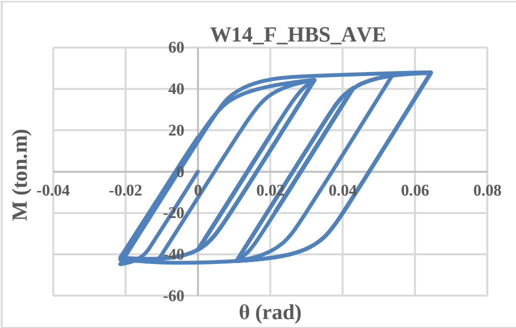


Fig. 4. M- θ hysteretic curve for W14_HBS_Ave under near-fault loading history

Table 1. Seismic performance factors

Type of loading	Triangular loading			Uniform loading		
No. of story	5	10	15	5	10	15
Ω	3.3	3.5	3.3	4.25	4.55	4.1
μ	1.87	1.67	1.6	1.65	1.57	1.62
C_d	6.3	5.8	5.3	5.5	7.1	6.6
R_μ (ATC 19, Newmark-Hall)	1.7	1.67	1.6	1.55	1.57	1.62
R_μ (Nassar-Krawinkler)	1.87	1.69	1.62	1.66	1.59	1.64
R (ATC19, Newmark-Hall)	5.6	5.8	5.3	6.6	7.1	6.6
R (Nassar-Krawinkler)	5.2	5.9	5.3	7	7.2	6.7

4. Conclusions

Regarding to the obtained results from the numerical investigation of this study, it can be concluded that HBS connections have the same strength as RBS in addition to the elimination of buckling failure mode. Moreover, in F_HBS and WF_HBS connections, the value of the required bending moment to plastic moment ratio at column face has been reduced that in turn prevents brittle fracture. Generally, based on the observations, the F_HBS_Ave connections indicate acceptable seismic performance without any considerable strength degradation in both near and far fault zones. Based on the limited study on global behavior of these connections in this paper, the value of 6.2 is proposed for response modification factor for special moment-resisting frames with HBS beam-column connections.

5. Acknowledgments

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6. References

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