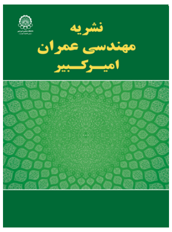

Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(8) (2021) 771-774
DOI: 10.22060/ceej.2020.17981.6727

Numerical Investigation of Shape Memory Alloys and Side Plates Perforation Effect on Hysteresis Performance of Connections

V. Saberi[1*] , H. Saberi[1], O. Misagh Mazaheri[1], A. Sadeghi[2]

[1] Department of Civil Engineering, University of Eyvanekey, Semnan, Iran
[2] Department of Civil Engineering, Mashhad Branch, Islamic Azad University, Mashhad, Iran

ABSTRACT: The most common disadvantage in moment connections is the brittle fracture of the welded area during an earthquake. One creative way to fix such disadvantages is to use Side Plates to connect the beam to the column. Previous studies have focused more on the performance of connections with side plates and comparison of these connections with other types of moment connections. In this study, the effect of material type, thickness, and perforation of the side plates on the cyclic performance is investigated. For this purpose, in addition to using side plates of soft steel (ST37) and high strength structural steel (ST52), nickel-titanium-shaped memory alloy (SMA-Ni-Ti) was also used to investigate the superelastic effect of this alloy on the connection performance. Modeling and analysis were performed in ABAQUS finite element software under cyclic loading. The results showed that the increased capacity and ductility of the side plate connections with shape memory alloy. Also, the findings revealed that optimal thicknesses can be obtained for a side plate to create the maximum possible ductility at the connection and preventing the formation of plastic hinges. According to the results obtained by changing the configuration and cutting in connection and in general, the capacity of the connection decreased by 0.04 radian (moment frame acceptance limit) and stress concentration in the cutting corners had the greatest effect on the failure of the side plates.

Review History:

Received: Feb. 22, 2020
Revised: Jun. 14, 2020
Accepted: Jul. 28, 2020
Available Online: Aug. 22, 2020

Keywords:

Moment connection
Side plate
Brittle fracture
Cyclic performance
Shape memory alloy

1. INTRODUCTION

The construction of steel moment-resisting frame structures underwent dramatic changes in the second half of the 20th century, resulting in the challenge of code design trends by earthquakes such as Northridge (1994) and Kobe (1995). The performance of steel structures in these two earthquakes was lower than expected in terms of ductility and the brittle failure was observed in steel moment-resisting frame joints. One of the connections that have become popular in recent decades is the connection of beams to columns using side plates. In the side plate connections, a pair of steel plates connect the beam to the column. This removes the welded connection of the end of the beam to the wing of the column and the beam does not have a direct connection to the column. In this type of connection, steel plates at the top and bottom of the beam are used only to fill the gap between the width of the beam and the width of the column [1]. Studies on the side plate joints have often focused on determining seismic performance, comparison with other joints. Vaseghi Amiri *et al.* [2] investigated the seismic parameters of dual systems with side plate joints and calculated seismic parameters such as ductility coefficients, allowable stress, and strength resistance parameters in this type of frame. Deylami and Shiravand [3] presented two samples of moment connections with the side plate under cyclic loadings were tested and their cyclic performance was investigated. Farmani and Ghassemieh [4] examined two categories of beam-to-column joints equipped with nickel-titanium shape memory alloy tendons and steel pins as complementary energy dampers and their role. They were determined in the seismic improvement of steel moment frame joints. Hashemi *et al.* [5] have modeled two frames with 6 and 12-story with buckling restrained braces in OpenSees software in two dimensions in two modes with and without shape memory alloys, and finally, the role of shape memory alloys has been investigated using incremental dynamic analysis (IDA) under 7 far-fault records. Based on the IDA curves, the collapse capacity of the frames is presented and finally, the fragility curves are developed. The results showed that the collapse capacity of buckling restrained braced frame equipped with shape memory alloys is higher than the buckling restrained brace. So far, most studies have focused on the bearing capacity and ductility of side plate connections. In this study, as a novelty, the effects of material, thickness, and perforation of the side plate on the performance of the connection cycles are investigated using ABAQUS finite element software [6]. Also, in this study, by modeling nickel-titanium shape memory alloys, in addition to mild and high-strength low-alloy steels, the superelastic properties of these alloys in the side plate joints were investigated and compared.

*Corresponding author's email: saberi.vahid@gmail.com

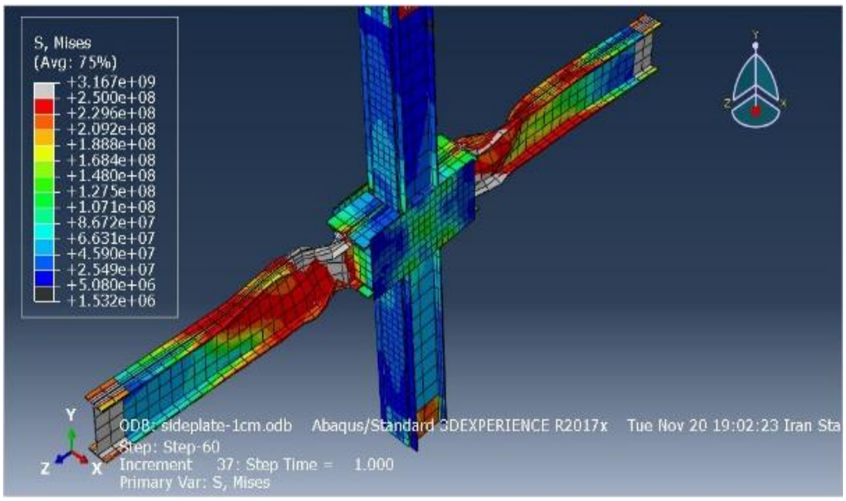

Fig. 1. Experimental sample modeled in finite element ABAQUS software

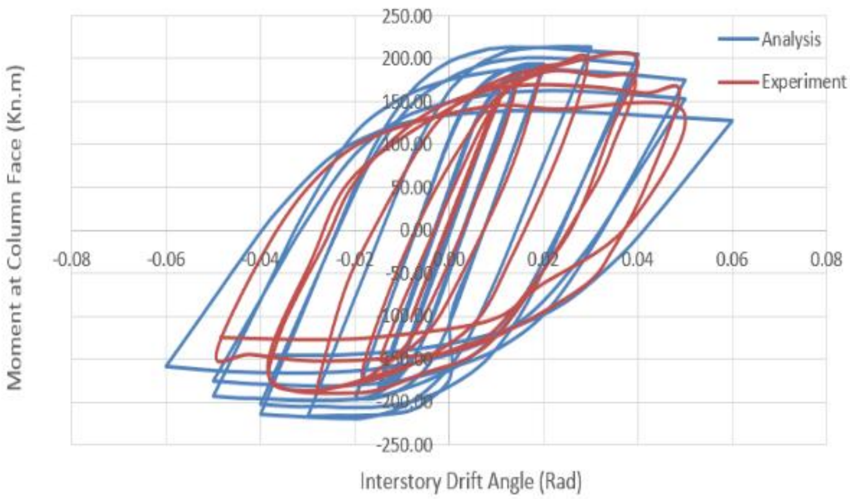

Fig. 2. Comparison of the moment-rotation hysteresis curve of Deylami and Shiravand's experimental sample [3] with the analytical model in ABAQUS software

2. METHODOLOGY

To verify the studied models, the finite element model of an experimental sample tested by Deylami and Shiravand [3] has been simulated in ABAQUS software. The configuration of the model is presented based on Fig. 1. Afterward, the shape memory alloy rod [7] is modeled in ABAQUS software.

As shown in Figs. 2 and 3, the moment-rotation hysteresis curve of the side plate and stress-strain diagram of shape memory alloy in ABAQUS software are in good agreement with the experimental results, respectively [3, 7]. The outputs were extracted with Matlab software [8]. Therefore, dynamic analysis was performed under cyclic loading and the behavior of side plates was investigated concerning changes of material parameters, thickness, and conFiguration on the cyclic performance of the joints. The first parameter was investigating the effect of side plate material on the performance of the connection cycles in the models M-1, M-2, and M-3. These specimens were made of ST37, ST52, and Ni-Ti shape memory alloys, respectively. In the following, the effect of side plate thickness was investigated on the cyclic performance of the connection. The models T-1 to T-5 are presented and finally, the effect of being perforated on the side plates (S-1 to S-4) was studied.

3. RESULTS AND DISCUSSION

In the models M-1 and M-2, in which the side plate is made of ST37 and ST52, respectively, it can be seen that the connection capacity during the 0.04 rad is highly dependent on the material of these steels. Basically, with the increase of the moment somewhat higher than the plastic moment of the beams, the occurrence of local buckling in the wing and the beam, the hysteresis curve of these specimens has decreased. In the model M-3, considering the use of nickel-titanium shape memory alloy and the superelastic properties of this material, it can be seen that firstly, considering the modulus of elasticity is less than the slope of the curves M-2 and M-1,

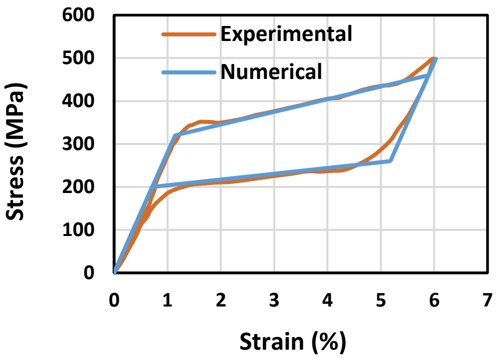

Fig. 3. The numerical and experimental shape memory alloy

while the drop in the hysteresis curve M-1 and M-2 is also seen in the M-3 curve. In model T-1, the thickness of ST37 has been reduced to 1 cm. This reduces the connection capacity during the 0.04 rad, however, in this case, the moment drop after displacement of 0.04 rad is not as strong as in the models M-1 and M-2. In other words, as the thickness of the joint plate decreases, the joint stiffness decreases relative to the stiffness of the beam, and less force is applied to the beam, but the stresses created on the joint plate will also be greater. In model T-2, the thickness of the side plate has been reduced again to 0.5 cm. By doing this, there is practically no moment drop in relative displacements above 0.04 rad, because local buckling and large deformations do not occur as in the previous cases. In this case, only the local buckling can be low. Observed the beam in the last loading cycle. The reason for the lack of local buckling in the upper wing is that the lower connecting plate is one piece and therefore has more stiffness than the upper plates and more forces on the lower wing of the beam than the upper wing. In model T-2, the stresses created in the side plate steel are very high, and unlike the side plates in the previous models, which had elastic behavior, in this case, the side plate shows the plastic behavior. Models T-3 and T-4 withstood up to 0.07 rad. In the models S-1 to S-4, the performance of the side plate was examined by creating a semicircular and rectangular section by changing the configuration. In the models S-1 and S-3, by creating two semicircular and rectangular cuts, the connection capacity was reduced by 3% compared to the non-cut plate mode. In models S-2 and S-4, four semicircular and rectangular cuts are made in the side plate and it is observed. In this case, the moment drop during 0.04 rad was significant, and also the connection was only able. It can withstand up to 0.05 rad.

4. CONCLUSION

In this study, the effect of changes in the material, thickness, and shape of the side plates was investigated on the moment joints under the effect of cyclic loading with ABAQUS finite element and Matlab softwares. In total, to evaluate the effect of mentioned changes, 12 numerical samples including 3 models for material effect, 5 models for thickness effect, and finally, 4 models were considered for the effect of configuration. The following results are summarized:

It was found that the side plates with nickel-titanium-shaped memory alloy in the same thickness withstand a higher force capacity and absorb more energy.

In models that include changes in the thickness of the side plate, it was found that in steel plates, although the anchor capacity of the joint decreases, still up to a thickness of 1 cm, the number of ductility increases, and the moment drop occurs less at higher displacements.

By further reducing the thickness of steel side plates at high displacements, the side plate showed the behavior of plastic and did not cause much deformation in the steel. But, since the amount of moment tolerated in the connection was more than 0.8 plastic moment, it can also be used in bending frames with special ductility.

Changing the configuration in the side plates such as being perforated until this change of configurations was not in stressful points (the central part of the connection plate and the area connected to the wing of the column). This change did not have much effect on the connection capacity, but changing the configuration in stressful areas, reduced connection capacity quickly.

REFERENCES

[1] FEMA-350. Recommended Seismic Design Criteria for New Steel Moment-frame Buildings, (2013).

[2] Z. Rahmani, M. Naghipour, J. Vaseghi Amiri, and R. Karimnezhad, Comparing Seismic Parameters in Dual Systems Equipped with Concentric and Eccentric Braces and Side Plate Connection, Middle East Journal of Scientific Research, 14(3) (2013) 300-308.

[3] A. Deylami, and M. Shiravand, The Experimental Study on Moment Connection of Beam to Double I Column Using Full Depth Side Plates. The 14th World Conference on Earthquake Engineering, Beijing, China, (2008).

[4] M. A. Farmani and M. Ghassemieh. Steel beam-to-column connections equipped with SMA tendons and energy dissipating devices including shear tabs or web hourglass pins, Journal of Constructional Steel Research, 135 (2017) 30-48.

[5] M. Pouraminian, S. Hashemi, A. Sadeghi, and S. Pourbakhshian, Probabilistic Assessment of the Seismic Collapse Capacity of Buckling-Restrained Braced Frames Equipped with Shape Memory Alloys. Journal of Structural and Construction Engineering, (2020). Doi: 10.22065/jsce.2020.236804.2174.

[6] Abaqus, Abaqus/standard. Version 6.11, ABAQUS, Inc., Pawtucket, R.I, (2012).

[7] F. Auricchio, D. Fugazza, and R. DesRoches, A 1D rate-dependent viscous constitutive model for superelastic shape-memory alloys: formulation and comparison with experimental data. Smart Mater Struct. 16(1) (2007).

[8] MATLAB (matrix laboratory), Multi paradigm numerical computing environment and proprietary programming language developed by Math Works, (2013). https://www.mathworks.com/help/matlab.

HOW TO CITE THIS ARTICLE

V. Saberi, H. Saberi, O. Misagh Mazaheri, A. Sadeghi, Numerical Investigation of Shape Memory Alloys and Side Plates Perforation Effect on Hysteresis Performance of Connections, Amirkabir J. Civil Eng., 53(8) (2021) 771-774.

DOI: 10.22060/ceej.2020.17981.6727