Investigation the cyclic behavior of rigid RBS connections with horizontal and vertical stiffeners in steel moment- resisting frame

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ABSTRACT

In this study, RBS connections behavior reinforced by horizontal and vertical stiffeners are assessed under cyclic loading and the effect of stiffeners is studied in order to improve the cyclic behavior of connections. The Finite Element ABAQUS software has been used to verify and simulate reduced beam section (RBS) connection behavior. Parametric study have been conducted by changing the stiffeners number, material and arrangement in connection area. The finite element analyses results showed that when using a combination of two horizontal and two vertical stiffeners, the initial and ultimate strength of the connection have been increased by 6.2% and 26.1%, respectively, compared to that of the connections without stiffeners. When using horizontal and vertical stiffeners in a rectangular arrangement with a length equals to 75% of the section reduction area length and its height equals to 75% beam height, the initial and ultimate strength of the connection has been increased by 6% and 20%, respectively in comparison the state without stiffeners. By comparing the use of ST37 and ST52 in stiffeners, it has been observed that both used steels have the same effect on the connection strength. Meanwhile, the effect of steel material of stiffeners could be ignored on improving the connection strength.

KEYWORDS

Reduced Beam Section (RBS) Connection, Cyclic Loading, Horizontal Stiffener, Vertical Stiffener, ABAQUS Software.

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1. Introduction

Beam-to-column connections in steel moment-resisting frames play a special role in their ductility, and for some time it was thought that the flexural connections used in this type of frame were responsible for providing the ductility. They do acceptance well. But the 1994 Northridge earthquake was a turning point in the performance of moment-resisting frames. After the earthquake, it was found that the beam-to-column connections in these frames in many buildings suffered brittle rupture and their ductility was questioned. Researchers conducted various experiments and studies to improve the behavior of beam-to-column connections in these frames and proposed two basic strategies to improve their performance, including strengthening the connection and deliberately weakening the beams connected to the RBS to the column. RBS means that the deliberate weakening of the bending capacity of the beam locally at a short distance from its connection to the column, which in itself increases the ductility and plasticity of the connection, without significantly reducing its stiffness and strength. Reducing the cross-section of the beam can be done in different ways, including reducing the cross-section of the wing in different ways and reducing the cross-section of the life. In some cases, it has been observed that the cross-sectional reduction strategy also has weaknesses such as reducing the connection resistance against lateral-torsional buckling and also reducing the load bearing capacity against large displacements. One of the methods to strengthen the beam connections with reduced cross-section (RBS) is the use of horizontal and vertical stiffeners at the point of reduction of the cross-section of the beam in its life [1-2]. In the following, the background of research about RBS connections using horizontal and vertical stiffeners is presented. Tahamouli Roudsari and Moradi (2018), in order to evaluate the efficiency of the proposed stiffeners, performed 4 tests on RBS connections with IPE140 and IPE270 beams in two modes with and without stiffeners. The results showed that the proposed stiffener significantly increases the ductility of the connection without significantly increasing the bond strength [3]. Kanao et al. (2018) analyzed the behavior of RBS connections with horizontal and vertical stiffeners. The results of this study showed that without the use of sufficient lateral restraint, horizontal and vertical stiffeners have the ability to delay local buckling and prevent stress concentration. In addition, the strength of the beam is more than 80% of its plastic strength [4]. Due to the fact that the research conducted on the reinforcement of RBS connections using stiffeners is very limited and small, in this study, the behavior of RBS connections that are reinforced using horizontal and vertical stiffeners is investigated. In this study, the effect of horizontal and vertical stiffener parameters on reinforcement and performance improvement of bending connections with reduced beam section such as number, material and arrangement of stiffeners is studied, which is a significant innovation.

2. Methodology

Li et al. (2009) analyzed the local instability behavior of RBS connection under cyclic load [5]. According to the reference for verification, the beam with W30X99 cross section was selected and modeled in ABAQUS software [6]. The RBS connection is modeled based on Fig 1. Figs 2 and 3 show the moment-rotation curve of the reference sample and finite element model. In this figure, the horizontal axis represents the rotation of the end of the beam relative to the fixed end and the vertical axis represents the ratio of the rotation of the end of the beam. The maximum strength of the test connection is in the first loading cycle and is equal to 0.980 times the plastic beam rotation. In the connection of the finite element model, this strength is equal to 1.023 times that of the plastic rotation, which indicates an error of 4.4% in estimating the maximum connection strength. The final connection strength in the test is equal to 0.539 plastic rotation, which is equal to 0.545 plastic beam rotation in the finite element model, which indicates 1.1% error of the finite element model.

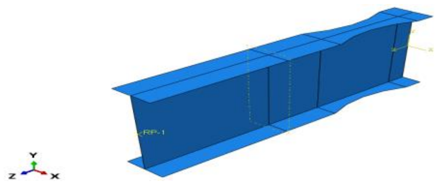

Fig 1. The finite element model of RBS.

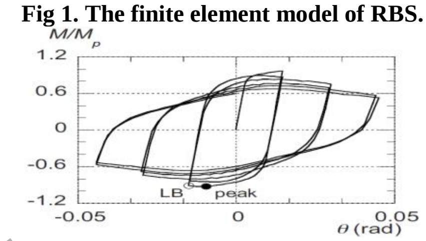

Fig 2. Hysteresis curve of reference model.

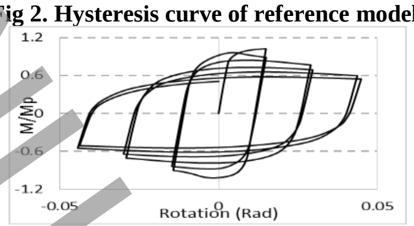

Fig 3. Hysteresis curve of finite element model.

3. Results and Discussion

In this study, the material of steel in the models has been examined. First, the steel in the models is ST37 with a yield strength of 240 MPa. To investigate the effect of the material of stiffeners in three cases, the material of stiffeners was changed to ST52 with a yield strength of 360 MPa and the results were compared with the results of the corresponding models of stiffeners made of ST37. In three models S-1, H-3 and V-3, the material of stiffeners was changed to ST52 and the resulting models were named S-1-ST52, H-3-ST52 and V-3-ST52, respectively. In Figs. 4 to 6, the effect of the stiffeners material on the final strength is compared at the end of each loading cycle. As it can be seen, the use of ST37 and

ST52 has an almost equal effect on increasing the final strength of the connection, and the effect of the stiffeners material on increasing the final strength of the connection can be ignored. Figs. 7 and 9 show the effect of the material of the stiffeners in reducing the maximum deformation of the beam core at the cross-sectional area, which indicates the local buckling of the beam at the RBS connection.

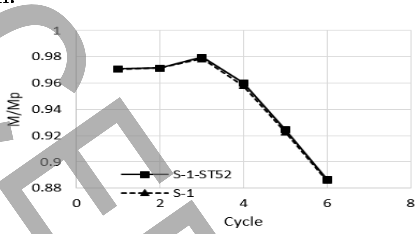

Fig 4. Comparison of the final strength of S-1.

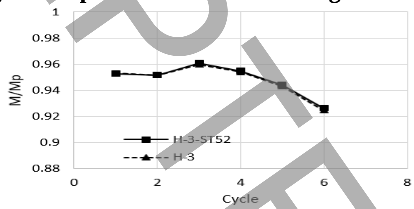

Fig 5. Comparison of the final strength of H-3.

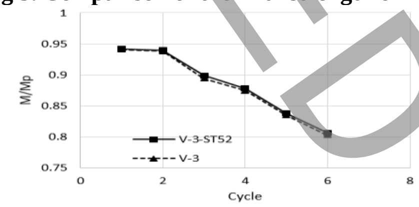

Fig 6. Comparison of the final strength of V-3.

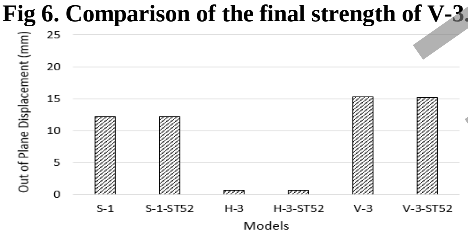

Fig 7. Maximum out-of-plane deformation of RBS model.

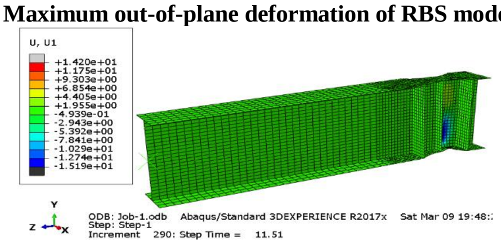

Fig 8. Stress distribution in the sixth loading cycle.

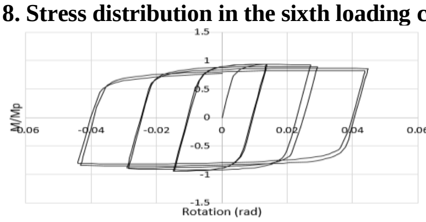

Fig 9. Hysteresis curve of moment-rotation of-end-of-beam at RBS connection.

4. Conclusions

In this study, the behavior of RBS connections reinforced by using horizontal and vertical stiffeners was investigated. Parametric study was performed by changing the material and arrangement of stiffeners at the RBS connection. The summary of the results is presented as follows:

• In addition to increasing the strength of reinforced connections by using horizontal stiffeners, in reinforced connections using two or three stiffeners, local buckling is reduced and the strength of the connection is decreased.

• In reinforced connections using a combination of two horizontal stiffeners and one or two vertical stiffeners, the deterioration of the connection strength is greatly reduced.

• Comparing the use of ST37 and ST52 in stiffeners, it was observed that both modes have the same effect in increasing the bond strength and the effect of the stiffeners material in increasing the bond strength can be ignored. .

• By adding stiffeners to the connection, the expansion of plastic strains in the beam core and at the cross-sectional area is prevented and the possibility of lateral buckling of the die is reduced.

• The results of this study are practical and can be extended to other sections of RBS connections to strengthen RBS connections using horizontal and vertical stiffeners by considering the number, material and arrangement of stiffeners.

5. References

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