Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 55(7) (2023) 311-314
DOI: 10.22060/ceej.2023.21567.7760

Evaluating the Behavior of Welding-Defected CFRP Fiber-Reinforced Double-Channel Steel Columns

F. Vazifehdan, M. Shahraki *

Department of Civil Engineering, Islamic Azad University, Zahedan, Iran

ABSTRACT: Engineers have faced many structural problems in recent years, such as buckling, corrosion and excessive loading in damaged steel structures. The labor force's mistakes during welding and the destruction of the weld are among the many problems in steel structures. Therefore, strengthening and repairing the welding place in steel structures is inevitable. This article investigates the influence of polymers reinforced with carbon fibers for strengthening steel studded double columns with defects caused by welding. For this purpose, seven steel columns were modeled in Abaqus finite element software. A CONTROL column was modeled as the first sample with no defects and welded all over. The rest of the defective samples were reinforced using CFRP fibers. On the other hand, strengthening using CFRP fibers to improve the location of the defect was investigated in detail for three specimens. Reinforcement of these sections using CFRP fibers is not only an effective method to increase the maximum axial force in these columns, but it has also helped to improve resistance and delay local buckling in them. According to the results, it was observed that among all the samples, the maximum bearing capacity is related to the 2UW3 model, and it has increased by 29.9% and 21.7% in the laboratory sample and numerical modeling, respectively, compared to the 2UW3C1 sample. In addition, 2UW3C1 and 2UW1C1 samples have the highest hardness among laboratory and numerical modeling samples, respectively..

Review History:

Received: Jul. 07, 2022
Revised: May, 16, 2023
Accepted: May, 24, 2023
Available Online: Jun. 19, 2023

Keywords:

Strengthening
Defects
CFRP
Double-Channel Steel Columns
Welding

1- Introduction

In general, composite utilization began in the 1940s and, like many other techniques and technologies, first had military applications and mostly used in the aerospace industry. After World War II, the use of polymers and polymer composites increased by almost 80% in the missile industry in the USA and Western Europe, and its low weight and high strength caused it to be used quickly in other fields such as construction /automotive, industry, dock/vessel/speedboat/ marine manufacturing and so on as well [1]. CFRP layers are used to strengthen masonry, wooden, and steel structures. CFRP covers are an alternative to other methods, such as steel plates, concrete, or metal column sheaths [2]. A wide range of adhesives can be used to bond between CFRP and metal materials, including epoxy, polyurethane and acrylic elements [3]. Below are some of the studies done.

Reza Dost et al. [4] investigated the effect of FRP fibers on the ultimate strength and deformation of X-shaped tubular joints under compressive axial loading. First, the results obtained from finite element models were validated with laboratory results. To investigate various variables in strengthening X-shaped tubular joints using FRP fibers, including material, length, twist angle and the number of layers, 75 joints in reinforced and unreinforced states were created and analyzed to study their nonlinear static behavior. Nasirai and Reza Dost [5] studied the static capacity of X-shaped tubular joints reinforced with fibers under compressive load. The results showed that FRP could significantly improve the stiffness, ultimate capacity and failure mechanisms. According to the above studies, it was observed that more research needs to be done on strengthening weld defects in double stud columns. In addition, the use of re-welding in places where defects in the weld in steel columns are caused by incorrect execution, corrosion caused by environmental conditions, problems such as high heat in the welding area and destruction of the defect area, creating residual stress due to Welding will result in the failure of Welding to be performed correctly in the columns in the columns under load and during operation. In addition to the ease of using CFRP fibers, the high resistance created compared to their small weight and the lack of need for re-welding in the columns can be among the advantages of using these fibers over re-welding.

2- Specifications of the Columns and Materials

The height of each 5 mm-thick steel column specimen was 1000 mm and its cross section was 100 × 100 mm. Supports were rigid at the bottom, welded and fixed with 1 steel plate and 8 angles for more strength, and hinged at the top with 1 steel

*Corresponding author's email: shahraki@iau.ac.ir

Table I.Specifications of the specimens.

Specimen	Weld length (mm)	CFRP length (mm)
CONTROL	1000	0
2UW1	750	0
2UW1C1	750	250
2UW2	500	0
2UW2C1	500	500
2UW3	250	0
2UW3C1	250	750

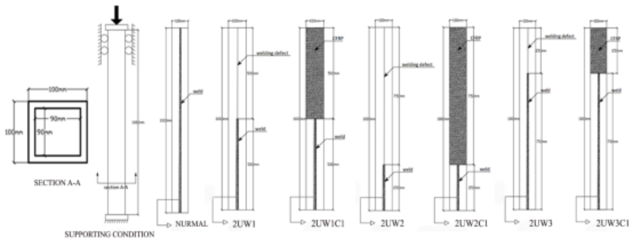

Fig. 1. Measured geometric dimensions of the specimens

plate. The slenderness ratio (λ = KL/r) was 18.66, calculated based on the National Building Code of Iran, Article 10. To make specimens with support conditions normally possible in practice, the design value of the effective buckling-length coefficient for the mentioned column specimens was taken to be 0.7 (as in the Code). The λ_Y selected column is in the inelastic buckling range, intermediate class; hence, it can be considered as a representative of intermediate columns to study and analyze the results. After studying the location, cross section and shape of the defects in the desired columns, all specimens were classified as in Table 1.

As shown, the CFRP fiber coating lengths at the defect locations are 250, 500 and 750 mm, respectively, the height is 1000 mm for all columns and specifications of steel materials are according to the tensile test requirements. Fig.1 shows the specifications of the defects and column dimensions of the no-defect CONTROL specimen and 2UW1, 2UW1C1, 22UW, 2UW2C1, 2UW3 and 2UW3C1 defective specimens with and without CFRP.

3- Experimental and Numerical Modeling

The axial load was then applied slowly by the pump at a constant speed, and axial deformations and the final load were accurately recorded by the software and a 16-channel data logger. Fig.2 shows an example of the columns, connected tools, and experimental specifications for columns under the effects of axial loads. The preparation of the specimens for compression tests is examined next.

Fig. 2. Loading jack and experimental conditions.

Fig. 3. Defect retrofitting by CFRP fibers and specimen preparation for loading process.

Fig. 3 shows some column specimens prepared after CFRP fiber retrofitting for compression tests under the loading jack.

The method of modeling samples in Abaqus software. Abaqus software version 2-14-6 was used to model the samples. To analyze the behavior of columns, local and overall buckling of samples, steel, glue and CFRP models, eight-point three-dimensional elements (3D-8R) were used. The Rex static type analysis method was chosen to observe better the local buckling of the samples in the buckling area.

3- 1- Failure Modes in CONTROL Column (Group 1)

As the failure mode, here, is not visible as a general buckling, the local deformations are observed as local buckling around the defect location. Fig.4 shows the local axial loading-induced stress distribution and buckling at the top of the CONTROL column.

3- 2- Fracture Mode of Group 4 Column Specimens

Fig. 5 shows the stress distribution and local buckling around the defect location in the non-retrofitted 2UW3 column having a 750 mm-long defect; as it is the weakest specimen compared to others, it can carry the lowest axial load. Its fracture results showed the separation of the two steel channels from the bottom of the support at the top to where welding started at the end of the column.

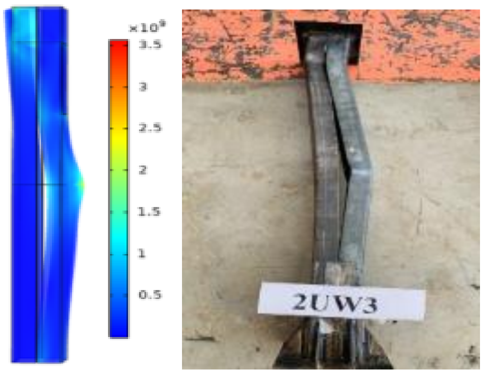

Fig. 5. Experimental and modeling local buckling for CFRP fiber-free 2UW3 steel column.

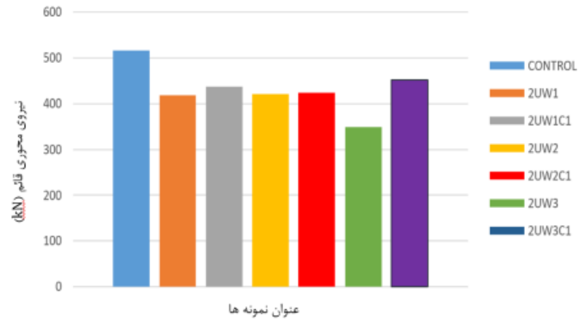

Fig. 6. Maximum bearing capacity of all columns in modelling specimens without CFRP fibers and reinforced with CFRP fibers

4- Result and Discussion

After examining and analyzing all the samples studied in this research, including seven samples, a numerical study and comparison of all the columns is made in Abaqus software through a bar chart in Figure 6.

5- Conclusion

The research results showed that the lowest and highest bearing capacity is related to the 2UW3 column, which has decreased by 32.3% compared to the control column. It was also observed that the maximum bearing capacity is associated with the 2UW3 sample, and it has increased by 29.9% and 21.7% in the laboratory sample and numerical modeling, respectively, compared to the 2UW3C1 specimens. In addition, samples 2UW3C1 and 2UW1C1 have the highest hardness among laboratory samples and numerical modeling, respectively.

References

[1] M. Shahraki, Improving the Structural Performance of Defective BOX-Section Steel Columns Using CFRP, PhD thesis, University of Sistan and Baluchistan.(2019), (in Persian).

[2] N. Geier, J.P. Davim, T. Szalay, Advanced cutting tools and technologies for drilling carbon fibre reinforced polymer (CFRP) composites: A review, Composites Part A: Applied Science and Manufacturing, 125 (2019) 105552.

[3] X. Zhang, H. Hao, Y. Shi, J. Cui, X. Zhang, Static and dynamic material properties of CFRP/epoxy laminates, Construction and Building Materials, 114 (2016) 638-649.

[4] P. Rezadoost, Nasirai, H. and Neshai, S.A., Investigating the performance of CFRP and GFRP coatings on improving the nonlinear static behavior of X-shaped pipe joints, Tabriz University Civil and Environmental Engineering Journal, (2021). (in Persian).

[5] H. Nassiraei, P. Rezadoost, Static capacity of tubular X-joints reinforced with fiber reinforced polymer subjected to compressive load, Engineering Structures, 236 (2021) 112041.

HOW TO CITE THIS ARTICLE

F. Vazifehdan, M. Shahraki, Evaluating the Behavior of Welding-Defected CFRP Fiber-Reinforced Double-Channel Steel Columns , Amirkabir J. Civil Eng., 55(7) (2023) 311-314.

DOI: 10.22060/ceej.2023.21567.7760