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Axial Behavior of Concrete Filled-steel Tube Columns Reinforced with Steel Fibers

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A B S T R A C T

Concrete filled steel tube (CFST) columns are being popular in civil engineering due to their superior structural characteristics. This paper investigates enhancement in axial behavior of CFST columns by adding steel fibers to plain concrete that infill steel tubes. Four specimens were prepared: two square columns (100*100 mm) and two circular columns (100 mm in diameter). All columns were 60 cm in length. Plain concrete mix and concrete reinforced with steel fibers were used to infill steel tube columns. Ultimate axial load capacity, ductility and failure mode are discussed in this study. The results showed that the ultimate axial load capacity of CFST columns reinforced with steel fibers increased by 28% and 20 % for circular and square columns, respectively. Also, the circular CFST columns exhibited better ductility than the square CFST columns due to better concrete confinement. Circular and square CFST columns with steel fibers showed improved ductility by 16.3% and 12%, respectively. The failure mode of the square CFST columns were local buckling which occurred near the end of columns, while, for the circular CFST columns, local buckling occurred near the mid-height. Also, the study involved sectional analysis that captured the behavior of CFST columns very well. The sectional analysis showed that increasing steel fiber content to 2% increased the axial load capacity by 51 and 38% for circular and square CFST columns, respectively. Furthermore, sectional analysis showed that doubling section size increased axial load capacity by approximately 4 and 5 times for circular and square columns, respectively.

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NOMENCLATURE

N_u	Analytical ultimate axial load capacity of CFST specimens (kN)	D	Steel tube diameter (mm)
N_{mu}	Measured ultimate axial load capacity of CFST specimens (kN)	*DI*	Ductility index
f_y	yield stress of steel (MPa)	$\Delta_{85\%}$	Column axial shortening when the column reaches to 85 % of its ultimate strength during the post-peak region (mm)
f'_c	Compressive strength of concrete (MPa)	Δ_u	Column axial shortening measured at ultimate strength (mm)
A_s	Cross-sectional area of the steel tube (mm^2)	E_c	Modulus of elasticity for concrete
A_c	Cross-sectional area of concrete (mm^2)	E_o	Modulus of elasticity for steel
SI	Strength index	E_p	Strain hardening modulus for steel
B	Steel tube width (mm)	ε_y	Yield strain of steel
t	Steel tube thickness (mm)		

1. INTRODUCTION

The idea of composite elements appeared as an attempt for maximum utilization of properties of various construction materials. A composite construction element is a construction element which is produced from two or more constituent materials where the properties of the composite section become different from, and ultimately better than those of the individual constituent material [1].

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One of the most common applications to utilize composite action to enhance properties of concrete members is using FRP composites [2-6].

Concrete filled steel tube (CFST) columns are widely being used in civil engineering applications, especially in large-span trusses in industrial cities, steel bridges and high-rise building structures. CFST columns have many advantages such as enhancement in column performance to fire resistance, increased concrete compression strength due to steel tube confinement effect, delayed local buckling due to the interaction between steel tube and concrete, and much less shrinkage and creep effects compared with conventional reinforced concrete column [7]. Using steel tube columns in construction field exhibited some issues like low resistance to fire and loss of stability under lateral and axial loads. Several solutions to strengthen steel columns have been presented such as covering the steel columns with concrete. This type of columns is used in steel structures exposed to fire. Usually, "I-section" or "T-section" steel are used for this type. Sometimes additional reinforcing steel is placed in the concrete layer around the section to prevent cracking under axial stress. Another type of steel columns is CFST columns. These columns are used in structures where risk of the fire is limited and they consist of square, circular or rectangular sections filled with concrete. These columns are commonly used in pillars of bridges, multi-story buildings, where they feature easy implementation when they do not need a template or any additional reinforcement. CFST columns can be a competitive choice for the common accelerated bridge construction techniques [8-13].

Several studies have been devoted to the field of CFST where properties of concrete infill was the main parameter discussed in these studies [14, 15].

The use of waste material in concrete has led to achieve economic benefits and improve environmental protection [16, 17], as well as enhancement in CFST behavior in the construction field. Yu et al. [18] conducted a study to investigate the replacement effect of different types of waste materials as alternatives for coarse aggregates on the performance of CFST. Five concrete mixes were used with different types of aggregate (normal coarse aggregate, lightweight coarse aggregate, steel slag coarse and fine aggregate, steel slag coarse aggregate and steel slag and glass coarse aggregate). The results indicated that using different types of aggregate influenced the failure mode, improved axial and lateral strain, decreased the ultimate strength of lightweight concrete by 8.2% compared with normal concrete. The ultimate strength of steel slag coarse aggregate concrete, steel slag coarse and fine aggregate concrete, steel slag coarse aggregate concrete and steel slag and glass coarse aggregate concrete increased by 15.1-24.9% compared with normal concrete. Ductility of CFST with steel slag coarse and fine aggregate concrete and steel slag coarse aggregate concrete enhanced, while lightweight concrete and steel slag and glass coarse aggregate concrete exhibited decreased ductility.

Recently, reinforced CFST piles are widely used in foundations of piers and bridges for its good mechanical properties. Li et al. [19] investigated enhancement of CFST using concrete with reinforcing bars to infill steel columns. All specimens were tested under axial compression load. The results showed that the CFST column with concrete reinforcing bars has a higher ultimate load capacity and more effective plastic behavior compared with columns without reinforcing bars.

Fire resistance is an important parameter that influences the design of CFST columns that should be seriously treated, specifically in large constructions. Exposure to fire temperatures can decrease the strength and durability of concrete, appearance and structural performance. Furthermore, CFST columns are widely used in large and high-performance constructions. The post-fire strength of CFST was investigated by Alhatmey et al. [20]. Fire exposure of CFST columns for 30 min increased the compression resistance a little, while fire exposure of one hour decreased the compression resistance for the tested specimens. The effect of confined concrete in the CFST played an essential role and led to smaller resistance losses.

Many methods considered enhancing the bond stress between steel tube and concrete in previous studies. Tao et al. [21, 22] studied the efficiency of using shear studs and an internal welded ring to improve the bond strength of CFST members. A series of push-out tests on circular and square CFST specimens showed that internal welded ring onto the inner surface of the steel tube is more effective than shear studs to enhance bond stress.

TABLE 1. Proportions of concrete mixes

Mix	Column ID	Cement (kg)	Coarse Agg. (kg)	Fine Agg. (kg)	W/C	Steel Fibers	Compressive Strength (MPa)	Tensile Strength (MPa)
M1	MC0	340	1110	729	0.45	0%	27.5	3.0
	MS0	340	1110	729	0.45	0%	27.5	٣,٠
M2	MC1	340	1110	729	0.45	0.5%	٣٠,١	٣,٩
	MS1	340	1110	729	0.45	0.5%	30.1	٣,٩

Adding fibers to concrete improves its homogeneity and isotropy and makes it a ductile material [23]. The present study is thus an attempt to study the efficiency of adding steel fibers to concrete mix to improve the behavior of CFST columns in terms of ultimate axial load capacity, ductility and failure mode.

2. EXPERIMENTAL WORK

2. 1. Material Properties Ordinary Portland cement was used with water cement ratio of 0.45 to produce plain concrete in the laboratory. In fiber-reinforced concrete mixes, hooked end steel fibers (tensile stress between 200-2600 MPa, modulus of elasticity 200 GPa, ultimate elongation 0.5-5 %, specific gravity 7.8 g/cm^2) were added with a ratio of 0.5 %. Fine and coarse aggregate from local sources were used according to Iraqi Specification No.45 (1984). Compression strength of concrete mixes were determined using concrete cubes (150*150*150 mm) and tensile strength for all mixes were determined by indirect tensile test (Brazilian Test) by using cylinder samples (100*200 mm). Proportion of concrete mixes and properties are presented in Table 1. Four CFST column specimens with a constant length of 60 cm were used and their steel tubes had a yield strength of 350 MPa.

2. 2. Specimen Preparation and Testing The experimental study included two circular columns with 100 mm in diameter and two square columns with a cross sectional area of 100*100 mm (Figure 1). All columns had the same length (L) of 60 cm. Also, all columns were closed in one direction to avoid concrete leakage (Figure 2). Two types of concrete mixes were used to infill columns: plain concrete and concrete reinforced with steel fibers.

Columns were filled with concrete mixes at three layers and compacted (25 blows per layer) with steel rod having a diameter of 20 mm. All the specimens were tested under axial loading in a vertical setup using a universal testing machine. Figure 3 shows the specimens after casting.

3. RESULTS AND DISCUSSION

3. 1. Ultimate Load The measured ultimate strength ($\boldsymbol{N_{mu}}$) for CFST specimens is listed in Table 2. Equation (1) is used to calculate the analytical axial load capacity ($\boldsymbol{N_u}$) for CSFT columns [24].

$$\boldsymbol{N_u} = f_y A_s + 1.3\, f_c' A_c \tag{1}$$

where $\boldsymbol{N_u}$ is the sum of section capacities of the steel tube and concrete, f_y and f'_c are the yield stress of steel and compressive strength of concrete, respectively; A_s and A_c are the cross-sectional areas of the steel tube and concrete, respectively. Equation (2) is used to calculate the strength index (SI) [25].

$$\boldsymbol{SI} = \frac{N_{mu}}{N_u} \tag{2}$$

Figure 1. Steel tubes for the CFST columns

Figure 2. Closing specimens from the bottom side

Figure 3. Specimens after casting

TABLE 2. Test results of columns

Column ID	Section			As (mm^2)	Ac (mm^2)	f'_c (MPa)	f_y (MPa)	N_u (kN)	N_{mu} (kN)	*SI*	*DI*
	B	D	t								
MC0	-	100	1.8	280	7574	27.5	350	368.8	398	1.08	2.83
MS0	100	-	2	392	9216	27.5	350	466.7	507	1.09	2.75
MC1	-	100	1.8	280	7574	30.1	350	394.4	507	1.28	3.29
MS1	100	-	2	392	9216	30.1	350	497.8	609	1.23	3.08

Figures 4 and 5 show the relationship between the axial load capacity and displacement for the columns in this study. The ultimate axial load capacity of circular

CFST column reinforced with steel fibers (MC1) increased by 28% compared with the control column (MC0), while it increased by 20% for square CFST column reinforced with steel fibers (MS1) compared with the control CFST column (MS0). This increase is related to the increase in compressive strength of the concrete that infills the tubes. The analytical ultimate strength estimated using Equation (1) was close to the experimental strength as seen in SI values in Table 2. However, the analytical strength was more conservative for CFST columns reinforced with steel fibers as seen in SI values. More accurate expressions are needed to estimate the axial strength for CFST columns reinforced with steel fibers.

3. 2. Ductility Ductility usually refers to the ability of the structure or the element to undergo deformation beyond the yield point. For CFST columns, the axial ductility is measured using the ductility index (DI). The ductility index (DI) is the ratio between the measured axial shortening when the column reaches to 85 % of its ultimate strength during the post-peak region and the axial shortening measured at ultimate strength, and it is defined in the following equation [22, 26]:

$$\boldsymbol{DI} = \frac{\Delta_{85\%}}{\Delta_u} \quad (3)$$

Generally, the circular columns exhibited better ductility than the square columns due to more uniform confinement that the circular shape provides for the concrete compared with the square shape. Circular and square CFST columns with steel fibers showed improved ductility by 16.3 and 12%, respectively, compared with the control columns without steel fibers. The improvement was due to the ductile behavior of steel fiber.

3. 3. Failure Mode Test observations showed that the failure mode of the circular CFST column was local buckling near the mid-height (Figre 6a), while the failure mode for square CFST columns was local buckling that appeared near the column ends (Figure 6b). Future studies are suggested to investigate seismic damage of CFST columns [27, 28].

4. MODELING VALIDATION

To verify the test outcomes and investigate the effect of other parameters on the axial behavior of CFST columns, numerical modeling can be very helpful.

Recent numerical studies have been conducted on axial behavior of CFST columns filled with conventional concrete and steel fiber-reinforced concrete that showed results which were in very good agreement with the test results [29-31]. Also, those numerical results are in good agreement with the experimental results in the current study. However, for axial behavior of composite

a) Circular column- local buckling at the mid-height

b) square column- Local buckling at the column end

Figure 6. Failure modes of the columns

members, complex finite element softwares are not necessary to conduct the numerical analysis. Section analysis using any available software can be sufficient. In this study, section analyses were performed using MATLAB software package.

The specimens tested in the study were modeled using the uniaxial behvior of both concrete and steel materials shown in Figures 7 and 8. Concrete was modeled using stress-strain relationship proposed by Hognestad [32] and steel was modeled using a bilinear stress-strain relationship.

The modeling results are shown in Figures 9 and 10 for circular and square columns, respectively. It can be observed that modeling adequetly captured the behavior of CFST columns. The initial stiffness of all columns is well captured using the numerical modeling.

The peak loads are also captured very well. Numerical post-peak behacvior is comparable to the experimental behavior except that linear decay is observed due to the use of Hognestad' model for concrete.

4. 1. Effect of Steel Fiber Content The tested specimens investigated one steel fiber content. However, using section analysis can be useful in investigating the behavior of other steel fiber contents. This is simply done by modifying the concrete stress-strain curve used in the modeling process. Figures 11 and 12 depict the numerical axial load-deformation relationship for circular and square specimens, respectively, with steel fiber content of (0, 0.5, 1, 2)% along with the experimental curves. It was observed that steel fiber content of 2% increased the axial load capcaity by 51 and 38% compared with the control circular and square CFST column, respectively. It also was found that ductility was increased by 22.3 and 20% with the increase of steel fiber content to 2% compared with the control circular and square CFST columns, respectively.

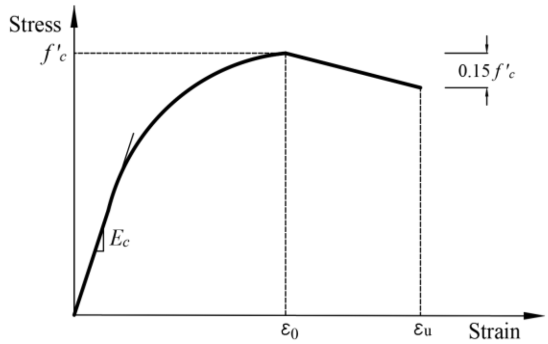

Figure 7. Hognestad' model for concrete

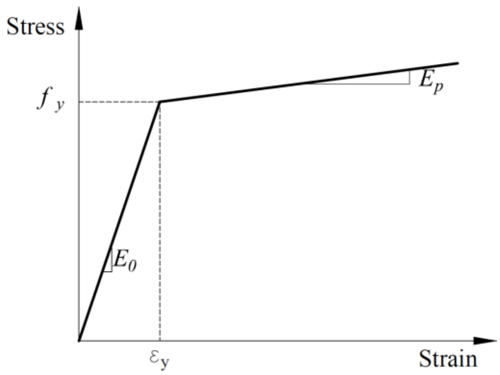

Figure 8. Stress-strain behavior of steel

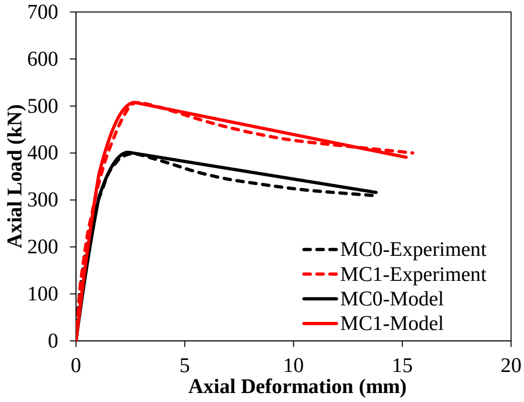

Figure 9. Experimental and numerical axial load-displacement curves for circular columns

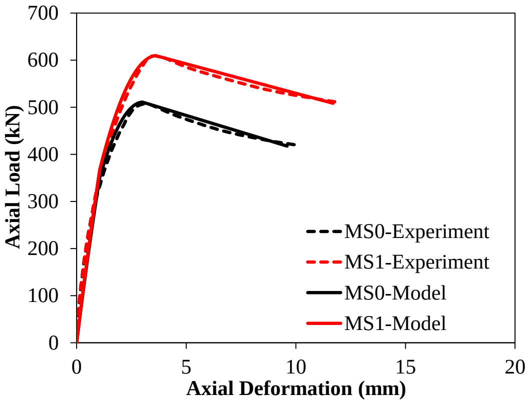

Figure 10. Experimental and numerical axial load-displacement curves for square columns

4. 2. Effect of Section Size Since, in real life applications, CFST coulmns are much bigger in size than the tested specimens, sectional analysis was utilized to investigate the behavior of large-scale size CFST columns. Section size of 200 mm and wall thickness of 4 mm for both circular and square columns are adopted for that purpose. Figure 13 shows the effect of the selected section size on the axial capacity of CFST columns. The numerical sections were made from regular concrete without steel fibers and compared with the control

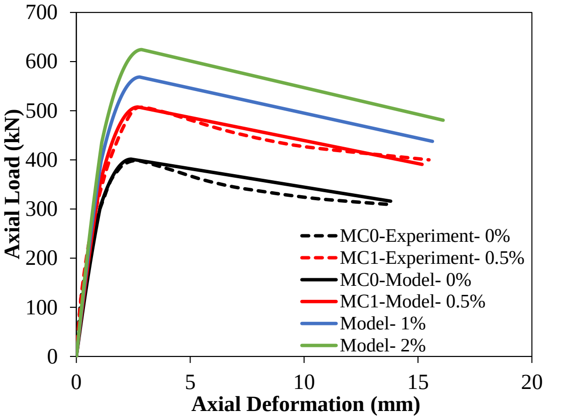

Figure 11. Effect of steel fiber content on axial load-displacement behavior for circular columns

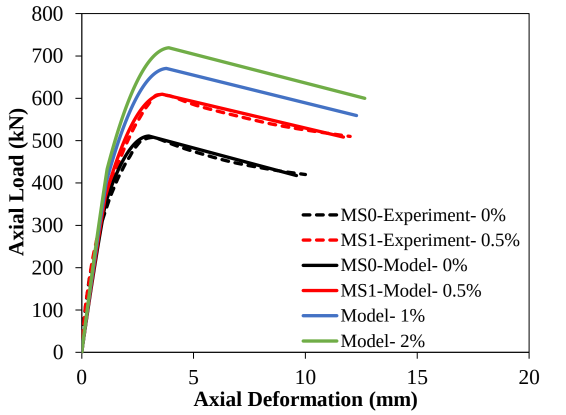

Figure 12. Effect of steel fiber content on axial load-displacement behavior for square columns

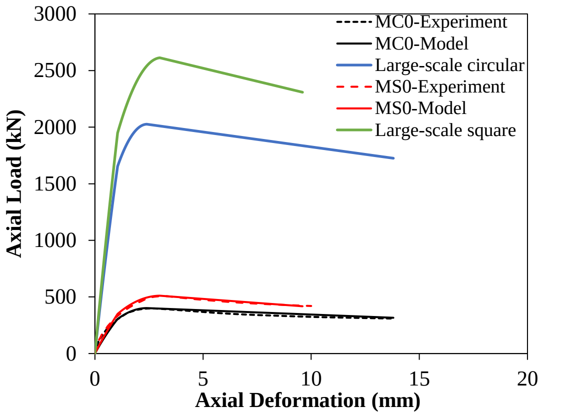

Figure 13. Effect of section size on axial load-displacement behavior for circular and square columns

specimens (MC0 and MS0) that do not have steel fibers. It can be seen that doubling section size incrased axial load capcity by approximately 4 and 5 times for circular and square columns, respectively.

5. CONCLUSIONS

Concrete filled steel tube (CFST) columns are gaining more interest in civil engineering applications due to their advantageous structural properties.

This study investigated axial behavior of CFST columns reinforced with steel fibers in comparison with regular CFST columns containing normal concrete. Four specimens were used: two square columns and two circular columns. Ultimate axial load capacity, ductility and failure mode were evaluated in this study. The test results showed that the ultimate axial load capacity of CFST columns reinforced with steel fibers increased by 28 and 20 % for circular and square columns, respectively, compared with the control CFST columns. Also, better ductility was achieved in the circular CFST columns compared with the square CFST columns due to the better uniform concrete confinement that circular shape provides for the infilled concrete.

Circular and square CFST columns reinforced with steel fibers showed improved ductility by 16.3 and 12%, respectively, compared with the control columns without steel fibers. The square CFST columns failed due to local buckling which occurred near the end of columns, while the circular CFST columns failed due to local buckling that occurred near the mid-height.

Also, the study incorporated numerical sectional analysis that was shown to capture the behavior of CFST columns very well. The sectional analysis was used to investigate other factors such as steel fiber content and column section size. It was seen that increasing steel fiber content to 2% increased the axial load capcaity by 51 and 38% compared with the control circular and square CFST column, respectively. Furthermore, It was observed that doubling section size incrased axial load capcity by approximately 4 and 5 times for circular and square columns, respectively.

6. REFERENCES

1. Alsadey, S., "Review of strengthening rc columns with frp composites fiber reinforced polymer (FRP), LAMBERT Academic Publishing, Germany, (2013).
2. Ozturk, B., Senturk, T. and Yilmaz, C., "Analytical investigation of effect of retrofit application using cfrp on seismic behavior of a monumental building at historical cappadocia region of turkey", in 9th US National and 10th Canadian Conference on Earthquake Engineering, Toronto, Canada., (2010).
3. Öztürk, B., Yilmaz, C. and Şentürk, T., "Effect of frp retrofitting application on seismic behavior of a historical building at nigde, turkey", (2010).
4. Al-Jelawy, H.M. and Mackie, K.R., "Durability and failure modes of concrete beams strengthened with polyurethane or epoxy cfrp", ***Journal of Composites for Construction***, Vol. 25, No. 3, (2021), 04021021.
5. Al-Jelawy, H., "Experimental and numerical investigations on bond durability of cfrp strengthened concrete members subjected to environmental exposure", (2013).

6. Naji, A.J., Al-Jelawy, H.M., Saadoon, S.A. and Ejel, A.T., "Rehabilitation and strengthening techniques for reinforced concrete columns", in Journal of Physics: Conference Series, IOP Publishing. Vol. 1895, (2021), 012049.
7. Morino, S., Uchikoshi, M. and Yamaguchi, I., "Concrete-filled steel tube column system-its advantages", ***Steel Structures***, Vol. 1, No. 1, (2001), 33-44.
8. Haber, Z.B., Mackie, K.R. and Al-Jelawy, H.M., "Testing and analysis of precast columns with grouted sleeve connections and shifted plastic hinging", ***Journal of Bridge Engineering***, Vol. 22, No. 10, (2017), 04017078.
9. Al-Jelawy, H.M., Mackie, K.R. and Haber, Z.B., "Shifted plastic hinging for grouted sleeve column connections", ***ACI Structural Journal***, Vol. 115, No. 4, (2018), 1101-1114.
10. Al-Jelawy, H., Mackie, K. and Haber, Z., "Experimental and numerical studies on precast bridge columns with shifted plastic hinging", in Eleventh US national conference on earthquake engineering. (2018), 25-29.
11. Al-Jelawy, H., Haber, Z. and Mackie, K., "Grouted splice precast column connections with shifted plastic hinging", in 16th World conference on earthquake—16WCEE., (2017), 9-13.
12. Al-Jelawy, H., "Shifted plastic hinge column connections using grouted sleeves for accelerated bridge construction", (2017).
13. Al-Jelawy, H., Haber, Z. and Mackie, K., "Seismic performance of grouted splice precast column joints with shifted plastic hinge mechanisms", in 2014 National accelerated bridge construction conference., (2014), 3-5.
14. Rahmani, Z., Naghipour, M. and Nematzadeh, M., "Flexural performance of high-strength prestressed concrete-encased concrete-filled steel tube sections", ***International Journal of Engineering, Transactions C: Aspects,*** , Vol. 32, No. 9, (2019), 1238-1247, doi: 10.5829/ije.2019.32.09c.03.
15. Mohammed, A.H., Khalaf, R.D., Mohammedali, T.K. and Hussin, A.K., "Experimental study on performance of fiber concrete-filled tube columns under axial loading", ***International Journal of Engineering, Transactions C: Aspects,***, Vol. 32, No. 12, (2019), 1726-1732, doi: 10.5829/ije.2019.32.12c.05.
16. Naji, A., Mousa, M. and Malik, S., "The production of the sustainable concrete by using different types of plastic waste", ***The Journal of Engineering and Applied Science,*** Vol. 14, (2019), 5557-5560.
17. Naji, A.J., Al-Yousefi, H.A., Mousa, M.A. and Hussein, M.J., "Optimization of water-cement ratio in concrete contains recycled polypropylene (pp) plastic waste", ***Periodicals of Engineering and Natural Sciences***, Vol. 7, No. 4, (2019), 1563-1566.
18. Yu, X., Tao, Z. and Song, T.-Y., "Effect of different types of aggregates on the performance of concrete-filled steel tubular stub columns", ***Materials and Structures***, Vol. 49, No. 9, (2016), 3591-3605.
19. Li, P., Zhang, T. and Wang, C., "Behavior of concrete-filled steel tube columns subjected to axial compression", ***Advances in Materials Science and Engineering***, Vol. 2018, (2018).
20. Alhatmey, I.A., Ekmekyapar, T. and Ayoob, N.S., "Post-fire resistance of concrete filled steel tube columns", in IOP Conference Series: Materials Science and Engineering, IOP Publishing. Vol. 988, (2020), 012036.
21. Tao, Z., Song, T.-Y., Uy, B. and Han, L.-H., "Bond behavior in concrete-filled steel tubes", ***Journal of Constructional Steel Research***, Vol. 120, (2016), 81-93.
22. Tao, Z., Han, L.-H. and Wang, D.-Y., "Experimental behaviour of concrete-filled stiffened thin-walled steel tubular columns", ***Thin-Walled Structures***, Vol. 45, No. 5, (2007), 517-527.
23. Samman, T.A., Wafa, F.F. and Radain, T.A., "Mechanical properties of normal and high-strength concrete with steel fibers", ***Journal of King Abdulaziz University: Engineering Sciences***, Vol. 12, No. 1, (1999), 87-104.
24. Giakoumelis, G. and Lam, D., "Axial capacity of circular concrete-filled tube columns", ***Journal of Constructional Steel Research***, Vol. 60, No. 7, (2004), 1049-1068.
25. Wang, W.-H., Han, L.-H., Li, W. and Jia, Y.-H., "Behavior of concrete-filled steel tubular stub columns and beams using dune sand as part of fine aggregate", ***Construction and Building Materials***, Vol. 51, (2014), 352-363.
26. Tao, Z., Han, L. and Zhao, X., "Behaviour of square concrete filled steel tubes subjected to axial compression", in Proceedings of the Fifth International Conference on Structural Engineering for Young Experts, Shenyang, China., (1998), 61-67.
27. Siqi, L., Tianlai, Y. and Junfeng, J., "Investigation and analysis of empirical field seismic damage to bottom frame seismic wall masonry structure", ***International Journal of Engineering, Transactions B: Applications,*** , Vol. 32, No. 8, (2019), 1082-1089, doi: 10.5829/ije.2019.32.08b.04.
28. LI, S., Yu, T. and Jia, J., "Empirical seismic vulnerability and damage of bottom frame seismic wall masonry structure: A case study in dujiangyan (china) region", ***International Journal of Engineering, Transactions C: Aspects,*** , Vol. 32, No. 9, (2019), 1260-1268, doi: 10.5829/ije.2019.32.09c.05.
29. Guler, S., Lale, E. and Aydogan, M., "Non-linear analysis of steel fibre reinforced concrete-filled steel tube columns", Proceedings of the Institution of Civil Engineers-Structures and Buildings, Vol. 166, No. 6, (2013), 298-306, https://doi.org/10.1680/stbu.11.00070
30. Katwal, U., Tao, Z., Hassan, M.K. and Wang, W.-D., "Simplified numerical modeling of axially loaded circular concrete-filled steel stub columns", ***Journal of Structural Engineering***, Vol. 143, No. 12, (2017), 04017169.
31. Nguyen, P.-C., Pham, D., Tran, T. and Nghia-Nguyen, T., "Modified numerical modeling of axially loaded concrete-filled steel circular-tube columns", ***Engineering, Technology & Applied Science Research***, Vol. 11, No. 3, (2021), 7094-7099, https://doi.org/10.48084/etasr.4157
32. Hognestad, E., *Study of combined bending and axial load in reinforced concrete members*. 1951, University of Illinois at Urbana Champaign, College of Engineering.

Persian Abstract

چکیده

ستون‌های لوله فولادی پرشده بتنی (CFST)به دلیل ویژگی‌های ساختاری برتر در مهندسی عمران محبوب هستند. این مقاله بهبود رفتار محوری ستون‌های CFST را با افزودن الیاف فولادی به بتن ساده که لوله‌های فولادی را پر می‌کند، بررسی می‌کند. چهار نمونه تهیه شد: دو ستون مربعی (۱۰۰ * ۱۰۰ میلی متر) و دو ستون دایره ای (قطر ۱۰۰ میلی متر). تمام ستون ها ٦۰ سانتی متر طول داشتند. مخلوط بتن ساده و بتن تقویت شده با الیاف فولادی برای پر کردن ستون های لوله فولادی استفاده شد. ظرفیت بار محوری نهایی، شکل پذیری و حالت شکست در این مطالعه مورد بحث قرار گرفته است. نتایج نشان داد که ظرفیت بار محوری نهایی ستون‌های CFST تقویت‌شده با الیاف فولادی به ترتیب ۲۸ و ۲۰ درصد برای ستون‌های دایره‌ای و مربعی افزایش یافت. همچنین، ستون‌های CFST دایره‌ای شکل‌پذیری بهتری نسبت به ستون‌های CFST مربعی به دلیل محصور شدن بهتر بتن از خود نشان دادند. ستون های CFST دایره ای و مربعی با الیاف فولادی به ترتیب ١٦.٣٪ و ١٢٪ شکل پذیری بهبود یافته را نشان دادند. حالت شکست ستون‌های CFST مربعی، کمانش موضعی بود که در نزدیکی انتهای ستون‌ها رخ می‌داد، در حالی که، برای ستون‌های CFST دایره‌ای، کمانش موضعی در نزدیکی ارتفاع وسط رخ داد. همچنین، این مطالعه شامل تجزیه و تحلیل مقطعی بود که رفتار ستون‌های CFST را به خوبی نشان می‌داد. تجزیه و تحلیل مقطعی نشان داد که افزایش محتوای الیاف فولادی به ۲٪ ظرفیت بار محوری را به ترتیب ۵۱ و ۳۸٪ برای ستون های CFST دایره ای و مربعی افزایش داد. علاوه بر این، تجزیه و تحلیل مقطعی نشان داد که دوبرابر کردن اندازه مقطع، ظرفیت بار محوری را به ترتیب تقریباً ٤ و ۵ برابر برای ستون‌های دایره‌ای و مربعی افزایش می‌دهد.