Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 233-240
© Universiti Tun Hussein Onn Malaysia Publisher's Office

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Strength of Modified Foam Concrete-Filled Hollow Section Using fly ash as Sand Replacement Added Steel Fiber

Ahmad Hazim Ahmad Firdaus[1], **Norashidah Abd Rahman**[2]*

[1]Faculty of Civil and Environmental Engineering,
Universiti Tun Hussein Onn Malaysia, Johor, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2022.03.01.025
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Steel hollow sections are frequently utilised in the building sector because of its structural benefits and ability to save construction time. The steel hollow section, on the other hand, is prone to buckling due to its high slenderness ratio. By introducing the concrete filled in hollow section, it will help to reduce the buckling of the steel section. Therefore, this study was carried out to determine the strength of lightweight cellular concrete filled steel hollow section added steel fiber. The dimension of steel hollow section that used is 100 x100 x350 mm with thickness of 2mm and 4mm. Specimen was tested under compression test.The result shows that steel fiber can help to increase the strength of lightweight Cellular concrete filled hollow section. The strength increase is due to the enhancing effect from the addition of fiber.

Keywords: Concrete Filled Steel Hollow Section, Foamed Concrete, Fly Ash, Steel Fiber.

1. Introduction

Steel hollow sections are used extensively in the construction, offshore, mining and security industries. In many applications these sections are concrete filled in order to gain strength advantages under axial compression loads. The steel hollow section will undergo local buckling easily due to high slenderness ratio (L/d) and sectional dimension to thickness (D/t) when subjected to bending or compression. Concrete is utilised to infill the steel hollow section in order to overcome the steel hollow section weakness. Concrete infill is used to prevent or postpone local buckling while also increasing the compressive strength of the steel hollow section.

Concrete filled steel hollow sections (CFSHS) is a type of composite structure that can replace traditional column structures, such as reinforced concrete columns or steel columns. CFSHS can help to delay the failure of hollow section. CFST section is much more significant than that of reinforced

---

*Corresponding author: nrashida@uthm.edu.my

concrete, positioned at the farthest end of the section. This could significantly increase the bearing capacity of the structure [1].

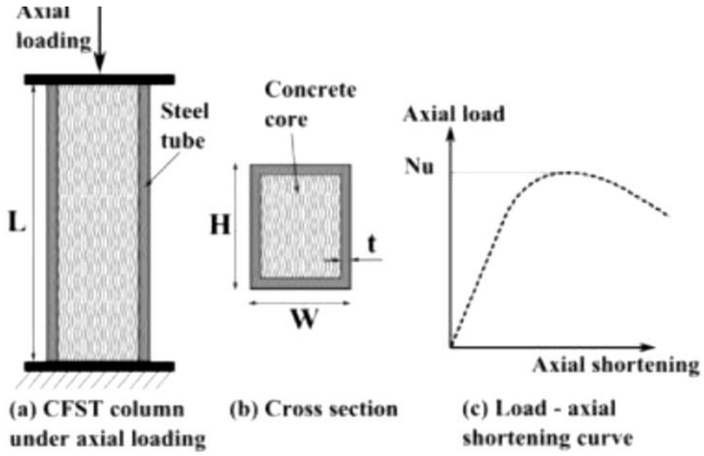


Figure 1: Concrete filled hollow section

A local buckling was detected on all of the specimens during the investigation. Local buckling causes increasing strain localization with repeated load cycles, and section ripping causes loss of carrying capacity. The change of the local buckling mode at steel hollow section filled concrete resulted in increased axial load capacity and ductility.

The used of normal concrete filled in steel hollow section will increase the self-weight of the structure. To reduce the self-weight of the structure, the used of lightweight concrete such as foam concrete is recommended due to light density range between 1000 kg/mm^3 to 1600 kg/mm^3. However, the strength of foam concrete is lower [2]. Fiber was added to foam concrete to improve its ductility, strength, and mechanical characteristics in order to improve its performance [3]. The compressive strength of foam concrete is increased by adding 0.4 percent polypropylene fibre and a proportion of steel fibre [4]. When steel fibre accounts for 1% of the volume of the concrete, however, compressive strength is reduced. Fly ash is one of the key components of lightweight cellular concrete, it resolves the issue of disposal and at the same time it's very economical. For same reason, foamed concrete is considered environment friendly. Therefore study of lightweight cellular concrete filled hollow section (LCCFHS) should be carried out.

The strength of steel hollow section is affected by several parameters such as slenderness, strength of material, shape of cross-section and volumetric steel-to-concrete ratio.

To identify the strength effect CFSHS on load bearing capacity of steel hollow section the SI is evaluate by using the formula in Eurocode 4 as:

$$SI = \frac{N_{ue}}{N_u} \tag{2}$$

Where,

$N_{ue} \ = \ Ultimate\ load\ reach\ during\ test$

$N_{uo} \ = \ \frac{A_s f_{sk}}{\gamma_s} + \frac{A_s f_{sk}}{\gamma_s}$

2. Material and Testing

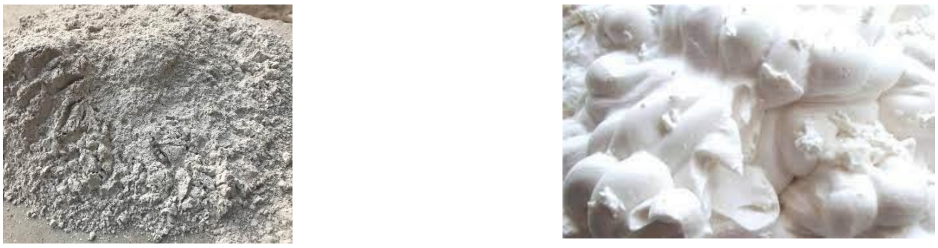
2.1 Material Preparation

In the material preparation for casting cube samples and short column specimen, the mix design of foamed concrete is based on the previous study proposed by Khairuddin [5] show in table 1. The materials used in Lightweight Cellular Concrete (LCC) are ordinary Portland cement (OPC), sand, fly ash (FA), steel fiber (SF), foam agent, superplaticizer and water. Figure 2 shows the materials for LCC. In this study, FA was used as partially sand replacement at 60% [6]. Meanwhile, the addition of superplasticizer is to improve the workability of foamed concrete. Another important material that need to be prepared is steel hollow section. In this study, square steel hollow section was used. The size of steel hollow section is 100 x 100 x 350 mm with 2mm and 4mm thickness.

Table 1: Mix design [5]

Mixture	Foam concrete	steel fiber foam concrete
Cement-sand ratio (C/S)	0.50	0.50
Foam-cement ratio (F/C)	0.70	0.70
Water-cement ratio (W/C)	0.55	0.55
FA %	60	60
Steel fiber %	-	0.8

a) Portland Cement   b) Sand   c) Steel Fiber



d) Fly Ash   e) Foam

Figure 2: Material of LCC

2.2 Specimen Preparation

Six sample cube of LCC with and without steel fiber was prepared for the compression test. The size of mould that used is 100 x 100 x 100 mm. The cube was undergoes air curing for 28 days before the cube were testing in compression test as show in figure 3. For the specimen short column, 12 specimens was prepare for axial compression test. The size of the specimen is 100 x 100 x 350 mm with thickness 2 mm and 4mm. After foam concrete was done pour in steel hollow section, the specimen was undergoes air curing for 28 days before axial compression test can be performed.

a) Sample of Cube b) Specimen

Figure 3: Air Curing

2.3 Concrete Strength

Six samples of the cubes were cast for each type of fibre foam concrete and foam concrete. A cube sample size of 100 × 100 × 100 mm was prepared. The cubes were subjected to air curing and were tested after 28 days (Figure 4). Table 2 show the compressive strength of LCC and LCC-SF. Figure 4 show the compression test for cube sample to determine the strength of LCC.

Table 2: Compressive strength of concrete cube at different age of testing

Type of foam concrete added FA	Compressive strength (Mpa) on 28 days curing			
	Sample 1	Sample 2	Sample 3	Average
With SF	26.8	28.7	27.4	27.6
Without SF	22.2	22.1	21.9	22.1

* FA – Fly Ash
* SF – Steel Fiber

Figure 4: Compression test for cube sample

2.4. Compression test on FCFHS

The 350 mm-long composite column was tested under axial compression load using different thicknesses to determine the bond strength between the steel section and concrete. Figure 4 illustrates the arrangement of test specimens. The universal testing machine was set at the minimum speed of 1mm/min to provide sufficient time for specimens to fail. Loading rate was maintained, and the readings were recorded.

Figure 5: Axial compression test setup

3. Results and Discussion

Axial compression test was conducted after the specimen were completely cured within 28 days. The test was held to determine the mode of failure on the specimen. LCCFHS with steel fiber of 2 mm thick hollow section can achieve maximum load 589.58 kN higher than foam concrete added fly ash without steel fiber, 498.11 kN. Other than that, the test also conducted on 4 mm thick hollow section. The results show that foam concrete added fly ash with steel fiber obtain the load of 997.66 kN before failure which is greater than foam concrete added fly ash without steel fiber, 927.05 kN.

Table 3: Result of FCFHS strength

Sample	Thickness (mm)	Load Value (kN)
FCFHS-FA-01	2	333.15
FCFHS-FA-02	2	483.68
FCFHS-FA-03	2	498.11
FCFHS-FA-01	4	927.05
FCFHS-FA-02	4	900.60
FCFHS-FA-03	4	914.57
FCFHS-FA-SF-01	2	589.58
FCFHS-FA-SF-02	2	550.45
FCFHS-FA-SF-03	2	509.90
FCFHS-FA-SF-01	4	971.11
FCFHS-FA-SF-02	4	986.34
FCFHS-FA-SF-03	4	997.66

3.1 Strength Index

According to table 4.3, strength index foam concrete added fly ash with steel fiber a higher compare to foam concrete added fly ash without steel fiber. The result shows that steel fiber can help to increase the strength index of concrete filled hollow section. The strength increase is due to the enhancing effect of fiber addition [7]. Thus, from table 4, SI for the steel fiber is greater than 1, it means that steel fiber is able to postpone local buckling effect on concrete filled hollow section [8]. According to Soundararajan [9], It was observed that low-strength concrete has a lower bond strength than normal mix concrete, fly ash concrete and quarry waste concrete.

Table 4: Data for strength index, SI

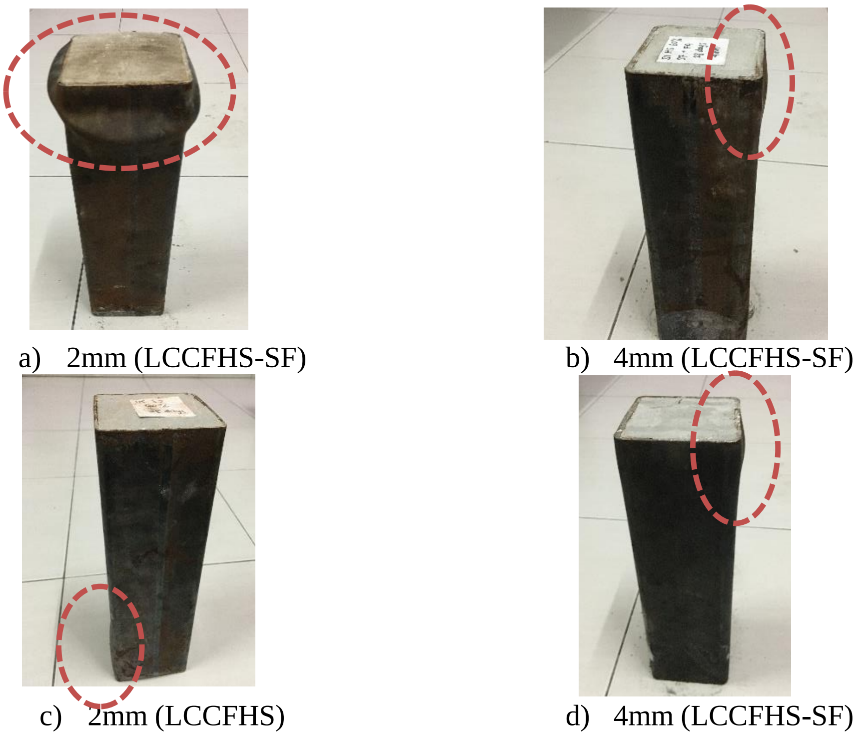
Sample	Thickness, t (mm)	f_{cu} (Mpa)	N_{uo} (KN)	N_{ue} (KN)	Strength Index, Si
FCFHS-FA -01	2	22.1	367.40	333.15	0.91
FCFHS-FA -02	2	22.1	367.40	483.68	1.32

FCFHS-FA -03	2	22.1	367.40	498.11	1.36
FCFHS-FA-SF-01	2	27.6	397.83	589.58	1.48
FCFHS-FA-SF-02	2	27.6	397.83	550.45	1.38
FCFHS-FA-SF-03	2	27.6	397.83	509.90	1.28
FCFHS-FA -01	4	22.1	407.62	927.05	2.27
FCFHS-FA -02	4	22.1	407.62	900.60	2.21
FCFHS-FA -03	4	22.1	407.62	914.57	2.24
FCFHS-FA-SF-01	4	27.6	438.05	971.11	2.21
FCFHS-FA-SF-02	4	27.6	438.05	986.34	2.25
FCFHS-FA-SF-03	4	27.6	438.05	997.66	2.28

The mechanical characteristics of the hollow section with different thicknesses are given in terms of stress, strain and deformation. It is found that the properties of the hollow section have an important relationship with the wall thickness. After loading, the model will still deform tension until it fails. Although the deformations are similar, the gap between the stresses is large.

3.2 Failure Mode

Failure mode of CFHS usually occurs either near or at the load end in the form of an elephant's foot or bulging. The assumption of elephant foot buckling has been made because the presence of concrete infill does not significantly affect the local buckling of steel tubes. The local buckling occurred to all specimen. The results show that the general failure mode was elephant foot at figure 6 (a) and local buckling behaviours in figure 6 (b) for modified FCFHS with SF specimens for 2 mm thickness. Buckling failure mode on modified FCFHS with SF occurs on the top of the specimen for the 4mm thickness while for specimen without SF the buckling failure mode occurs on the bottom which is 2mm thickness hollow section. However, the amount of buckling that occurs on the same size specimen varies since some specimens have more buckling and others have less.



a) 2mm (LCCFHS-SF)

b) 4mm (LCCFHS-SF)

c) 2mm (LCCFHS)

d) 4mm (LCCFHS-SF)

Figure 6: Typical local buckling of specimen typical local buckling of specimen

4. Conclusion

Twelve specimens were tested under axial compression test to determine the behaviour of the modified FCFHS. All 12 specimen are infill modified FC using FA as sand replacement with and without Sf. Six of the specimens have the thickness have 2 mm thickness while the rest have 4 mm thickness. Based on the information presented in this study, several observations and conclusions may be derived.

Modified FCFHS with SF reveal that modified FC with SF exhibit higher strength than FC without SF. From the axial compression test, this can be concluded that modified FCFHS using fly ash with SF improve the strength of the CFHS under axial load. From the observation, there is failure mode occur after the specimen undergoes the axial compression test. The composite column has inconsistent failure mode that occurs on top and bottom of the column. In figure 6 show that the general failure mode was elephant foot and buckling failure mode on modified FCFHS with and without SF occurs on the top and bottom of the specimen for the 2mm and 4mm thickness.

As the conclusion, the strength of modified FCFHS using FA with SF is stronger compare to without SF. In addition, the cube test shows that SF slightly helps increase the compressive strength of the foam concrete.

Acknowledgement

Authors would like to thank Universiti Tun Hussein Onn Malaysia (UTHM) and Ministry of Education Malaysia for the continuous supports in term of facilities and financial.

References

[1] Quang Hung Nguyen, Hai-Bang Ly, Van Quan Tran, "A Novel Hybrid Model Based on a Feedforward Neural Network and One Step Secant Algorithm for Prediction of Load-Bearing Capacity of Rectangular Concrete-Filled Steel Tube Columns," *Molecules 2020,* pp. 1-26, 2020.

[2] Yanbin Fu, Xiuling Wang, Lixin Wang, Yunpeng Li, "Foam Concrete: A State-of-the-Art and State-of-the-Practice Review," *Advances in Materials Science and Engineering,* p. 25, 20220.

[3] L You-Fu Yang, Lin-Hai Han, "Experiments on rectangular concrete-filled steel tubes loaded axially on a partially stressed cross-sectional area," *Journal of constructional Steel Research,* pp. 1617-1630, 2009.

[4] Norashidah Abd Rahman, Siti Amirah Azra Khairuddin, Mohd Faris Faudzi, Mohd Harith Imran Mohd Asri, Norwati Jamaluddin, "Axial strength of modified fibrous foamed concrete-filled hollow section," *World Journal of Engineering,* 2019.

[5] Azra Khairuddin A., Rahman N. A., Jamaluddin N. , Jaini Z. M., and Ali N., "Ultimate strength capacity of a square hollow section filled with fibrous foamed concrete," vol. 271, 2017.

[6] Papayianni, I. and Milud, I.A., "Production of Foamed Concrete with," *Proceedings: International Conference on the Use of Foamed Concrete in Construction, University of Dundee,* vol. 11, no. 23–28, pp. 231-254, 2005.

[7] Campione G, Mindess S, Scibilia N, Zingone G., "Strength of hollow circular steel sections filled with fibre-reinforced concrete," *Canadian Journal of Civil Engineering,* 2000.

[8] Z Tao, Z., Han,L., Wang, D., "Strength and ductility of stiffness thin-walled hollow steel structure stub column filled with concrete," *Thin-walled structures,* pp. 1113-1128, 2008.

[9] Shanmugasundaram, Arivalagan Soundararajan and Kandasamy, "FLEXURAL BEHAVIOUR OF CONCRETE-FILLED STEEL HOLLOW SECTIONS BEAMS," *JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT,* pp. 107-114, 2008.

[10] A. Williams, Steel Structures Design, New York: McGraw Hill Companies, 2011.

[11] Xiaodan Wei, Xiangrong He, "The Application of Steel Structure in CIvil Engineering," *Internatinal Conference on Education, Management and Computing Technology,* pp. 253-256, 2014.

[12] Ruslan Kanishchev, Vincent Kvocak, "Local Buckling of Axially Compressed Rectangular Concrete-Filled Steel Tubes," *MATEC Web Conferences,* p. 04017, 2016.

[13] Liu, Dalin, "Test on high-strength rectangular concrete-filled steel hollow section stub columns," *Journal of Constructional Research,* pp. 902-911, 2005.

[14] Kamyar Baghrerinejad, Emad Hosseinpour, Seyed Hamed Hosseini, "Evaluation of Rectangular Concrete-Filled Steel Hollow Section Beam-Column," *Journal of Asian Scientific Research,* pp. 46-59, 2015.