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Strength of Modified Foam Concrete Filled Hollow Section Using fly ash as Sand Replacement Added Polypropylene Fibre

Nurul Syahirah Ramli[1], **Norashidah Abd Rahman**[1]*

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat, MALAYSIA

*Corresponding Author Designation

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Abstract: Concrete-filled hollow section (CFHS) was widely used in steel construction such as bridge, building and other structures. The combination of concrete and steel will prevent buckling and deforming of the concrete-filled hollow section (CFHS). The aim of this study is to determine the strength of modified foamed concrete filled hollow section using fly ash as sand replacement added polypropylene fibre. In this experimental study, a square steel hollow section was used with a size of 100mm x 100mm x 350mm with 2mm and 4mm thickness. The modified foam concrete contains fly ash as sand replacement with fibre and without fibre was prepared as a filled concrete to steel hollow section. The modified foam concrete filled hollow section was test under compression load. As result, the use of fly ash added with fibre improves the concrete strength of concrete filled hollow section. It shows that, modified foam concrete using fly ash as sand replacement added fibre can be utilised in the steel industrial sector as filled concrete.

Keywords: Concrete Filled Hollow Section, Foamed Concrete, Modified Foam Concrete Polypropylene Fibre, Fly Ash

1. Introduction

One of the greatest obstacles in structural design is the self-weighting of the members, particularly if the aim is to design members with a high strength to weight ratio. There are two potential ways to minimize this weight by using a lightweight material such as lightweight concrete or using a composite structure. In the composite construction, the advantageous properties of the constituent materials are combined to produce a high-performance structure at a reasonable expense [1]. Recently, concrete filled hollow section (CFHS) is widely utilised due to aesthetically qualities and a substantial gain in load-carrying capacity without needing an increase in cross-sectional area [2]. CFHS is a structural component that combines tensile strength and steel ductility with compressive concrete strength. Because of its strength and size, CFHSs are effective structural components that allow quick construction [3]. The distinctive features of the CFHS columns motivate the design engineers to use

**Corresponding author: nrashida@uthm.edu.my*

these methods in high-performance structures, such as tunnels, bridges, high-rise towers, and tower buildings. Due to improved energy absorption, stiffness and ductility properties, the use of CFHS columns is recommended in earthquake areas. The concrete infills give the steel hollow section with strength and flexural rigidity and prevent the column from buckling locally. Nardin [4] studies indicate that CFHS made a significant contribution. A further delay in failures is the implementation of a concrete infilling core of CFHS. The containment of concrete infill raises strength and prevents the spread of seismic loads and impact tests that are present in a reinforced concrete column in subsequent loads. Even so, this previous research that focuses only use normal concrete, of which the major drawback is weight penalty. Thus, CFHS is potentially beneficial in lightweight cellular concrete. The foamed concrete (FC) is a lightweight and versatile material for different types of applications that can be easily manipulated. Therefore, the use of modified FC as a filled material in steel hollow section should be carried out.

2. Materials and Methods

2.1 Materials

According to Marceau [5], the use 60% fly ash as a sand replacement will produce concrete with good mechanical properties and durability. Therefore, 60% of fly ash (FA) was added in foamed concrete mix design. The density of the foamed concrete is 1,600 kg/m^3. While 0.4% polypropylene fibre (PF) were added in the mix to identify the effect of fibre to the strength of foamed concrete. The cement sand ratio use for this experiment is 1:2 and water content of 0.55 was selected for the mix materials. Table 1 show detail of mix design proportion. Cube test was carried out to determine the material properties of concrete as shown in table 2.

Table 1: Mix design proportion

Mixture	FC-FA-PF	FC-FA
Cement-sand ratio(C/S)	0.5	0.5
Foamed-cement ratio	0.7	0.7
Water-cement ratio(W/C)	0.55	0.55
Fly Ash (%)	60	60
Polypropylene fibre (Mega Mesh Type) (%)	0.4	-
Foamed agent	1:20	1:20

Table 2: Compression result on cube samples

Sample labelled	Compressive strength (MPa) 28 Days	Average Compressive Concrete 28 Days
FCHFS-FA-1	21.9	22.1
FCHFS-FA-2	22.1	
FCHFS-FA-3	22.2	
FCHFS-FA-PF-1	25.2	26.7
FCHFS-FA-PF-2	27.1	
FCHFS-FA-PF-3	27.8	

2.2 Compression test on modified foam concrete filled hollow section (FCFHS)

Compression test is used to investigate the material behavior under applied crushing loads and is usually carried out using plates or special fixture on a universal test unit by applying compressive pressures to the test specimen. The various material properties are analyses throughout the test. Compression tests are also conducted on finished products, unlike tensile tests, which are typically performed for determining the tensile properties of a specific material. To determine the strength of modified Foamed Concrete Filled Hollow Section (FCFHS) samples. Specimen was prepared for the compression test of modified foam concrete filled hollow section. The size of both types of concrete, which are cast for the hollow section shape of size 100mmx100mmx350mm. The samples were test after 28 days with the size of 100mm x 100mm x 100mm for cube and 100mm x 100mm x 350mm.The samples were tested under compression load as shown in figure 1. To determine the strength Index (SI) of modified FCFHS added PF, equation 1 was used [6].

$$SI = N_{ue} / (f_c A_c + f_{yt} A_{st}) \quad (1)$$

SI = Strength Index
N_{ue} = Ultimate load
f_c = Characteristic of concrete strength
A_c = Area of the concrete
f_{yt} = Yield strengths of the steel
A_{st} = Area of the steel

Figure 1: Compression test on modified foam concrete filled hollow section (FCFHS)

3. Results and Discussion

3.1 Strength of modified FCFHS

The aim of this study to determine the strength of the modified FCFHS using FA as sand replacement added PF. From table 3, it shows the compressive strength of FCFHS added polypropylene fibre is greater than the FCFHS without fibre. The increase of voids caused by the foam in the mixture throughout a FCFHS sample reduces the compressive strength of the foamed concrete. The addition of polypropylene fibres in the FCFHS, however, increased the FCFHS' compressive strength by increasing the density properties. Aside from that, the addition of polypropylene can lead to increasing compression strength by preventing microcracks and improve energy absorption rate. The outcomes show compressive strength as it relates to the effect of the B/t ratio. If the B/t ratio increases, the compressive strength of the concrete-filled hollow section decreases. According to Gore [7], this is due to less concrete confinement in the concrete-filled steel tube.

Table 3: The compression strength of modified FCFHS added polypropylene fibre and FCFHS without fibre

Samples	B/t	Load (kN)	Compression strength (MPa)
FCHFS-FA-PF-21	25	441.1	44.1
FCHFS-FA-PF-22	25	456.77	45.7
FCHFS-FA-PF-23	25	424.96	42.5
FCHFS-FA-PF-41	50	976.31	97.6
FCHFS-FA-PF-42	50	914.93	91.5
FCHFS-FA-PF-43	50	966.34	96.6
FCHFS-FA-21	25	333.15	33.3
FCHFS-FA-22	25	483.68	48.4
FCHFS-FA-23	25	498.11	49.8
FCHFS-FA-41	50	927.05	92.7
FCHFS-FA-42	50	900.60	90.1
FCHFS-FA-43	50	914.57	91.5

3.2 The effect of strength index (SI) on load capacity

The strength index (SI) which is used to evaluate the local buckling on the load capacity. The strength index (SI) value of the different samples CFHS is recorded in Table 4.

Table 4: The strength index (SI) value of the different samples CFHS

Sample of CFHS	Fc (MPa)	Area of the concrete, Ac (mm^2)	Yield strengths of the steel, f_{yk} (MPa)	Area of the steel, As ($mm^{2)}$	Nue (kN)	Strength Index, SI
FCHFS-FA-PF-21	27.6	9216	323	784	441.1	1.29
FCHFS-FA-PF-22	27.6	9216	323	784	456.77	1.34
FCHFS-FA-PF-23	27.6	9216	323	784	424.96	1.25
FCHFS-FA-21	22.1	9216	323	784	333.15	1.06
FCHFS-FA-22	22.1	9216	323	784	483.68	1.54
FCHFS-FA-23	22.1	9216	323	784	498.11	1.59
FCHFS-FA-PF-41	27.6	8464	376	1536	976.31	1.67
FCHFS-FA-PF-42	27.6	8464	376	1536	914.93	1.56
FCHFS-FA-PF-43	27.6	8464	376	1536	966.34	1.65
FCHFS-FA-41	22.1	8464	376	1536	927.05	1.65
FCHFS-FA-42	22.1	8464	376	1536	900.60	1.61
FCHFS-FA-43	22.1	8464	376	1536	914.50	1.63

From figures 2 and 3, the ultimate strength of FCFHS added polypropylene fibre has increased when compared to FCFHS without fibre. The compression was described by the hollow section's outward buckling mode. According to Yang [8], the local buckling was delayed by the tube wall. The increased thickness of the hollow section delays local buckling. In addition, PF were added to increase the load carrying capacity of modified FCFHS. The ultimate strength of FCFHS-FA added polypropylene fibres is then found to be higher than that FCFHS-FA without fibre for 4 mm thicknesses of hollow section.

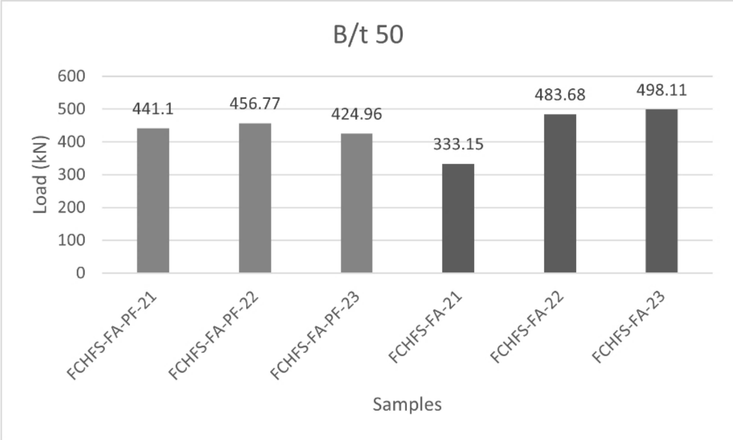

Figure 2: Ultimate strength of sample B/t=50

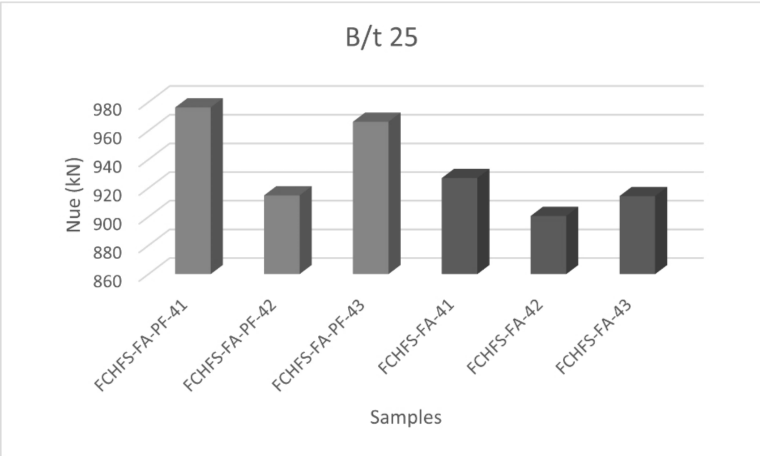

Figure 3: Ultimate strength of sample B/t=25

The higher value of strength index CFHS was delays specimens to failure and local buckling. SI value more than 1.00 are postponed the local buckling of steel tube [9]. The SI values samples of modified FCFHS added polypropylene fibres are quite close to unity for 2mm and 4mm thickness of hollow section, as shown in Figure 4. This could be due to the benefits of confinement improvement. The average SI value of modified FCFHS added polypropylene fibres then becomes slightly higher than the average SI value of FCFHS without fibre. This is because polypropylene fibres were added to the modified FCFHS. The addition of PF improves confinement on the concrete core to increase modified FCFHS strength.

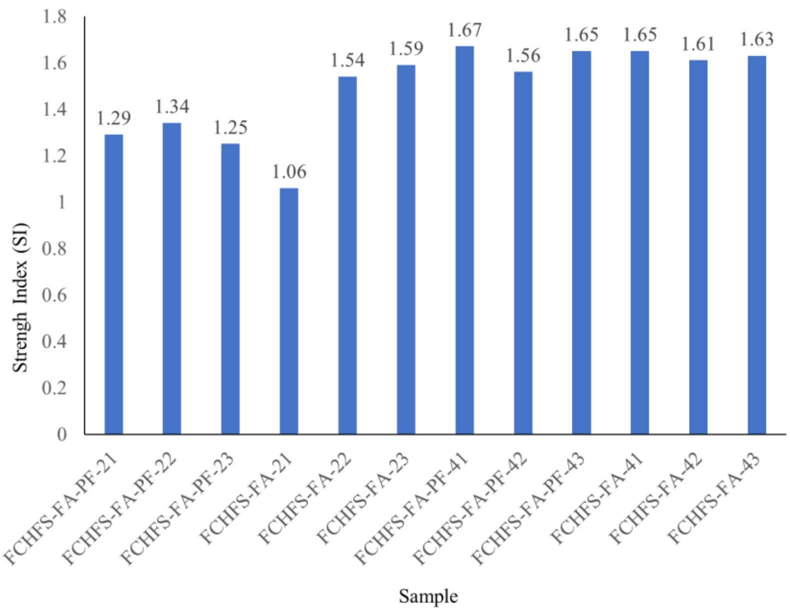

Figure 4: Strength index versus samples

4. Conclusion

In this research area, hollow sections filled with foamed concrete without fibre and foamed concrete added polypropylene fibre are very interesting structural materials to discuss. This is due to the numerous benefits and untapped secrets to be discovered by the researchers. This study examined at the strength of modified foamed concrete filled hollow sections with polypropylene fibre, as well as the comparison of the FCFHS without fibre and modified FCFHS with polypropylene fibres. Even though, the scope of the research is limited, the need to understand fundamental knowledge was used to complete this experiment.

From the study, it is found that the strength of the modified FCFHS using fly ash as a sand replacement added PF increased when compared to the modified FCFHS without PF. The confinement provided by the PF to the concrete core has increased the strength of the modified FCFHS.

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References

[1] Al-Eliwi, B. J.-S. (2018). Behaviour of Reinforced Lightweight Aggregate Concrete-Filled Circular Steel Tube Columns Under Axial Loading. *Structures, 16(July)*, 101-111.

[2] Lam, D. and Williams, C. (2004), "Experimental study on concrete-filled square hollow sections", Steel and Composite Structures, Vol. 4 No. 2, pp. 92-112.

[3] Bagherinejad, K. H. (2016). Evaluation of Rectangle Cncrete-Filled Steel-Hllow Section Beam-Columns. *Journal of Asian Scientific Research, 5(1)*, 46-59.

[4] Nardin, S. D. (2007). Shear transfer mechanisms in composite columns: an experimental study. *Steel and Composite Structures*, Vol 7, No 5, 377-390.

[5] Marceau, M. G. (2002). Use of Fly Ash in Concrete: Normal and High-Volume Ranges. *PCA R&D Serial No 2604*.

[6] Tao, Z. H. (2008). Strength and ductility of stiffened thin-walled hollow steel structural stub columns filled with concrete. *Thin-Walled Structures, 46(10)*, 1113-1128.

[7] Gore, V. V, & Kumbhar, P. D. (2015). Performance of Concrete Filled Steel Tube (CFST) Section: A Review, (November), 2-5

[8] Yang, Z., & Xu, C. (2018). Research on Compression Behavior of Square Thin-Walled CFST Columns with Steel-Bar Stiffeners. *Applied Science.*

[9] Hazlin, A. R., Afif. I., Mohamad, N., Goh, W. I., Sia, L. M., Samad, A. A. A., and Ali, N., (2019), Characteristics Foam Concrete with Polypropylene Fiber and Styrofoam, IOP *Conf. Series: Journal of Physics: Conf. Series 1198*