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Research paper

Coconut Fiber Strengthen High Performance Concrete: Young's Modulus, Ultrasonic Pulse Velocity and Ductility Properties

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Abstract

This paper emphasis on experimental investigation to govern the engineering properties such as young's modulus, pundit ultrasonic pulse velocity (UPV) and ductility of High Performance Concrete (HPC) with grade M60 with addition of coconut fibre (CNF) together with silica fume (SF) and pulverised fuel ash (PFA). For this study, 3 mixes were prepared. First was the CNFRC without any additives, secondly the CNFRC made by 10% replacement of cement weight with PFA and thirdly composition of 10% of cement weight was exchanged with SF. It should be pointed out that for each mix; CNF was included in the mixture (0.5% of the mix volume). The investigational results had shown that the Young's modulus of CNFRC, CNFR SFC and CNFR PFAC enhanced by about 6%, 3%, and 12% correspondingly. In terms of ductility, when control HPC specimens were subjected to axial compressive strength, slight preliminary cracks shaped on the surface of specimens. Among all HPC specimens tested, CNFR PFAC attained the utmost UPV at 28 day.

Keywords: *Cellular mortar; Coconut fiber; Compressive strength; Flexural strength; Lightweight concrete; Tensile strength*

1. Introduction

These days, the construction industry has been enthusiastically considering for novelty in the concrete which has high strength as well as durability, for the construction of high rise buildings, bridges and restoration of old structures [1,2,3,4]. High rise structures are typically solidly reinforced and have very little room for concrete element to be filled in which can be a major flaw if not filled and compressed entirely [5,6,7]. High Performance Concrete (HPC) is self-compacting and easily fills up the spaces between the reinforcing bars [8,9,10].

High Performance Concrete (HPC) became commercially obtainable in Malaysia in the year 2004 [11,12]. The existence of HPC had led to the use of HPC in numerous bridge applications, comprising precast, pre-stressed girders; precast waffle slab for bridge decks and as a joint material between precast concrete deck panels and girders and between the flanges of neighboring girders [13,14,15].

The coconut fibre (Figure 1) is commercial available in three forms, namely bristle (long fibres), mattress and decorticated [16]. These different types of fibres have different uses depending upon the requirement. In engineering, brown fibres are mostly used [17,18]. There are many general advantages of coconut fibres e.g. they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean [19,20,21]. Coconut fibre also has been used to enhance concrete and mortar, and has proven to improve the brittleness, ductility and toughness of the concrete and mortar [22,23,24].

Fig. 1: Coconut nucifera fibre [16]

Therefore this this research aims to investigate the engineering properties of of High Performance Concrete (HPC) of grade M60 with addition of treated coconut fibre (CNF) together with silica fume (SF) and pulverised fuel ash (PFA) such as young's modulus, ultrasonic pulse velocity (UPV) and ductility.

2. Materials

The Type I Portland cement was used in this study. The sand added into the mix has the modulus of 3.07 and specific gravity of 2.59. The maximum size of sand utilized was 5 mm which passing the 10 mm sieves analysis. On the other hand, silica fume implemented in the mix design has a specific surface of 0.236 m²/g and specific gravity of 2.25. In addition, the pulverised fuel ash utilized has a specific gravity of 2.12. Figure 2 shows the samples prepared for this study.

Fig. 2: Cube samples prepared for this study

Foam generator TM1 supplied by DRN resources was used as a foam generator machine in this study as shown in Figure 3.

Fig. 3: Foam generator TM1

3. Experimental

3.1. Young's Modulus and Ductility

To monitor the Young's modulus, ductility and mode of failure, the axial compressive strength test was performed of a cube with a 100mm x 100mm x 100mm dimension (Figure 4). The tests have been conducted as specified in the test method MS EN 12390-3: 2012 [25] with the aid of GOTECH GT-7001-BS300 Universal Testing Machine [26]. For each mixture, there were 9 samples were prepared and the tested at 7-day and 28-day.

Fig. 4: Compression test on HPC cube

3.2 Ultrasonic Pulse Velocity (UPV)

The pundit UPV test was executed to govern the eminence of the HPC and occurrence of major and minor cracks in HPC. Ultrasonic Pulse Velocity was retrieved by Portable Ultrasonic Non-destructive Digital Indicating Test [27]. The test was performed conferring to the technique in BS EN 12504-4:2004. A prism sample with dimension 100mm x 100mm x 500mm was prepared for this test (Figure 5).

Fig. 5: Ultrasonic Pulse Velocity (UPV) Test on HPC prism

4. Results and Discussion

4.1. Dry Density of HPC

Density of HPC was measured at 7, 14 and 28 day which is achieved by weighting cubes before the compression test. For all mixes it was detected that, density of HPC was marginally enlarged over the age of testing [28]. Densities of the 4 admixtures are in the range of 2380-2595 kg/m³ which are above the considered range for conventional normal strength concrete. It is important to attain a determined potential density because a high density stops the water vapour inside the HPC from absconding out of the concrete weight. On the other hand, there was an insignificant drop in the density of CNFR PFAC and CNFR SFC compared to CNFRC because PFA and SF have a lesser specific gravity compared to the cement. Specific gravity of PFA and SF are 2.21 and 2.18 correspondingly, which are rather lighter than Portland cement with a specific gravity of 3.14. Consequently, adding this pozzolans to a HPC mixture will not densify the material itself [29]. Influence of coconut fiber also reduced the HPC density by about 1.5% since attendance of voids in HPC decreases the density and strength as well.

4.2. Young's Modulus

Table 1 shows the results of dynamic Young's modulus of HPC at 28 day. Comparing to the control mix, the dynamic Young's modulus of CHFRC, CHFR SFC and CFHR PFAC improved by about 6%, 3%, and 12% respectively. Among the factors affecting Young's modulus, moisture condition plays an important role comprehensively. Moist curing of the sample until testing time abridged drying and augmented Young's modulus of HPC as drying creates extra micro cracks in the transition region [8], which affects the stress-strain behaviour of the HBP specimens. It should be pointed out that coconut fiber also plays an important role to reduce the micro cracks in the transition zone [30].

Table 1: Dynamic Young's Modulus results of HPC

HPC Mix	28-Day dynamic modulus of elasticity (Gpa)
Control	44.74
CNFRC	47.42
CNFR SFC	46.08
CNFR PFAC	50.11

4.3. Ultrasonic pulse velocity (UPV)

Table 2 shows the Ultrasonic pulse velocity (UPV) results of HPC. Among all specimens, CNFR PFAC obtained the highest ultrasonic pulse velocity at 28 day. It was higher than UPV of the CNFR PFAC attained the utmost UPV at 28 day. It was higher than UPV of the CNFRC about 2% and the lowest UPV was achieved by CNFR SFC that was lower than that of CNFR SFC about 2%. This has indicated that the pulverised fuel ash series specimens might have more compressed microstructures than silica fume series samples. It should be pointed out that HPC with less permeability has better strength and higher UPV since the presence of void on the path will upsurge the path length as it goes around the void. Ultrasonic pulse velocity of CNFRC, CNFR SFC and CNFR PFAC were between 4.2 and 4.5 km/s. Consequently, conferring to IS: 13311 Part 1, they were categorized as sound concrete with appropriate quality comprehensively.

Table 2: Ultrasonic pulse velocity results of HPC

HPC Mix	28-Day dynamic modulus of elasticity (Gpa)
Control	44.1
CNFRC	45.8
CNFR SFC	44.9
CNFR PFAC	46.2

4.4. Ductility of HPC

During the compression test, the crack pattern occurs was observed precisely. When the control specimen of HPC was exposed to axial compression, it can be seen that some minor initial cracks were shaped at the surface of the tested sample. The failure of the HPC sample took place as soon as the decisive axial compressive load was accomplished. Conversely, when the CNFRC samples were loaded, it can be seen that it's still unbroken although the decisive axial compressive loading was applied on the sample.

5. Conclusion

After conducting extensive experimental research work, following conclusions can be drawn from the results:

- For all mixes it was detected that, density of HPC was marginally enlarged over the age of testing. Densities of the 4 admixtures are in the range of 2380-2595 kg/m³ which are above the considered range for conventional normal strength concrete. It is important to attain a determined potential density because a high density stops the water vapour inside the HPC from absconding out of the concrete weight. On the other hand, there was a insignificant drop in the density of CNFR PFAC and CNFR SFC compared to CNFRC because PFA and SF have a lesser specific gravity compared to the cement
- Comparing to the control mix, the dynamic Young's modulus of CHFRC, CHFR SFC and CFHR PFAC improved by about 6%, 3%, and 12% respectively.
- CNFR PFAC obtained the highest ultrasonic pulse velocity at 28 day. It was higher than UPV of the CNFR PFAC attained the utmost UPV at 28 day. It was higher than UPV of the CNFRC about 2% and the lowest UPV was achieved by CNFR SFC that was lower than that of CNFR SFC about 2%.

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