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Research paper

Experimental Study to Establish Compressive and Flexural Strength of High Performance Concrete (HPC) with Addition of Treated Cocos Nucifera Fiber

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Abstract

This paper focuses on laboratory investigation to establish the mechanical properties of High Performance Concrete (HPC) of grade M60 with addition of treated cocos nucifera fiber (CNF) together with silica fume (SF) and pulverised fuel ash (PFA). There are 3 diverse mix designs of CNF strengthened concrete (CNFRC) were prepared accordingly. Foremost CNFRC deprived of any additive, subsequent CNFRC made by 10% replacement of cement mass with PFA, followed by arrangement of 10% of ordinary cement (by weight) was supplanted with SF. For respective mix design, CNF was included in the mix 0.5% from the total volume. Test results had indicated that by adding CNF lead to 3% decrease in axial compressive strength of the HPC which was due to dropping the quality of compaction. Through the axial compression test performed, the strength of CNFRC PFAC was about 8% greater associated to the control specimen as PFA by means of its globular element form. Moreover, the inclusion of fiber in the mix had develops the strength under flexure load of CNFRC, CNFRC SFC, CNFRC PFAC by about 10%, 8%, and 25% correspondingly.

Keywords: *Cellular mortar; Compressive strength; Bending strength; Lightweight concrete; Tensile strength*

1. Introduction

In this day and age, attentiveness on the natural fiber can be seen gradually in Malaysia since it has retains green and efficient in construction industries [1,2]. Innumerable natural fibers specifically cocos nucifera, abaca, jute, bamboo, kenaf and many others. are broadly used in industries for making high performance concrete (HPC). From a structural point, the principal motivation for adding fibers to progress structural properties of HPC through the fibers ability [3,4]. Fibers acts as a multi-dimensional support and it boosts the connection between the surrounding substance that in turn upsurges the tensile strength and structural reliability of the concrete [5,6]. It seem that natural fiber is a better choice compared to synthetic fiber as natural fiber is a sustainable material and suitable as composite material in the production of HPC [7,8,9]. Likewise, natural fiber have been gaining significant interest to be explored as alternative raw materials to synthetic or inorganic fiber due to its benefits including cheaper in overall construction cost, very light and moveable, renewable and greater in terms of health and safety issue [10,11,12].

The use of cocos nucifera composites as reinforcement is currently one of the more interesting area of research [13,14,15,16]. Several sectors, especially from the research field involved in the use of natural materials as a reinforcement fiber, claim that cocos nucifera to be among the best material available to replace synthetic fiber [17,18]. The advantages of natural cocos nucifera included in increasing toughness, enhancing cracking behavior, enhanced durability and improving fatigue and impact resistance [19,20].

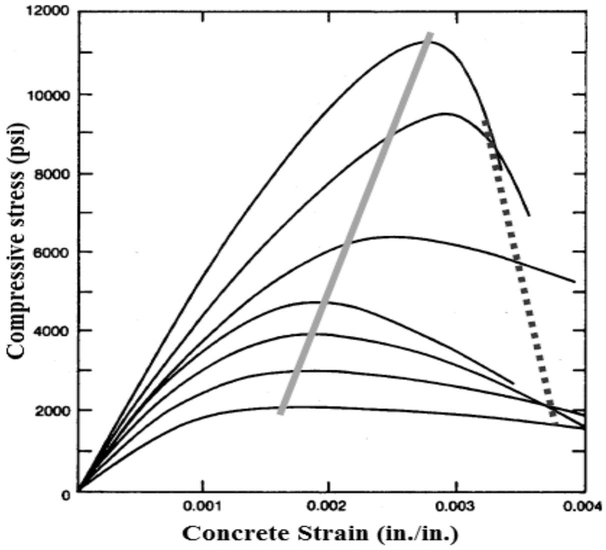

Fig. 1: Typical concrete stress-strain curves in concrete [24]

It should be pointed out that High Performance Concrete (HPC) had been broadly utilized in the global market around the countries as it has excellent engineering features and great rheological performance as well in comparison to normal concrete [21,22,23]. HPC encompasses compound component; for instance for the water lessening ensuring axial strength between in the range of 45 to 90 N/mm^2. Figure 1 shows typical concrete stress-strain curves in HPC and Figure 2 demonstrates the crack opening vs tensile stress of HPC.

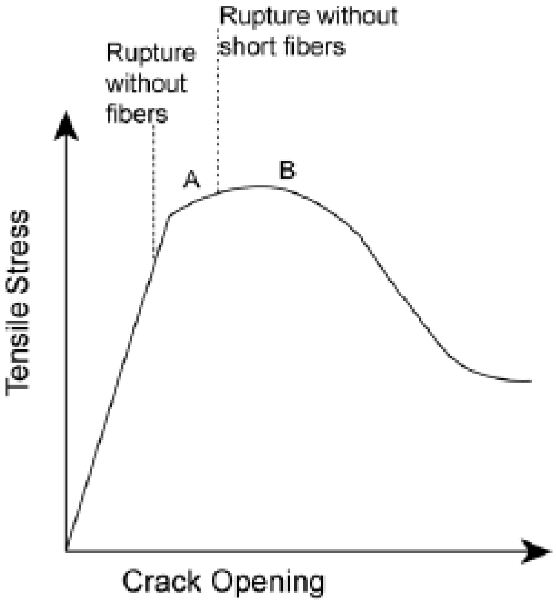

Fig. 2: Crack opening vs tensile stress of HPC [25]

Hence this this paper aims to investigate the axial compressive strength and bending strength of High Performance Concrete (HPC) of grade M60 with addition of treated cocos nucifera fiber (CNF) together with silica fume (SF) and pulverized fuel ash (PFA).

2. Materials

For this investigation, Type I ordinary Portland cement was used which was supplied by local company based in Penang which is Lafarge Cement Sdn Bhd (Malaysia). The fine aggregates have the modulus of fineness approximately 2.98. In addition the specific gravity for the aggregate is 3.01. Lastly the fly ash used was F-class with specific gravity of 1.97 and the particle size was roughly 25.76 µm.

3. Experimental

The axial compressive strength test (Figure 3) for HPC specimens was accomplished on a cylindrical shape with a diameter of 100mm and height of 200mm [26]. This test had been carried out as per itemized in Malaysian Standard 12390 (Part 3: 2012). To perform this strength test, a GO-TECH GT7001 (BS300) Universal Testing Machine at the HBP Testing Unit was utilized [27]. For each mixture 9 specimens were and the tested at 7 and 28 days. The bending strength test (Figure 4) was performed on rectangular specimens with dimensions of 100mm in elevation, 100mm in breadth 500 mm in length using the four point loading procedure of MS 26: Part 2.

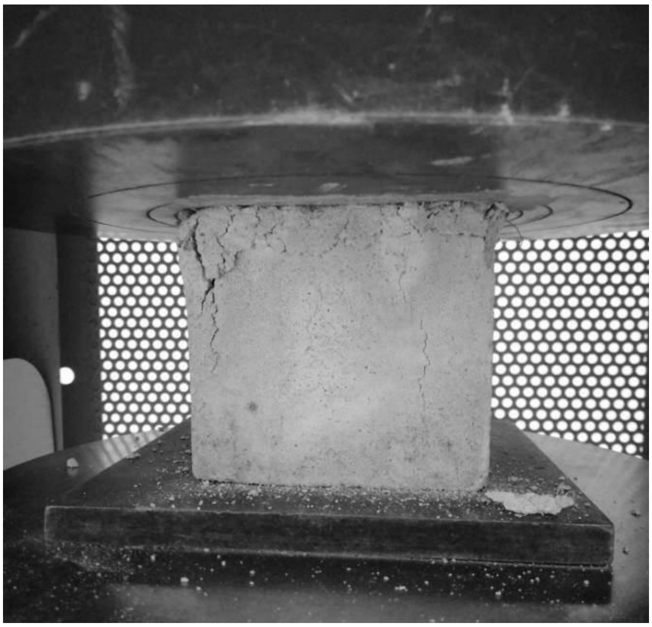

Fig. 3: Axial Compressive Test Machine

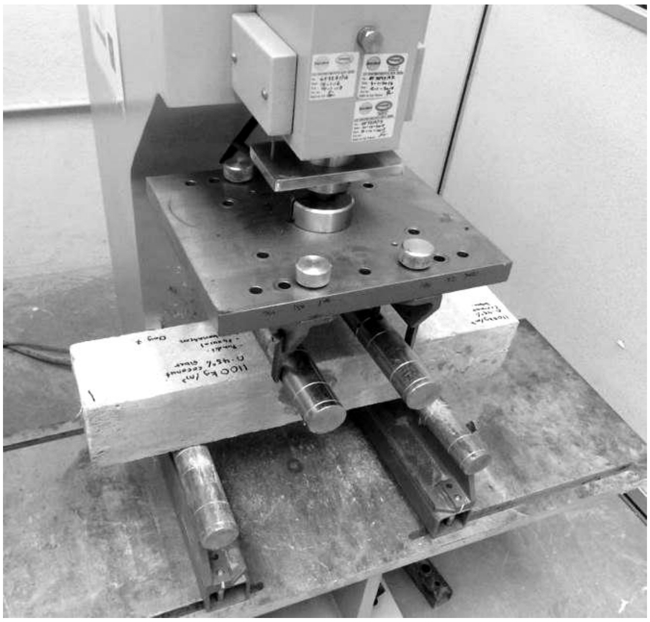

Fig. 4: Bending Test Setup

4. Results and Discussion

4.1 Axial Compressive Strength of HPC

Figure 5 indicates the axial strength of diverse mixes at 7-day test and 28-day test. It can be clearly seen that for entire blends, the strength augmented with the testing days. Cocos nucifera fiber insertion in HPC instigated small decrease in its axial compressive strength ability. Nevertheless, a substantial enhancement in the axial compressive strength of cocos nucifera fiber reinforced HPC with 10% cement replacement with PFA was recorded. Compressive strength of cocos nucifera fiber reinforced concrete including SF was marginally lesser paralleled to that of cocos nucifera fiber reinforced concrete devoid of any additive.

It also can be seen from Figure 6 that the strength of CNFRC stayed 2% lesser equated to HPC (control mix) on 28-day of testing. Cocos nucifera fiber reduced the axial compressive strength of HPC by growing voids content owing to lesser effectiveness in HPC compaction. Hence, subsequently at hand is no connection occurs amongst fibers and it’s not attached through the matrix adequately, the breakage transpires afore attaining the selected strengths capacity of the material [4]. On the other hand, the axial compressive strength of CNFR PFAC was about 10.4% greater compared to control HPC. Addition of cocos nucifera fiber augmented the voids content in HPC which lead to lessening of axial compressive strength. PFA can be said to have void-filler capability than Ordinary Portland Cement (OPC). The globular form of PFA elements similarly, permitted it to run with no trouble in the mix. This condition will lead to formation of additional pores in the hardened matrix [28, 29].

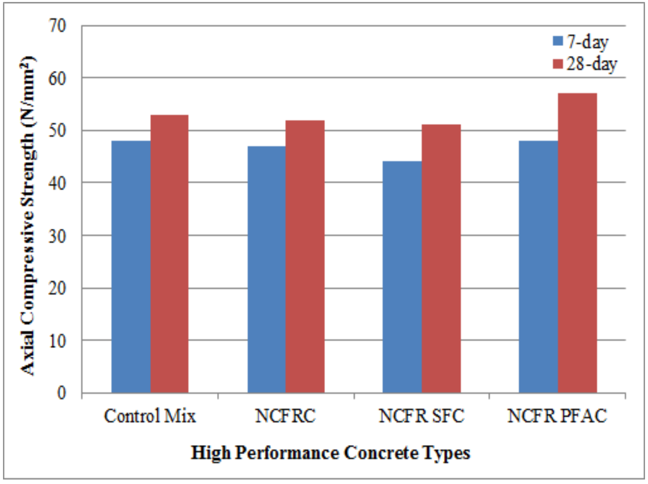

Fig. 5: Axial compressive strength of HPC of different mixes

4.2 Bending Strength of HPC

Bending strength is the most important parameter in designing beam for building. Figure 6 establishes strength of HPC under bending load for various mixtures which were tested at 7-day and 28-day. It can be clearly seen in Figure 6 that the bending strength of CNFRC, CNFR SFC, CNFR PFAC enriched around 8.7%, 6.9%, and 22.7% individually when compared to the Control HPC specimen.

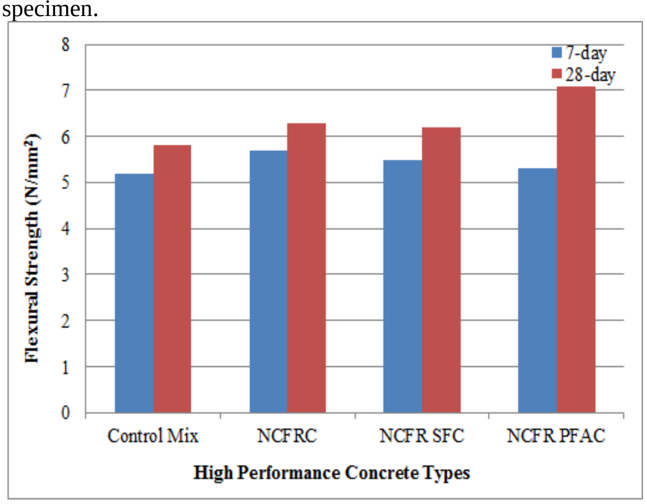

Fig. 6: Bending strength of HPC of different mixes

The cement compound milieu has a vital role of conveying realistic weight on fibers laterally thru keeping the fibers composed [30]. Competence of fibers strengthened HPC be contingent inside the fiber medium boundary and the aptitude of pressure transmission on or after the matrix to the fiber component. Intermittent fibers are indiscriminately dispersed through the cement matrix in order to delay and control the ductile serious cracks of HPC. Fibers transmute intrinsic unsteady ductile fissure spread to a deliberate meticulous crack development [31]. These cracks monitoring possessions of fiber fortification postponements the beginning of bending cracking and upsurge the bending strength of HPC [32]. In addition, the fibers did managed to get grasp of giving extra workable strength and contraction in HPC under bending hence the compound won't be able to sustain the additional load which reacted in the specimen once the primary crack took place. The cocos nucifera fiber also decline the additional crackings in the conversion and shows important role in distressing the curve of stress over displacement of HPC as the transition region physiognomies distress the Young's modulus of HPC [33]. Figure 7 shows the patterns of crack for normal concrete and HPC. As far as HPC is concerned, there were diversity of cracks length is smaller in comparison with normal concrete.

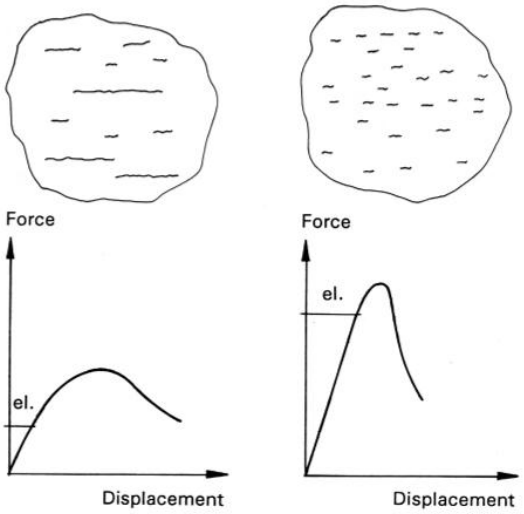

Fig. 7: Crack patterns for normal concrete (left) and HPC (right)

Figure 8 visualizes the differences of traditional concrete (normal strength concrete) and the high performance concrete (HPC) in terms of pore distributions once its hardened. In traditional concrete, there were formations of many capillary pores in the hardened matrix.

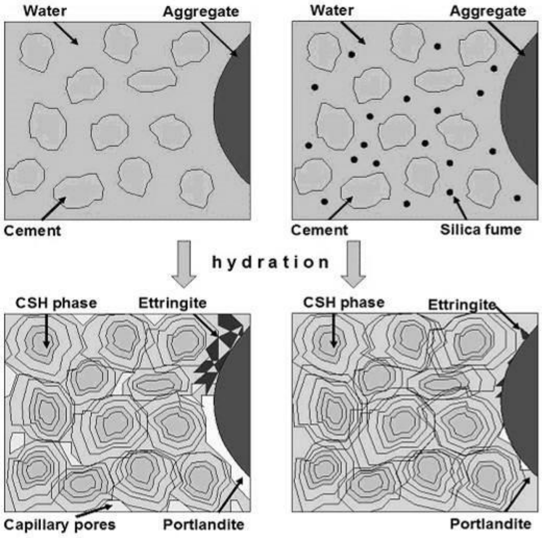

Fig. 8: Axial compressive strength of HPC of different mixes

5. Conclusion

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

- By adding cocos nucifera fiber lead to 3% decrease in axial compressive strength of the HPC which was due to dropping the compaction superiority in existence of cocos nucifera fiber and growing porosity.
- The strength under axial compression of CNFRC PFAC was about 10.4% greater when comparing with the control mix as PFA with its sphere-shaped component profile
- In addition, the study also found that the concrete voids diminished and porosity reduced dramatically.
- Incorporation of cocos nucifera in the mixture had improved bending strength of CNFRC, CNFRC SFC, CNFRC PFAC by

about 10%, 8%, and 25% correspondingly. The cocos nucifera fiber transforms inherent unsteady stretchy cracks spread to a deliberate meticulous cracks development in the sample. The cracks monitoring possessions of fiber strengthening postponements the beginning of bending cracking and upsurge the bending strength of HPC

Cocos nucifera fiber able to offer extra ductility and improved deformation of HPC through bending. The cocos nucifera fiber also declines the additional cracking's which took place in the cement matrix.

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