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Comparative Study of Mechanical and Microstructural Properties of Interlocking Concrete Blocks Reinforced with Chicken Feather Fiber and blend of Chicken Feather Fiber/Synthetic Hair Fibers

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Abstract
Concrete reinforcement with fibers is undergoing findings in order to manufacture concrete with low cost but improve mechanical and microstructural properties.Chicken feather fiber(CFF) possesses characteristics, which can improve the mechanical and microstructural properties of the concrete. Concrete is a brittle material with no tension. In this study, samples A (control sample), B1 and C1 constitute of 0%, 1% and 3% by weight of CFF while B and C constitute of 0.5% and 1.5% equal proportion of CFF and Synthetic hair fiber(SHF) respectively. Concrete with CFF and CFF/SHF composites were tested to determine water absorption (WA), thickness swelling (TS), compressive strength (CS) and splitting tensile strength (STS) between 7 to 28 days of curing. Results of WA of concrete increased after 28 days to 10.01%, 12.52% and 23.11% for samples A, B1, C1 and 11.83% and 17.67% for samples B and C respectively. Similarly, TS increased after 28 days to 0.13%, 0.22% and 0.32% for samples A, B1and C1 and for samples B and C it remains stable at 0.25%., respectively. CS of samples A and B1 increased with curing days to values of 20.66 MPa and 9.36 MPa, respectively. However, for samples C1, B and C it decreased to 3.74 MPa, 9.98 MPa and 4.29 MPa. STS of A, B1 and C1 increased with curing days with values of 13.94 MPa, 8.91 MPa and 2.26 MPa respectively while samples B and C decreased with curing days with values of 5.43 MPa and 2.39 MPa respectively, after 7 days. Results of SEM deduced that CFF improves the ductility of ICBs but increased in the proportion resulted in reduction of the STS of the concrete. Similarly, SHF offers higher CS but also serves the purpose of reduction in micro cracking and increasing structural stability.

Keywords: Concrete block, CFF, splitting tensile strength, Compressive strength, Curing.

Introduction
In recent years, the manufacturing of concrete blocks has been subjected to the inclusion of waste materials following intensive research work. Most research considered the incorporation of natural fibers in concrete blocks because of the ever-increasing global demand for sustainable infrastructures development (Cheng *et al*., 2009). Concrete is a brittle material that has low tensile strength and low strain capacity. Many deteriorations and failures in the concrete structures are due to the brittle nature of this material. The most common imperfection of this material is shrinkage cracking in concrete, which reduce the penetration resistance of concrete, influence the use of the buildings, and accelerate the erosion.

Fiber-reinforced concrete is widely used today. Fiber can improve the tensile strength, deformability, durability and resistance to the dynamic ability of the concrete. Woranuch*et al*. (2017) investigated the effect of banana fibers on mechanical and physical properties of lightweight concrete blocks. The report showed that increase of fiber content led to the increase of water absorption and changing length but decrease of density of concrete block. According to Sarada *et al*. (2018) the effectiveness of the surface modified jute fiber as fiber reinforcement in controlling the physical and mechanical properties of concrete paver blocks. The experimental results reveal that the compressive strength, flexural strength, and flexural toughness of tannin and polymer modified jute fiber reinforced concrete paver block (TJP) are 30% and 49%, and 166% higher, respectively, as compared to that of reference paver blocks (RP).

Therefore, reinforcing concrete such as interlocking concrete blocks with chicken feathers fibers (CFFs) will improve the properties of the concrete. The use of CFFs as reinforcement in composites offers an environmentally benign solution for feather disposal and also provides profits for the poultry industry. Chicken feather (CF) generated in the poultry industry are considered as waste products. An estimated millions of tons of chicken are consumed annually all over the world according to the Food and Agriculture Organization of the United Nations (Forgács *et al*., 2013). At the same time, about 3 billion pounds of the chicken feathers are generated annually. The traditional disposal strategies of CF are expensive and difficult; and are often burned in incineration plants, buried in landfills or recycled into low quality animal feeds. However, these disposal methods are restricted or generate greenhouse gases that pose danger to the environment.

Approximately, chicken feathers consist of fifty percent (50%) of feather fiber (barbs) and quill (rachis) by weight, the quill being the stiff central core with hollow tube structure. Both feather fiber and quill have 90% by weight of their constituent made of keratin, an insoluble and highly durable protein found in hair, hoofs, and horns of animals (Schmidt, 2002). Keratin in CFF only consists of a large number of amino acids (made up of cystine, lysine, proline, and serine). These amino acids tend to cross-link with one another by forming disulfide or hydrogen bonds resulting in fibers that are tough, strong, lightweight, and with good thermal and acoustic insulating properties (Kumar *et al*., 2015). These exceptional properties and characteristics of keratin have brought about different research works on the use of waste chicken feathers for a number of potential industrial applications (Aluigi *et al*.,2008; Yang *et al*.,2016). In addition, human hair not only offers higher compressive strength but also serves up the purpose to reduce the micro cracking and increasing structural stability (Ganiron, 2014). Ganiron (2014) also stated that human hair is strong in tension and can be used as a fibre reinforcement material. It is an alternate non-degradable matter that is available in abundance at a little or no cost, and it also creates environmental problem for its decompositions. Hair can be used as a fibre material in concrete because of its high tensile strength which is equal to that of a copper wire with similar diameter. In addition, it is very obvious that concrete is weak in tension and hence some measures must be adopted to overcome this deficiency. A way of overcoming this is by introducing hair fibre, which is strong in tension and readily available in large quantity, into the concrete. Fibre reinforced concrete has been reported to be convenient, practical and economical method of overcoming micro-cracks and other deficiencies in concrete (Nila *et al*., 2015; Pawar *et al*., 2015). This study investigated the effect of chicken feather fiber on mechanical and microstructure properties of interlocking concrete block.

Materials and Methods

Chicken feather, Portland cement, synthetic hair fiber, stone dust and water are the materials that were used in this study for the investigation of the effect of chicken feather fiber (CFF) and synthetic hair fibre (SHF) on the mechanical properties of interlocking concrete block. The chicken feathers (CFs) were obtained from Lawoya poultry farm in Ogbomoso, Oyo State, Nigeria. These were brought to the laboratory in sacks and washed several times with water mixed with laundry detergent and sodium chloride to remove blood, extraneous materials and poultry droppings attached to the chicken feathers. The chicken feather fibres were dried in open air, with direct solar radiation to evaporate the water content. The chicken feather fiber was processed by grinding using Wiley milling machine and the powder was sieved out which is stored at room temperature after which the chicken feather fibers were used as filler into Interlocking concrete block. Also, used synthetic hair was collected from different hairdressing saloons and beauty parlour in Ogbomoso environment, and were similarly washed properly using cool water and wig shampoo. The synthetic hair was exposed to sunlight for proper drying. The hair was cut into smaller length using scissors.

Portland cement was used as the mixture binding material. The Portland cement used is premium quality 42.5R grade 'Dangote 3X Cement', which have high clinker content and are suitable for most building uses including high rise and some infrastructure works. The Portland cement used was purchased from a cement retail shop in Ogbomoso, Oyo State. Accurate percentage of water was used with the cement to form the concrete-chicken feather fiber aggregate. The proportion by weight of Portland cement was maintained (remain constant) for all aggregate of chicken feather fiber and stone dust. Stone dust is a fine aggregate of granite that is crushed from its natural granite stone size to 20 mm and was obtained from FAGAD Investment Global Service Limited, Quarry section, Iresa-Pupa (8.0563^o N, 4.3462^o E), Ogbomoso, Oyo State.

Preparation, casting and curing of interlocking concrete block (ICB)

A total of two hundred (200) pieces of interlocking concrete blocks were cast, which represents forty (40) pieces each for Sample A to C. The interlocking blocks consist of different mixed proportion of stone dust and chicken feather fiber, in this order of Samples A (0% CFF), B1 (1% CFF), C1 (3% CFF), B (0.5% CFF& 0.5% SHF) and C (1.5% CFF& 1.5% SHF) with 25% weight of Portland cement in each of the Samples respectively as shown in Table 1 using (Sarada *et al*., 2018) cement to sand ratio of 1:3. The formulation of the composition for the ICB was mixed thoroughly for homogeneous mixture using concrete mixing machine.

The concrete molds were free of all impurities by washing and scraping. The wet mixture was filled into the mold and rammed. The excess mixture on the sides and surface of the mold are scraped off and leveled using a straight edge rammer. The weight of the materials used for the preparation of each sample is shown in Table 2. The cast ICB samples were cured for 7, 14, 21 and 28 days.

Determination of water absorption and thickness swelling of ICB

The effect of inclusion of cement, chicken feather and synthetic hair fibres on the hygroscopicity and dimensional stability were measured using water absorption and thickness swelling tests in accordance with the American Society for Testing Materials D 1037 (ASTM, 1995).

Table 1: Composition by weight of cement bonded concrete containing the chicken feather and blend of chicken feather and synthetic hair fiber

Sample	CFF % weight	SHF % weight	Portland Cement %weight	Stone-Dust% weight	Sample Numbers
A	0	0	25	75	40
B1	1	0	25	74	40
C1	3	0	25	72	40
B	0.5	0.5	25	74	40
C	1.5	1.5	25	72	40
				Total	200

Water absorption and thickness swelling tests were determined by submerging samples in water at room temperature. Excess water was drained and change in thickness, amount of water absorbed and final weight of the sample were measured. Thickness swelling (nearest 0.01) was measured from two marked points along the length of each sample with a sliding caliper. Water absorption and thickness swelling were expressed as a percentage of the original weight and thickness, respectively. Ten (10) replicate samples were used for each curing day's treatment. Equations 1 and 2 give the formula for percentage water absorped and thickness swelling respectively.

Table 2: The Weight of the Components of Interlocking Concrete Blocks

Sample	Portland Cement (kg)	Stone Dust (kg)	CFF(kg)	SHF(kg)	Number of Sample
A	29.20	89.00	0.00	0.00	40
B1	25.00	74.00	1.00	0.00	40
C1	20.83	60.00	2.50	0.00	40
B	25.00	73.50	0.50	0.50	40
C	20.50	60.00	1.25	1.25	40

$$\% \, waterabsorped = \frac{W_2 - W_1}{W_1} \times 100\% \qquad (1)$$

$$\% \, thicknessswelled = \frac{L_2 - L_1}{L_1} \times 100\% \qquad (2)$$

Where, W_1 and $L_1$are the weight and the thickness of the dry sample and W_2 and $L_2$are the weight and thickness of the wet sample after immersion.

Determination of compressive strength of ICB

Compression testing machine was used as shown in Plate 1 to obtain the compressive strength of each of samples A, B1, C1 and B, C which were prepared for each of the ICB after water absorption test according to (ASTM, 1995) for tests on concrete. Maximum compressive strengths were also determined, the readings were recorded and computed using Equation 3 for the compressive strength for each sample tested and the average value for three trial was recorded.

$$Compressive\ Strength = \frac{P}{A} = \frac{P}{LB} \qquad (3)$$

Where, P is the applied load, A is the cross-sectional area, L is the length and B is the width.

Determination of splitting tensile strength of ICB

Splitting tensile strength tests were performed at room temperature on the cured interlocking concrete block samples using Universal testing machine in Plate 2 at a constant loading rate of 0.2 mm/min, following ASTM C496/C496M-11. The splitting tensile strength was calculated using Equation 4.

$$SplittingTensileStrength\ (T) = \frac{2P}{LH} \qquad (4)$$

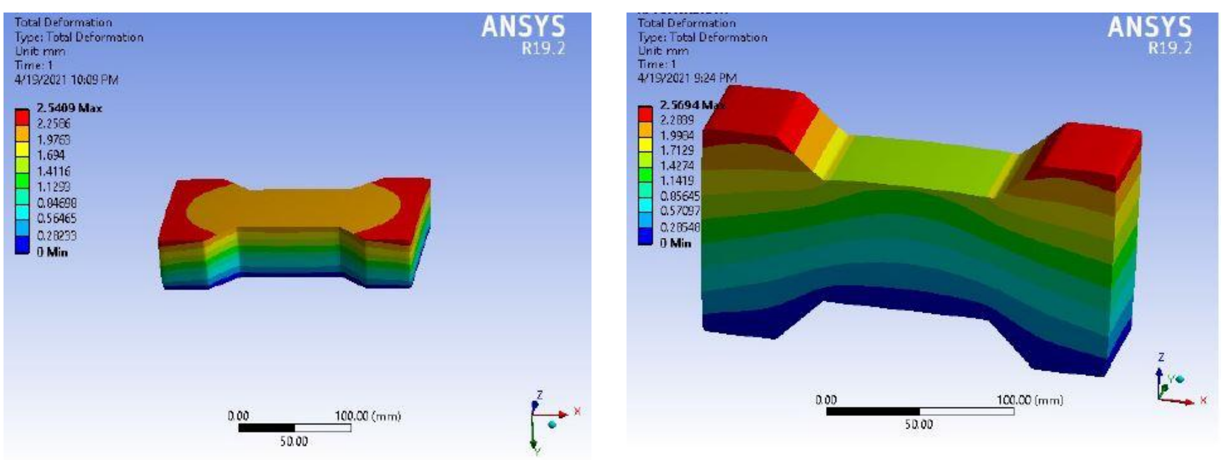
Where T is the splitting tensile strength (MPa), P is the maximum load on the specimen (N), and L is the length of the concrete (mm) and H is the height of the concrete. Three (3) samples were tested for each of samples A, B1, C1 and B, C with respect to the duration of curing. The averages of the measured values were determined.

Structural simulation of ICB

The stress distribution and displacement of the concrete during the compression and splitting tensile test were simulated using ANSYS Workbench 19.2 finite element software. It was also used to determine the maximum loading of the interlocking block. The geometry of the interlocking concrete block was designed on Ansys workbench geometry modeler. Under engineering data, new materials were created and the properties were specified according to the experimentally obtained compressive strength and tensile strength for each sample of interlocking concrete blocks for different curing days. The material was assigned in solid under geometry and a fine mesh was generated with 0.5mm sizing.

Plate 1: The Compression Testing Machine **Plate 2**: The Splitting Tensile Test

For compressive test, the base surface was set as fixed support while a compressive force was applied on the other surface until the maximum stress approach the ultimate compressive strength of the material. Similarly, for the splitting tensile test, one lateral side surface was set as fixed support while compressive force was applied on the other side until the maximum stress approach the ultimate tensile strength of the material. This procedure was repeated for all samples for each curing days based on the principle shown in Figure 1a and b respectively.



(a) **(b)**

Figure 1: The Principle of Curing Days on (a) Compressive and (b) Splitting Tensile Simulation

Scanning electron microscopic (SEM) analysis of ICB

The morphology of the tensile fracture surfaces of the interlocking concrete blocks were analyzed at International Institute of Tropical Agriculture (IITA) in Ibadan, Oyo State using scanning electron microscopic model JOEL-JSM 7600F. Prior to the SEM-EDS analysis, all samples must be of an appropriate size to fit in the specimen chamber and are generally mounted rigidly on a specimen holder called a specimen stub. Samples were coated with platinum coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation.

Results and Discussion

The results of water absorption and thickness swelling properties of the interlocking concrete blocks (ICB) are shown in Figure 2 and 3, which indicated the percentage change in weight and thickness of the concrete block at the initial weight and thickness of the blocks respectively. Fig. 2 shows that the water absorption of sample C decreases with increase in curing days for each concrete samples. While, Samples A, B1, C1 and B show that the water absorption increases from 5.20% to 10.01%, 9.44% to 12.52%, 16.08% to 23.11% and 10.80% to 11.83%. Figure 3 shows that the thickness swelling of sample B and C remain stable at 0.25% before decreasing with curing days. However, the thickness swelling increased after 28 days of curing to 0.13%, 0.22% and 0.32% for Sample A, B1and C1, respectively.

The compressive strength of the interlocking blocks was obtained according to the curing days for each of the samples. Figure 4 shows the results of compressive strength of the ICB for 7 to 28 days of curing. The compressive strength for sample A and B1 increased with increase in curing days, with maximum compressive strength of 20.66 MPa and 9.36 MPa, respectively. Similarly, the compressive strength of Samples C1, B and C was stable with curing days with maximum compressive strength of 3.74 MPa, 9.98 MPa and 4.29 MPa, respectively.

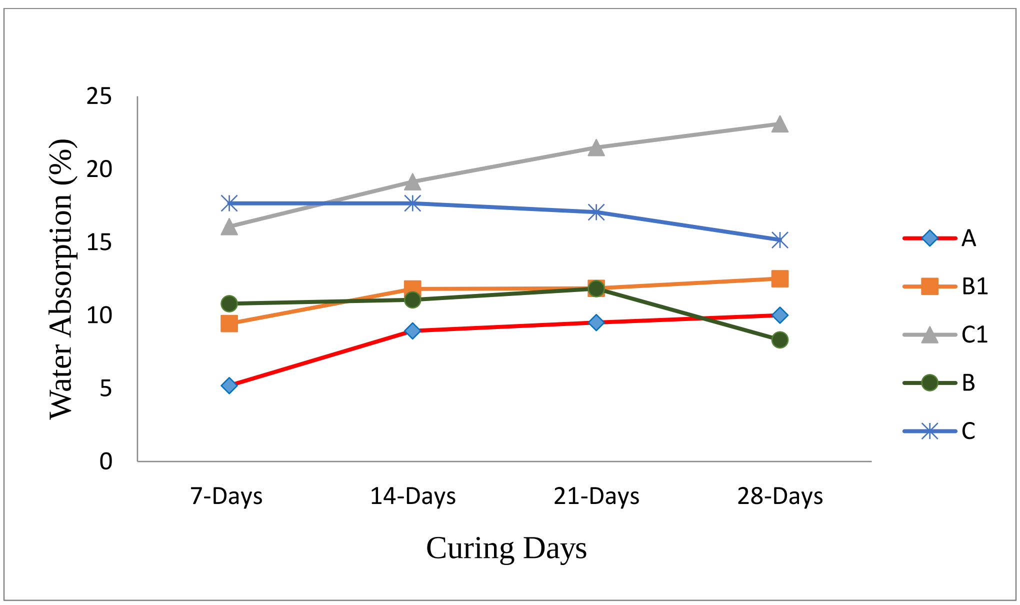


Figure 2: The Water Absorption Properties (%) of Interlocking Concrete Blocks for Different Curing Days

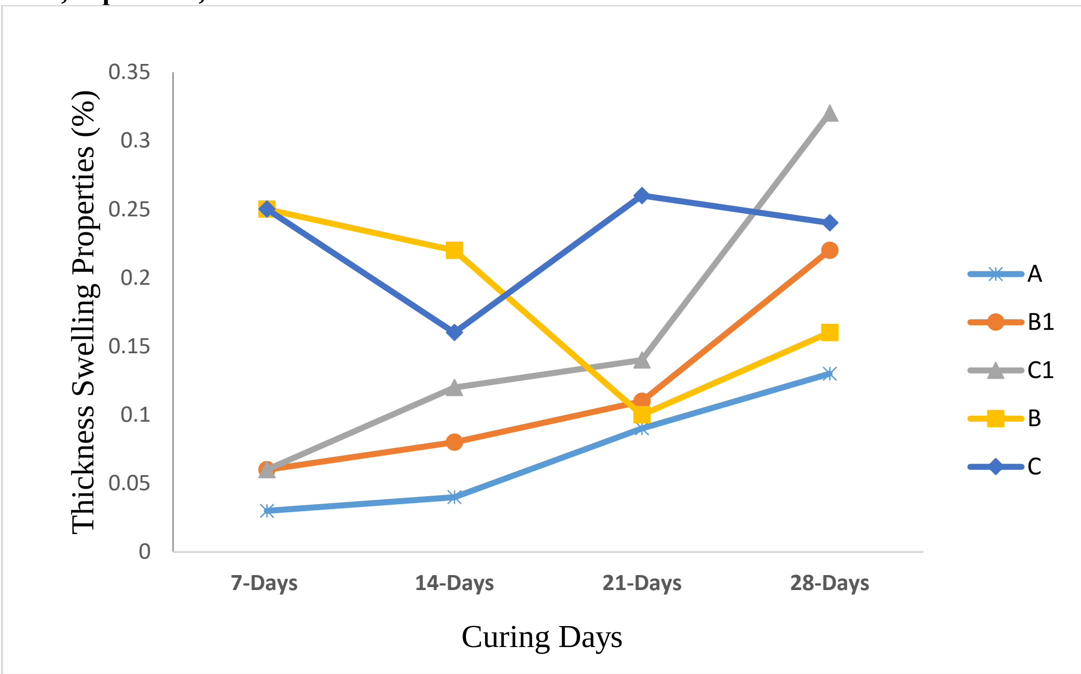


Figure 3: The Thickness Swelling Properties (%) of Interlocking Concrete Blocks for Different Curing Days

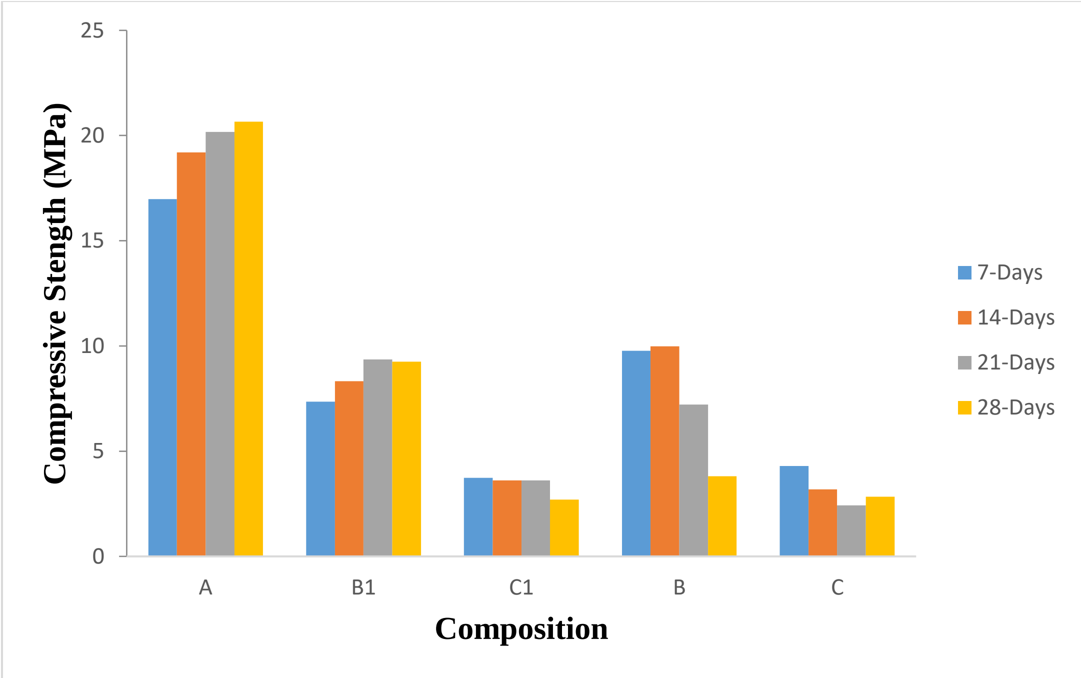


Figure 4: The Compressive Strength of Composites of ICB/CFF and ICB/CFF/SHF for different Curing Days

The results of splitting tensile strength of the interlocking blocks were obtained according to the curing days for each sample of the block. Figure 5 shows the results of splitting tensile strength of the ICB for 7, 14, 21 and 28 days of curing respectively. It shows that the splitting tensile strength of Sample A, B1 and C1 increased with curing days with maximum strength of 13.94 MPa, 8.91 MPa and 2.26 MPa respectively. In contrary, the splitting tensile strength of sample B and C decreased after 7 days of curing to a value of 5.43MPa and 2.39MPa respectively. This shows that curing days does not bring about any improvement on the splitting tensile strength for samples B and C.

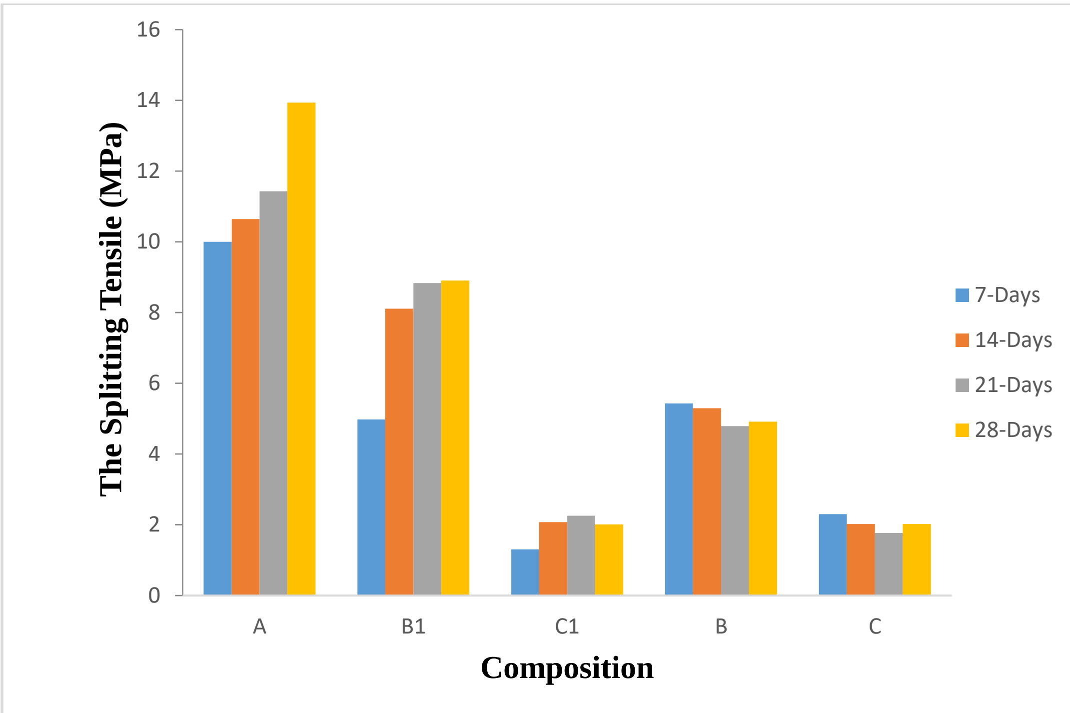


Figure 5: The Splitting Tensile of Composites of ICB/CFF and ICB/CFF/SHF for different Curing Days

The maximum simulated results of compressive force that can be applied on all samples in this study are shown in Figure 6 as 250.30 kN, 113.80 kN, 45 kN, 148 kN and 64kN for samples A, B1, C1, B and C, respectively. These values were attained for samples A and B1 at 28 days of curing while for samples C1, B and C they were attained after 7 days of curing. The maximum compressive loading increases with increase in the number of curing days for sample A and B1, while in sample C1, B and C it decreases after 14 curing days. Similarly, maximum simulated results of splitting tensile force for samples A, B1, C1, B and C, respectively are as shown in Figure 7, which are 63.8 kN, 43.20 kN, 15 kN, 11 kN and 4.80 kN respectively.

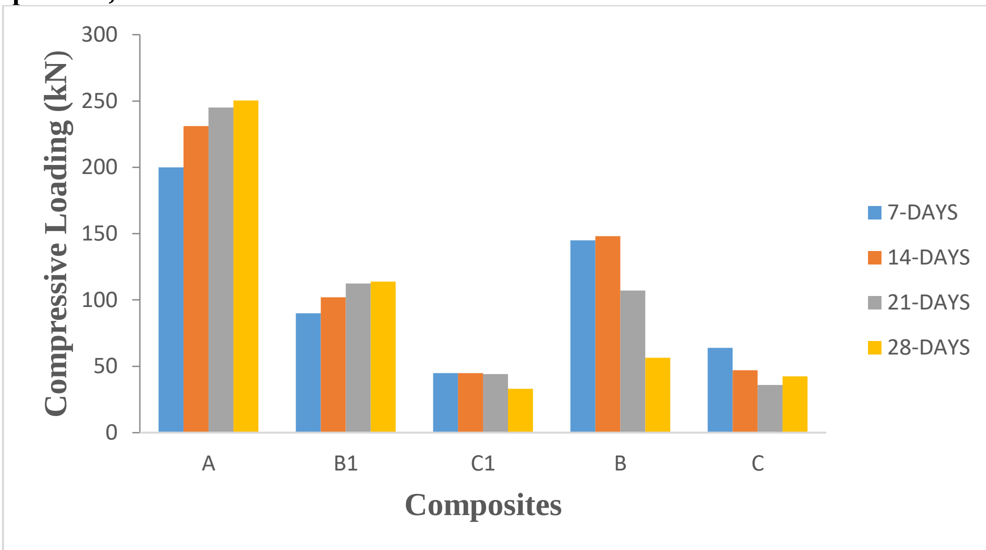


Figure 6: The Simulated Result of Maximum Compressive Loading Versus Composites

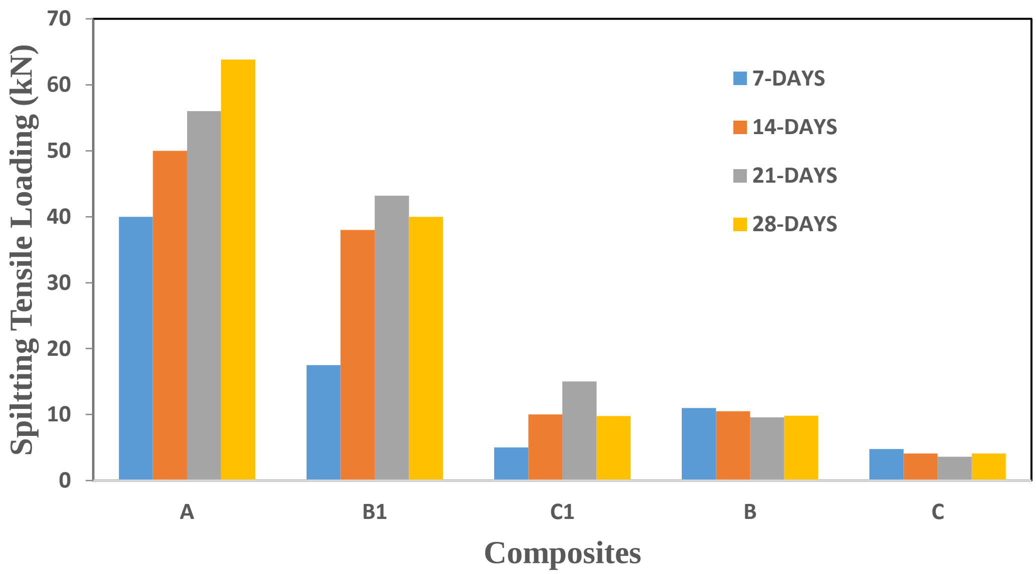


Figure 7: The Simulated Result of Maximum Splitting Tensile Loading Versus Composites

Figure 8 (a)-(e) show the scanning electron microscope (SEM) morphology of fracture surfaces of Sample A, B1, C1, B and C after 28 days of curing respectively. Figure 8a indicates rough surfaces and less tear lines, showing brittle failure mode. Figure 8b show rough surfaces, which are smooth than that of sample A, indicating brittle failure mode but more ductile than sample A. Similarly, Figure 8(c)-(e) show rough surfaces, poor interfacial adhesion and voids between the concrete matrix and the fiber and more pull out of the fiber from the matrix, which result in the reduction in the tensile and compressive strength of the composites. It can be deduced that the CFF improve the ductility of the interlocking concrete blocks but increased in the proportion resulted in reduction of the tensile strength of the concrete blocks.

Figure 9 (a)-(e) show the EDS spectra of samples A, B1, C1, B and C at 28 days of curing. All samples retained the major elemental composition found in cement and stone dust which are Ca, Fe, Si, C and Mg at slightly varying composition. The presence of about 20 wt% oxygen in most of the samples indicate that majority of the metallic elements are in oxidative state or compounds of oxygen which EDS has no capability of reporting.

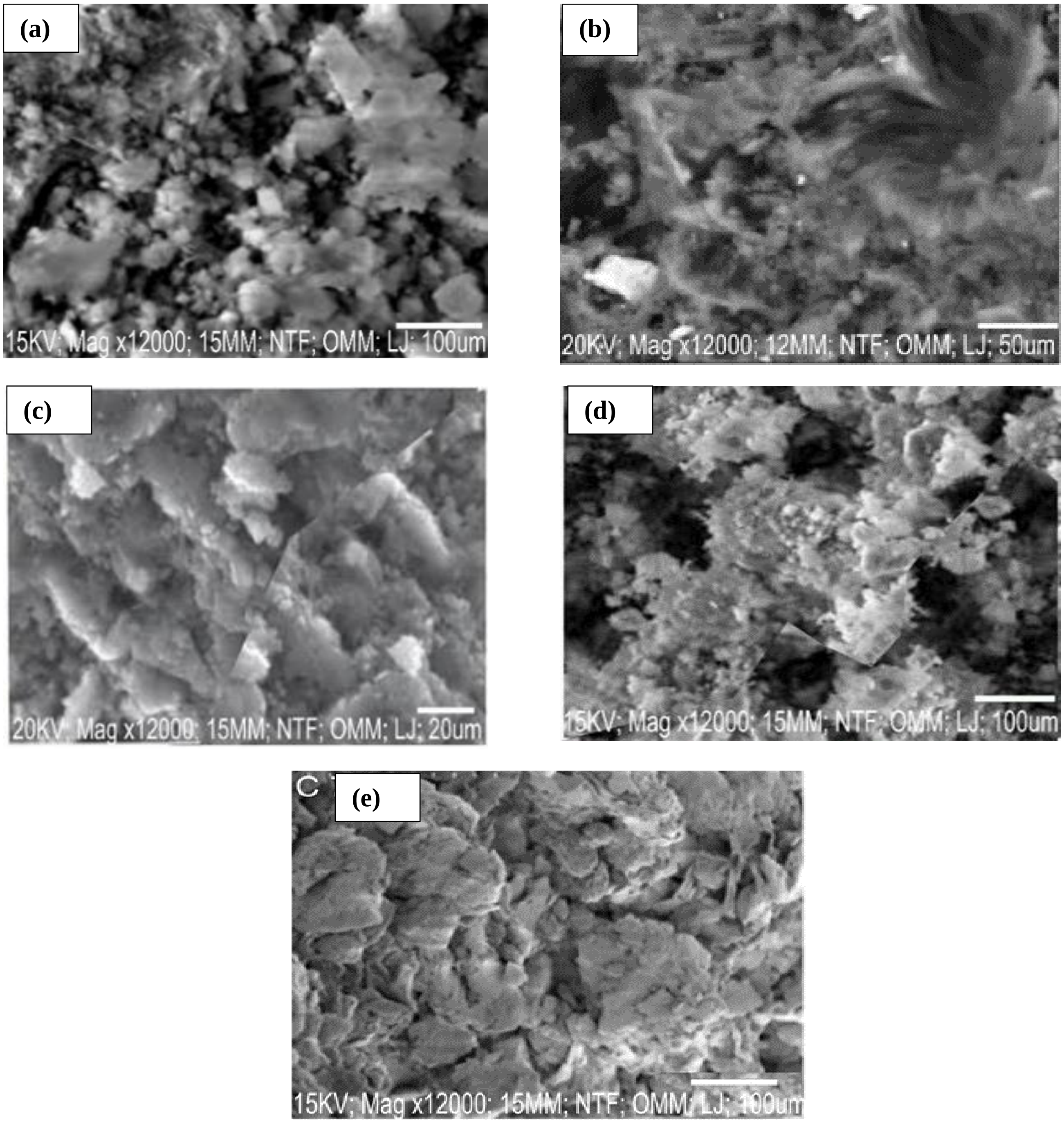


Figure 8(a)-(e): The Scanning Electron Microscope (SEM) Morphology of Fracture Surfaces of Sample A, B1, C1, B and C at 28 Days of Curing

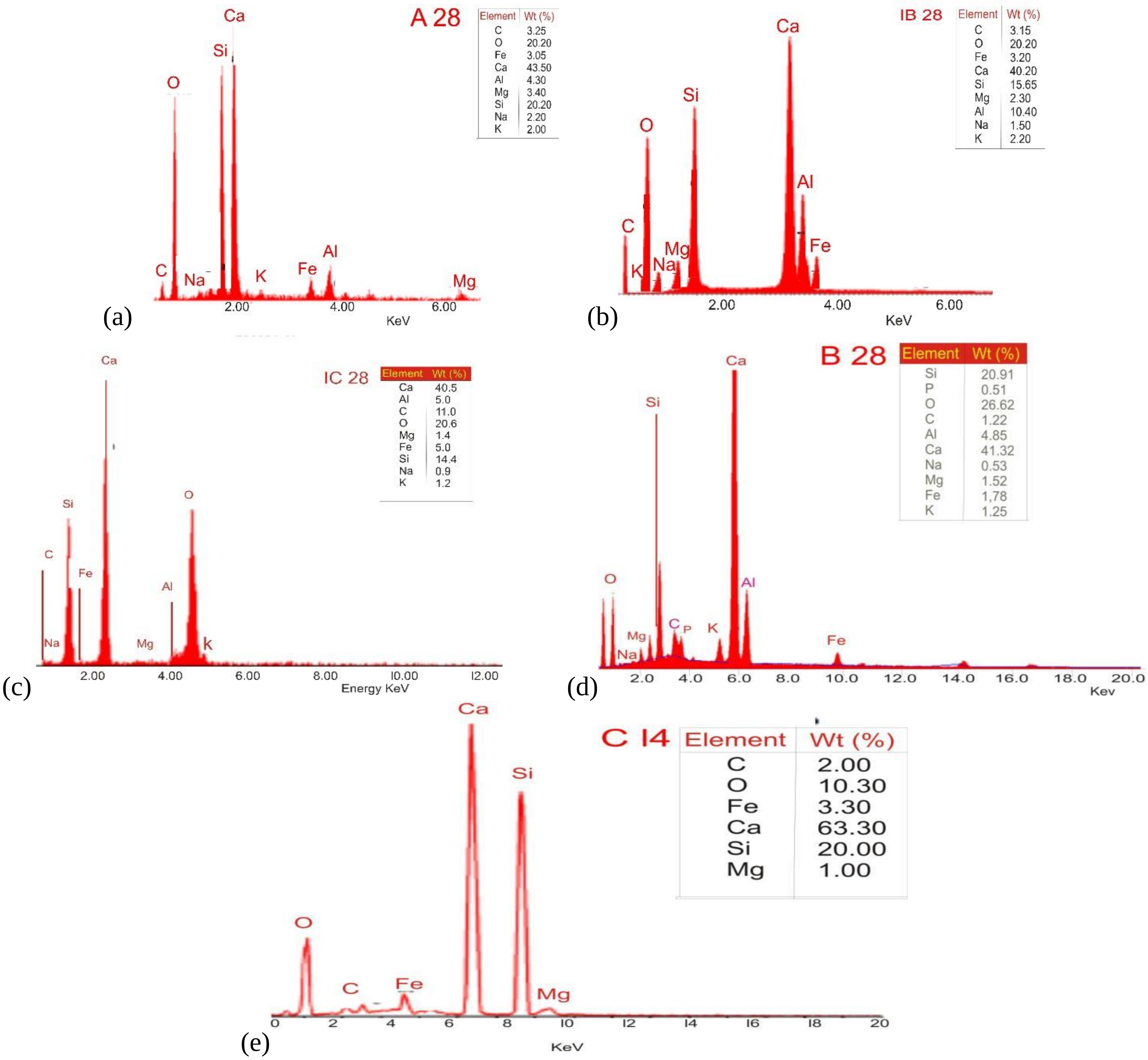


Figure 9(a)-(e): The Energy-Dispersive X-ray Spectroscopy (EDS) of Sample A, B1, C1, B and C, respectively at 28 days of Curing

Conclusion

From the results, ICB/CFF/SHF composites have lower water absorption and thickness swelling properties compared to corresponding ICB/CFF composites. Similarly, the ICB/CFF/SHF composites have low splitting tensile strength but show an improved compressive strength at only 7 and 14 days of curing compared to ICB/CFF composites. Therefore, ICB/CFF/SHF composites can withstand more compressive loading but less splitting tensile loading than ICB/CFF composites.

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