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Strength Characteristics of Concrete Produced with Bamboo Charcoal as an Admixture

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Abstract: *In recent times construction industries have embarked on the use of environmental waste materials as an admixture to concrete to enhance performance and reduce the cost of production. This study investigated the use of bamboo culm charcoal as an admixture in the production of concrete to improve performances in terms of strength. Bamboo culm was processed into charcoal and analyzed using Energy Dispersive x-ray Spectroscopy (EDS); Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectrometer (FTIR). Freshly mixed concrete cubes were produced with coarse and fine aggregates, Ordinary Poland Cement, and Bamboo Charcoal using BS 12 (1996). Water and cement ratio was done at 0.70% for control (conventional) and modify by adding 3-4% bamboo charcoal dosage for production of freshly concrete cubes. The EDS, FTIR, and SEM test revealed a strong bond of C=C, silicon chlorine, zinc titanium, potassium, etc., and a micro-porous structure with irregular shapes. 3% admixture concrete cubes had the same average compressive strength as conventional concrete at 7 and 14days with a 2.25% increase as compared to 47% increment. While at 28days loss of strength of about 20% were recorded. Similarly, 4% admixture had a maximum increasing strength of 10.98 -11.78 N/mm^2 with 4.67 N/mm^2 massive loss in strength at 28days as compared with conventional concrete. Strength increase may have resulted from the strong bond of C=C in charcoal particles and loss as a result of the large surface area of ash that remained unburned. The investigation had proven that bamboo charcoal can be employed as an admixture in concrete production while curing is limited to 21days at 4% mix.*

Keywords: Bamboo Charcoal, Concrete Cubes, Compressive Strength, Admixture and Freshly Mix

1.0 INTRODUCTION

Concrete is a composite material that is very useful in constructing buildings, bridges, roads, dams, etc. In the use of concrete as a major construction material, concrete should possess properties such as durability, workability, weather resistance, strength, erosion resistance, chemical resistance, water tightness, and economy [1]. These properties are achieved with the addition of admixture to concrete. Admixtures include all materials other than cement, water, and aggregate added to concrete before or during mixing, [2,3]. Several works of the literature identified different types of concrete admixture [2, 3]; air-entraining admixtures, water-reducing admixture, plasticizers, accelerating admixtures, and retarding admixture. The use of admixture in concrete is to reduce the cost of concrete construction and achieve certain properties more effectively than other means [4]. Furthermore, the admixture is used to increase the strength of concrete, accelerate the initial setting time of concrete, improve workability and durability of concrete and produce lightweight concrete [2]. However, Component of Concrete noted that the workability, strength, durability, watertight and wear-resistant qualities of concrete can be achieved through proper design mix using suitable materials without resorting to admixtures except for air-entraining admixtures [1]. Air entraining admixtures are used to improve workability, increase durability, ease of placing, better resistance to frost action, and reduction in bleeding [3]. The common air-entraining are natural wood resins, neutralized vinsol resins, polyethylene oxide polymers, and sulfonated compounds [3]. Most admixtures including air-entraining admixtures are chemical admixtures and they hurt the environment and create leaching problems in concrete [4, 5]. The use of organic admixture to prevent the adverse effect of chemical admixture in the environment and improve the properties of concrete was proposed [5]. Organic admixtures are derived from plants and animals with major contents as proteins. Proteins have air-entraining and hygroscopic properties [5].

A plethora of literature focused on using organic materials as admixtures in concrete. The strength and durability properties of concrete using starch admixture were investigated by [6], it was observed that concretes with starch admixtures give better performance than the control concrete [4].,when prickly pear extracts are used to produce cement-based mortars and cement pastes

[4]. The result shows an increase in setting time for both water and powder replacements. Thus, prickly pear can be used as retarding agents. Produced blended cement concrete using periwinkle shell ash and bamboo leaf ash as cement supplements was used by [7]. It was concluded that at 20% replacement of cement with periwinkle shell ash and bamboo leaf ash, the concrete achieves higher compressive and tensile strength and lower water absorption and porosity values than the referenced concrete. The engineering properties of concrete blocks made with bamboo leaf ash blended with Portland cement was studied by [8] and concluded that blended leaf ash can be used as a partial replacement of cement in the production of concrete blocks.

Although previous literature employed the use of the bamboo leaves as admixtures in concrete, the [9] suggested the use of bamboo charcoal as an alternative for admixture in the production of concrete. According to [10] the properties of bamboo charcoal are micro-porous structure, high surface area, and great adsorption, hence can be used to purify water and blood and absorb electromagnetic waves. Bamboo charcoal has more cavities, mineral content, and adsorption rate than wood charcoal. Bamboo charcoal is also greater in surface area than wood charcoal [10]. Furthermore, the air-entrained admixture is aimed at entraining additional air pores with appropriate shape, size, and distribution in concrete [11]. Hence, the micro-porous structure properties of bamboo charcoal will make it suitable as an organic air entraining admixture.

In the use of air entraining admixture in concrete, [12] used three different air-entrained agents namely olive oil, oleic acid, and hydrogen peroxide in the production of concrete. The addition of the admixtures at different percentages increases the workability of concrete and decreases the strength of the concrete. The investigated effect on the use of a high dosage of air entraining admixture on the properties of self-compacting concrete was done by [13]. The result shows that the air entraining admixture highly decreases the compressive strength up to 52%.

Previous studies employed the use of organic material such as bamboo leaf ash, prickly pear extracts as an admixture in concrete [8, 7, 4, 6]. In addition, chemical materials were used as air-entrained admixtures in concrete. There seems to be limited research on the use of bamboo charcoal as an organic air-entrained admixture in concrete. Thus, there is a gap in research on the use of bamboo charcoal as an admixture in concrete production. In a bid to increase the air-entraining properties of concrete with the use of bamboo charcoal, attention should be paid to the strength characteristics of the concrete. Hence, this study aims at examining the strength characteristics of concrete produced with bamboo charcoal as an admixture. Specifically, the study produced concrete using bamboo charcoal as an admixture and compares the strength with that of conventional concrete.

2.0 MATERIALS & METHODS

The study utilized the following materials in experimentation: coarse aggregate, fine aggregate, cement (Ordinary Portland Cement) and granular Bamboo charcoal. A species of bamboo, *Bambusa vulgaris* was employed because of its availability in the region. Fresh bamboo clums were washed dried at room temperature to remove impurities. After which carbonization was done at 350^{O}C in muffle furnace into charcoal and a granular sieve size of 1.18mm was used. Structural organization, elemental component, and adsorptive properties of the bamboo cell wall were observed with Energy dispersive x-ray spectroscopy (EDS); Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectrometer (FTIR) [14]. See plate 2.2

2.1 Preparation and Production of Concrete and Concrete admixture with Bamboo

All collected samples used in this experiment were adequately washed (coarse aggregate), in other to remove impurities that may adversely affect the strength of concrete. Samples were properly sieved to obtain the required size aggregate as specified in the standard (ASTMC), after which they are dried at room temperature 32^{0}C. Sand and granite were mixed with ordinary Portland cement in the ratio of 1:3:6 with a water-cement ratio of 0.70 using hand mix methods. Concrete castings were done by filling concrete specimens into moulds of 150mm regular dimension. Castings of the mixed specimen were done in three layers as cubes and each layer was vibrated 25 times using a tamping rod on metal mould, surfaces of concrete were toweled to produce a flat surface to produced cubes of regular dimension. After which they are properly set. British standard was used for the designing and proportioning of freshly mixed concrete. After production of the control, the experiment sample was then modified by adding bamboo charcoal dosages of 3% and 4 % in the formation of fresh concrete. See plate 2.1

2.2 Slump Test/ Workability Test

A slump test was carried out to investigate the workability of the freshly mixed concrete with a resulting value of 20mm which is a Shear slum. A steel cone with an interior free of impurities, except a release agent for ease of removal of the cone from concrete was utilized. The mould was placed on the horizontal rigid platform, the mould was firmly held on it and concrete was filled in three layers, each layer being tamped uniformly across the layers with 25 strokes of tamping rod.

Before tamping certain amount of concrete was inputted (heaped) above the mould, an additional amount of samples (concrete) were mounted to maintain excess above the mould, throughout the experiment. The excessive concrete was struck off and leveled with the mould still held down.

Fallen concrete that had to the lower edge of the mould was cleared. The mould is then gently vertically removed from the concrete after which the slump was measured to the nearest 5mm by using the meter rule to determine the height difference between mold and the fresh concrete specimen. After determination of workability, the concrete was remixed and used in the casting of cubes.

2.3 Compressive Strength Test

The compressive strength of the specimens was determined by the destructive test method at the Concrete Laboratory of Yaba College of Technology and the name of the machine is tecno test Modena-italy, model: 2007, Serial No. F050-TC, a capacity range of 500-2000KN was used for the research to carry out the test on the cubes.

This is used to determine a property of concrete, after the proper curing of the concrete cube sample, and the compressive strength is properly determined by crushing the sample with a crushing machine. Individual concrete cube sample is subject to crushing until they fail or crumble. The pressure at which the sample is crumbled is noted and the average compressive strength is stated in N/mm^2 [15].

The mixed concrete is cast into cubes of 150mm x 150mm x 150mm by the size of 32 cubes of mix 1:3:6 the water-cement ratio of 0.70 shall be cast and these will be removed from steel mould after 24hours of setting. Then the curing is effectively commenced.

To determine the compressive strength and age relation, the four different hydration stages i.e 7days, 14days,21days and 28days of which two of each sample of 3% concrete admixture with two of conventional concrete and two of 4% concrete with admixture and two of conventional concrete was taken out of water for crushing.

The maximum load at the breakage of the concrete block was noted. In each category, two cubes were tested and their average value is recorded. From the noted values, the compressive strength was calculated by using Compressive strength (MPa) = Failure load / cross-sectional area. See plate 2.3

Compressive strength = P/A…………………………………..

P= Crushing load

A= Cross-sectional area

Density = mass of concrete/volume of cube…………………….

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Plate 2.1: It shows the cast concrete cubes, well dressed and labeled with a standard dimension of 150*150*150mm. after proper compaction using a vibrating table or compacting rod to compact the concrete in 3 layers. Each layer requires 25 blows.

Plate 2.2: It shows the powdered bamboo charcoal on a weighing machine.

Plate 2.3: it shows the crushing machine during crushing of the concrete cubes so as to determine the crushing load and compressive strength of the concrete cube.

3.0 RESULTS AND DISCUSSION

3.1 Microstructural analysis of bamboo

The SEM-EDS analysis of the modified bamboo species in Fig. 3.1 reveals that the chemical compositions of the bamboo surface of each spectrum include carbon, oxygen, nitrogen, silicon chlorine, zinc, potassium, phosphorus, magnesium, and titanium.

The FTIR test in Fig 3.2 shows that there exists a strong bond (C=C) aromatic bending between bamboo particles, thus, increased frequency seen in the bamboo particle was an indication of increased bond strength.

The SEM micrographs in Fig 3.3 also reveal the surface structure i.e. textures and morphology characteristics of the activated carbons reveal the porous structure of the samples, the number of pores within each species for sorption, and the agglomeration of particles within the structures in distinctive irregular shapes.

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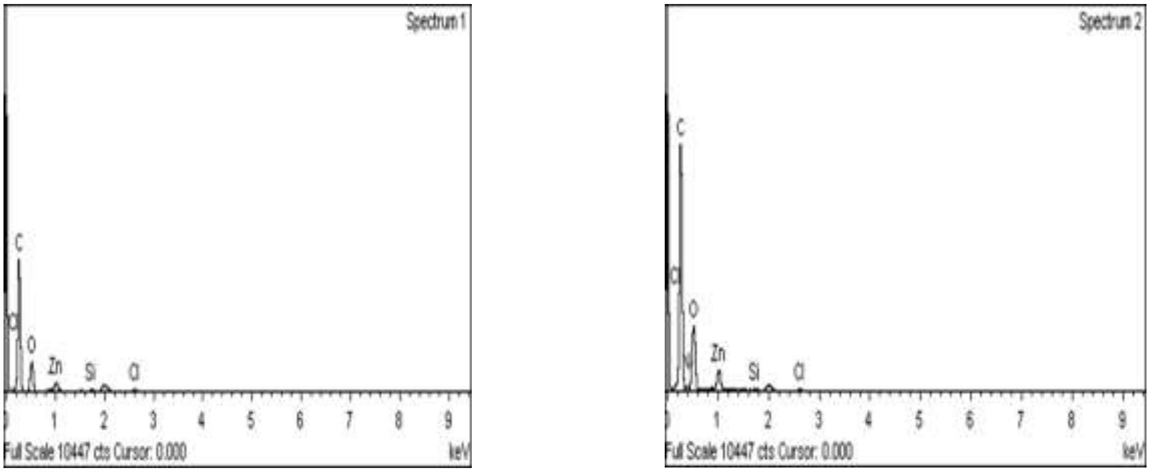


(a) (b)

Fig 3.1 : Elemental dispersion spectral of selected areas on SEM -EDS for *Bambusa vulgaris* at 350 ^{O}C (a) EDS spectrum 1, (b) EDS spectrum

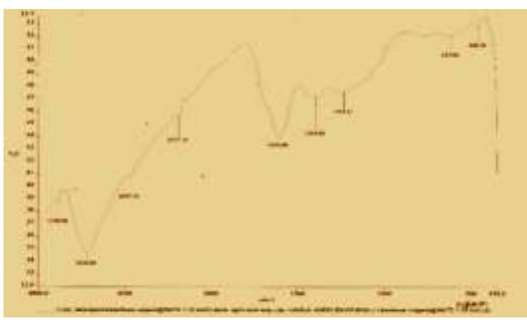


Fig 3.25: Fourier Transform Infrared Spectrometer of CBV at 350^{O}C

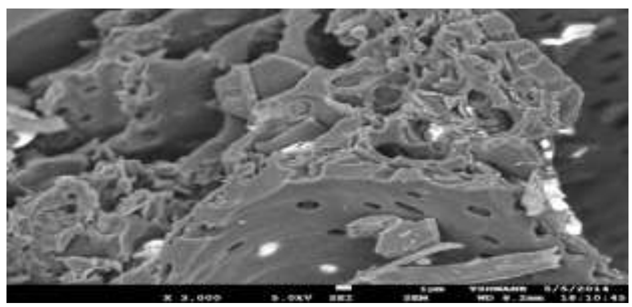


Fig 3.3: SEM image of Bambusa vulgaris (CBV 350^{O}C

3.2 Strength of concrete produced with or without bamboo charcoal as admixture at 7, 14, 21, and 28 days

The weights of the concrete and crushing load of cubes are shown in Tables 3.2 and 3.2.1; the weight of the concrete varies as a result of the type of means of compacting the concrete. The best means to do this is through the use of the vibrating table, the force used in compacting the concrete can lead to segregation of the concrete if it is done forcefully. Improper compaction can contribute to the formation of honeycomb in the concrete which gives room for void and hence aids reduction in strength. Concrete with 3% admixture has the same average compressive strength as that of conventional concrete at 7days and 14days, 3% has an increment of 2.25%, and conventional concrete increases by 47% of its 14 days and 21 days while at 28days there was the loss of strength of about 20% that is produced with admixture and a loss of 7% for conventional concrete. This is due to the higher rate of hydration during the first 24 hours of setting before curing, due to the weather (hammartan) which may have led to the inconsistency of the concrete cube and failure after 21days and the concrete produce with 4% bamboo charcoal as admixture has a maximum strength at 21 days and 28days there is a maximum loss of compressive strength of concrete cube with 4% admixture.

Table 3.2: Weight of Cube concretes with or without admixture in days

Curing (Age) in days	Weight of cubes without admixture (A)	Weight of Cubes with 3% admixture (B1)	Weight of Cubes with 4% admixture (B2)
7	8450 8400 8750 7900	8700 - 8500 -	- 7700 - 8250
14	8500 8450 8040 8200	8150 - 8100 -	- 9350 - 8450
21	8550 7950 8150 8350	8650 - 8500 -	- 8000 - 7950
28	8400 8150 8450 7500	8100 - 8200	- 8200 - 7650

Source: test result (2016).
(A)= convectional concrete
(B)= concrete with bamboo charcoal as an admixture

Table 3.2.1 Crushing load of concrete cubes.

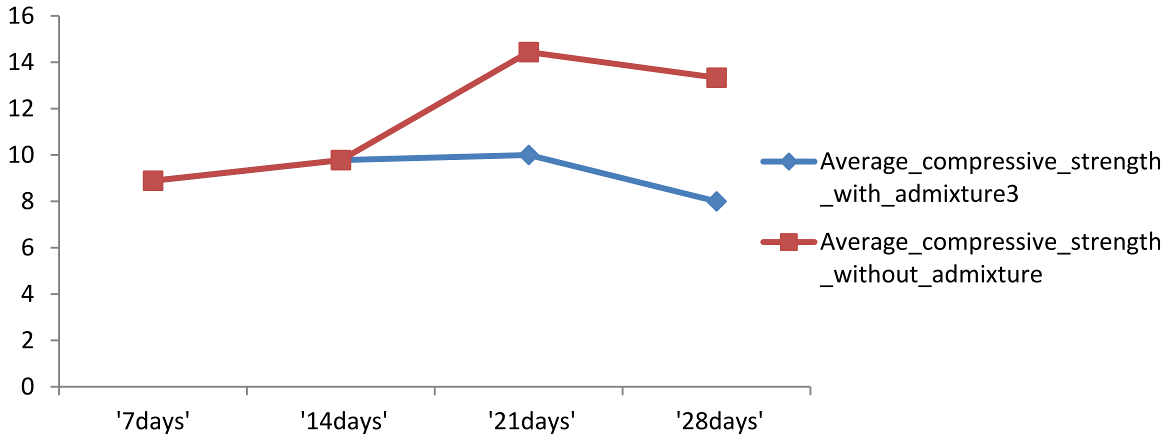
S/N	Sample	Crushing load for 7 days (KN)	Crushing load for 14 days (KN)	Crushing load for 21days (KN)	Crushing load for 28days (KN)
1	Without admixture {A}	200	160	300	280
	Without admixture {A}	200	280	350	320
	With admixture (3%) {B}	210	200	200	160
	With admixture (3%) {B}	190	280	250	200
2	Without admixture {A}	200	250	200	300
	Without admixture {A}	200	240	250	190
	With admixture (4%) {B}	200	240	280	110
	With admixture (4%) {B}	260	190	250	100

Source: test result (2016).
(A)= convectional concrete
(B)= concrete with bamboo charcoal as an admixture.

3.3 Comparing Average Compressive Strength of Convention Concrete (without admixture) to Concrete with an admixture

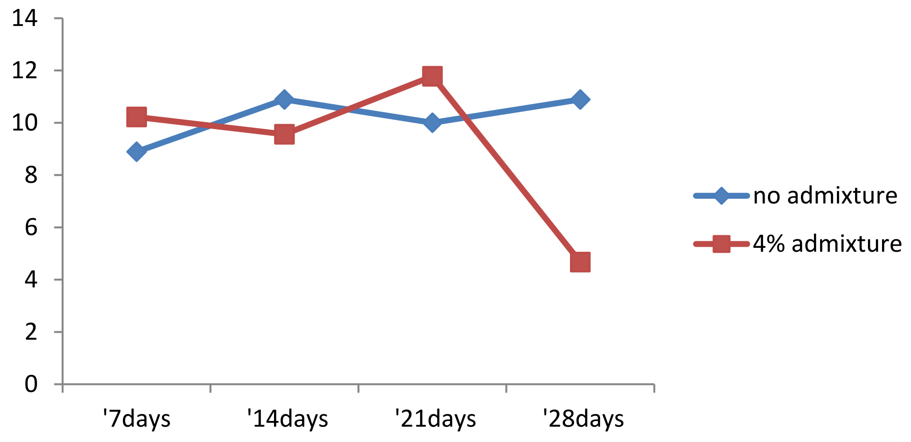
Figure 3.3shows that the average compressive strength of the conventional concrete and concrete with 3% admixture. The average compressive strength of the conventional concrete and concrete with 3% admixture have the same strength of (8.89N/mm^2) at an early stage of 7day but at 14 days concrete with 3% admixture and its control specimen have the same strength of 9.78N/mm^2, at 21days concrete with 3% admixture which rises from 9.78N/mm^2 to 10N/mm^2 which was its maximum strength before dropping from 10N/mm^2 -8N/mm^2 and without admixture was 14.44 N/mm^2 at 21days and drops to 13.33N/mm^2 at 28days.

Similarly, figure 3.4 shows that concrete with 4% admixture gains earlier strength at 7 days with the strength of 10.22N/mm^2 than conventional concrete at 7days with the strength of 8.89 N/mm^2, at 14days the strength of concrete without admixture increases to 10.89N/mm^2 while the strength of the 4% admixture was 9.56N/mm^2, at 21 days concrete with admixture gained a maximum strength of 11.78N/mm^2 while that without admixture is 10.00N/mm^2 and at 28days there was a massive loss in strength for concrete with admixture which was from 11.78N/mm^2 to 4.67N/mm^2 .



Source: test result (2016)
Fig 3.3: Average Compressive Strength of Convention Concrete (without admixture) to Concrete with 3% admixture

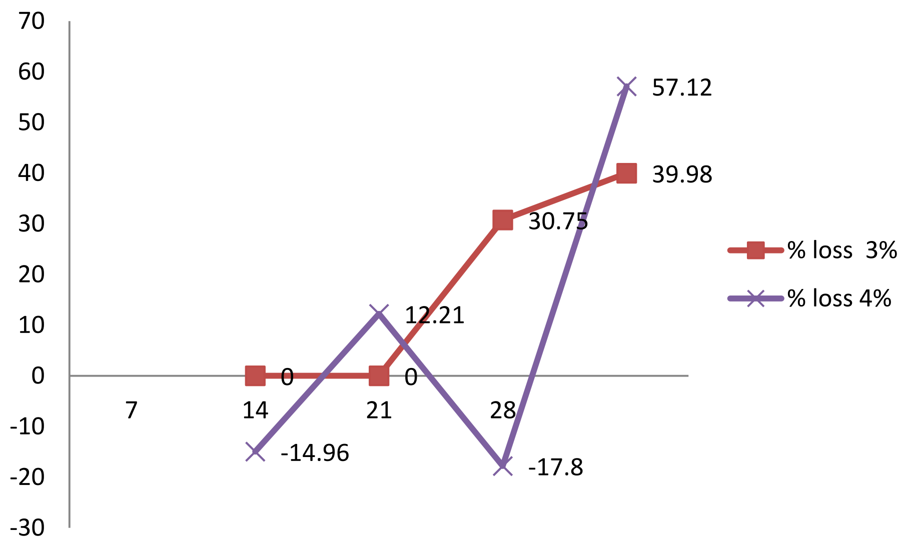
The increase in strength with 3% and 4% admixture from 7-21 days may had resulted from the presence of C=C bond which exists between the bamboo particles indicates that the charcoal content affects the compressive strength. This could be as a result of a high amount of Si0^2 and CaO present in the charcoal also improve the workability. The reduction in strength at 28days for 3% and 4% admixture concrete could be connected to the huge surface area of the ash and excessive content of cellulose product that remained unburned.



Source: test result (2016).
Fig 3.4: Average Compressive Strength of Convention Concrete (without admixture) to Concrete with4% admixture

3.4 Analysis of loss in strength in concrete produced with 3% and 4% bamboo charcoal as admixture at 28 days.

Figure 3.5 shows the percentage loss of strength in concrete produced with 3% and 4% bamboo charcoal as admixture at 28 days.



Source: test result (2016).
Fig 3.5 shows the percentage loss of strength in the cube samples

4.0 CONCLUSION

The results obtained from the laboratory investigation indicate that bamboo charcoal can be admixed in the production of cube concrete. Compressive test result indicate that strength increases from 7-21 days for both admixture at 3% and 4% and decreases or fails at 28days, indicating that inorganic admixture can be employed as an admixture in concrete production while curing is limited to 21days at 4% mix

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REFERENCES

[1 Components of concrete, 2018. Concrete Field. Viewed on 3rd June. 2021

[2] Shah, D.S., Shah, M.P. and Pitroda, J., 2014. Chemical admixtures: a major role in modern concrete materials and technologies. In National Conference on Trends and Challenges of Civil Engineering in Today's Transforming World Civil Engineering Department SNPIT and RC, Umrah.

[3] Singh, S. and Upasana, 2017. Different types of admixtures in concrete structure - A review. International Conference on Recent Innovation in Science, Agriculture, Engineering, and Management. University College of Computer Applications, Guru Kashi University, Bathinda, Punja, India, 20th November 2017. Pp 1459-1466.

[4] Aquilina, A., Borg, R.P. and Buhagiar, J., 2018, November. The application of Natural Organic Additives in Concrete: Opuntia ficus-indica. In IOP Conference Series: Materials Science and Engineering (Vol. 442, No. 1, p. 012016). IOP Publishing.

[5] Patel, G.K. and Deo, S.V., 2016. Parametric study of natural organic materials as an admixture in concrete. International Journal of Applied Engineering Research, 11(9), pp.6271-6277.

[6] Akindahunsi, A.A. and Uzoegbo, H.C., 2015. Strength and durability properties of concrete with starch admixture. International Journal of Concrete Structures and Materials, 9(3), pp.323-335.

[7] Umoh, A.A. and Femi, O.O., 2013. Comparative evaluation of concrete properties with varying proportions of periwinkle shell and bamboo leaf ashes replacing cement. Ethiopian Journal of Environmental Studies and Management, 6(5), pp.570-580.

[8] Adewuyi, T.O., Olusola, K.O. and Oladokun, M.G., 2013. Engineering properties of concrete blocks made with blended bamboo leaf ash (BLA) and Ordinary Portland cement. A Multidisciplinary Journal of Graduate School, University of Uyo, Uyo Nigeria, 1(3), pp.48-59.

[9] American Bamboo Society. 2008, visit at www. americanbamboo .org. viewed on june 10 2021

[10] Isa, S.S.M., Ramli, M.M., Halin, D.S.C., Anhar, N.A.M. and Hambali, N.A.M.A., 2017, September. Different carbonization process of bamboo charcoal using Gigantochloa Albociliata. In AIP Conference Proceedings (Vol. 1885, No. 1, p. 020226). AIP Publishing LLC.

[11] Babiak, M., Ratajczak, M., Kulczewski, P. and Kosno, J., 2018. Effect of modern air entraining admixtures on physical properties of construction mortars. In Materials Science Forum (Vol. 923, pp. 115-119). Trans Tech Publications Ltd.

[12] Giridhar, V., Kumar, P. N. and Kumar, S. P., 2013. Strength characteristics of air-entrained concrete. The International Journal of Engineering and Science, 2(9), pp.7-14.

[13] El Mir, A., and Nehme, S.G., 2017. Effect of air entraining admixture on the properties of self-compacting concrete incorporating supplementary cementitious materials. Pollack Periodica, 12(3), pp.85-98.

[14] Ijaola, O. O. and Sangodoyin, A.Y. 2021. Remediation of Emerging Pollutants in Industrial Contaminated Water using Oxytenanthera abyssinica and Bambusa vulgaris in a Treatment Media. IOP Conf. Ser.: Mater. Sci. Eng. 1036 012012. Pp 1-12

[15] BS EN 1881-125, "Testing concrete. Methods for mixing and sampling fresh concrete in the laboratory", British Standards Institution, London, UK, 2013

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Author's Name, Author's profile.

Author's picture should be in grayscale.

Picture size should be absolute 3.18cm in height and absolute 2.65cm in width

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