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An Investigation of the Fire Resistance of Concrete Incorporating Sugarcane Bagasse Ash as Partial Replacement for Cement.

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***Abstract**: The use of renewable or waste materials for construction work has increasingly become an important area of research over the years with various results showing that sustainability, proper waste disposal, better fresh and harden concrete properties as well as cost effectiveness can all be improved. Sugarcane bagasse is a dry pulpy fibrous waste material that remains after crushing sugarcane to extract their juice. Sugarcane bagasse ash (SBA) is obtained from biomass burning and has been observed to have great potential as supplementary cementitious materials due to it being high in silica which has been found to have pozzolanic properties. Several research works have been done on the strength properties of partially replacing cement with SBA in concrete and sandcrete blocks. However, this study seeks to examine the fire properties of concrete produced with sugarcane bagasse ash. 100×100×100mm cubes specimens were produced for this study. The cubes were placed in the oven and heated from room temperature with no visible change until both the control and 5% SBA cement replacement specimens showed a long thin hairy crack at 600℃, which indicates a sign of failure. Both samples failed completely at 930℃ showing multiple hairy cracks on the samples, but unlike the 5% SBA specimen, the control sample was falling off or breaking due the effect of fire. The fire resistance test of 10% SBA cement replacement only showed sign of failure at 700℃ where double hairy cracks was noticed on the sample but the sample failed at 980℃. This shows that the 10% SBA cube sample has better fire resistivity compared to the control specimen but it could only attain a compressive strength of 15.17N/mm² at 56days curing. It was therefore concluded that both 5% and 10% substitution of cement with SBA improves the fire properties of concrete however the compressive strength of 10% SBA cement replacement indicates it can be used where M15 concrete grade is required,*

1.0 INTRODUCTION

Concrete is a composite product obtained from a mixture of cement, sand, gravel and water in pre-determined proportions. When these ingredients are mixed; they form a plastic mass which can be molded into desired shapes, where it hardens into a hard solid mass. Traditionally, concrete was understood as a material produced with the mixture of cement, aggregate and water. The uses of chemicals as additives and admixtures are recognized to be relatively more obvious approaches to answer the needs of modern concrete production for more energy efficiencies and carbon footprint reductions (Yohannes et al, 2017). Modern concrete is understood as a material with mixture of cement, additive, aggregate, admixture, fiber, water etc. Pozzolanic additives have increasingly become a potentially useful material in concrete production.

1.1 Sugarcane Bagasse Ash:

Sugarcane bagasse is an agricultural waste from sugar industry. Sugarcane bagasse consists of 45% cellulose, 28% hemicellose, 20% lignin, 5% sugar, 1% mineral and 2% ash. The sugarcane bagasse is burnt at a temperature varying from 240°C to 600°C, depending on the moisture content and feed of the bagasse to obtain sugarcane bagasse ash. Sugarcane Bagasse Ash (SBA) consists of approximately 50% of cellulose, 25% of hemicellulose and 25% of lignin. The residue after incineration presents a chemical composition dominated by Silicon Dioxide (SiO_2) (Kumar & Vignesh, 2017). In spite of being a material of hard degradation and that presents few nutrients, the ash is used on the farms as a fertilizer in the Sugarcane farming (Bangar et al, 2017). Presently in sugar factories, bagasse is burnt as a fuel so as to run their boilers and the bagasse ash residue is generally spread over farms and dump in ash pond which causes environmental problems. Also, research states that Workplace exposure to dusts from the processing of bagasse can cause the chronic lung condition pulmonary fibrosis, more specifically referred to as bagassosis, so there is great need for its reuse.

The manufacturing process of Sugarcane bagasse ash–Quarry dust–Lime (SBA–QD–L) bricks results in 50% and 60% reduction in energy consumption over the commercially available burnt clay and fly ash–cement building bricks. (Madurwar, Mandavgane, & Ralegaonkar, 2014). Maneela et al., (2019) prepared mix design for different proportions of SBA content. From the result it was noted that 20 % replacement of bagasse ash gives maximum compressive strength when compared to 40 % & 50 % replacement. With the replacement of 20% of bagasse ash there is good bonding between particles and no cracks are formed.

1.2 Fire Resistance

While concrete may undergo strength loss at temperatures 300°C and above, the main losses are not apparent until above 500°C. Even though flame temperatures are up to double 500°C, the temperature of the internal concrete remains relatively low as a result of concrete's slow heat absorption. Therefore, only intense fires of long duration may cause any weakening of concrete structures (Hull, 2008). The fire resistance is measured by the time taken for the cool face of the panels to reach the required temperature. These tests are designed for concrete, brick or steel (protected) elements and fire resistance is usually measured in terms of ½, 1, 2, 4, 8 hours' integrity (Aldefae, Fadhel, & Edan, 2020). Firing and high temperature level is strongly affect the microstructure of clay brick and compressive strength of the concrete specimens with low permeability.

1.3 Fire resistance of Pozzolans

Ali & Masoud (2009) observed strength loss for all concrete exposed to 600°C especially the concrete that contained silica fume despite their good mechanical properties at room temperature. The effect of the temperature on mass loss of the ground granulated blast furnace slag (GGBFS) concrete was less than 8% below 700°C, which was similar to the ordinary Portland cement (OPC) concrete (Rashwan, Diab, & Gad, 2014). Their study further showed the specimen unit weights decrease with increasing temperature.

2.0 MATERIAL AND METHODS

2.1 Cement

A local brand of ordinary Portland cement (OPC) of grade of 32.5R designation by manufacturer, produced in Nigeria was used in this research and it is manufactured in accordance with BS 1881: (1970).

2.2 Sugarcane Bagasse Ash

The sugarcane bagasse was obtained from a juice processing outfit in Jos, Plateau State and Sun-dried. The dry sugarcane bagasse was transported to Bauchi, Bauchi State and was burnt in a furnace under a control temperature of 600°C for six hours and allowed to cool for 24 hours to obtain sugarcane bagasse ash. Sieve size:75µm was used to sieved the ash, following BS 12 (1991), stipulations.

2.3 Fine Aggregate

The fine aggregate was river bed coarse grained sand; locally referred to as 'sharp sand', which is a naturally occurring clean sand obtained from Magama-Gumua, in Toro, of Bauchi State. Sieve analysis was conducted on the aggregates in accordance to BS 812: (1975). Aggregate less than 4.75mm are known as fine aggregates and are used to make the concrete dense by filling the voids of coarse aggregate and also helps to reduce the shrinkage of cement on hardening.

2.4 Coarse Aggregate

The Coarse aggregate was 10mm size and made of machine crushed rock obtained from Mista Ali in Jos, Plateau State. The aggregate was checked and observed to be free from deleterious substances. Aggregate which passes through a 75mm mesh sieve and are entirely retained on 4.75mm mesh sieve, is called coarse aggregate. A crush aggregate of 20 to 25mm maximum size of coarse aggregate is utilised.

2.4 Water

For ease of mixing, placing, consistency of mix, curing and workability; water used for this research was clean water, free from impurities. The water was sourced from boreholes, which was also used for curing of samples.

2.5 Fire Resistance Test

This was done to determine or measure the performance of concrete in terms of fire incidents in accordance to ASTM E119 and section 4 of BS 8110-2 (1985). Specimens of the concrete cubes after 56days of curing were inserted in the electrical turbine oven which is set up to have the slope of 600, T1=450 and T2=1000. The sample was monitored and checked at the interval of 1hour to observe any changes. Signs of failure was noted at the temperature at with the changes start or appears on the specimens. When the sample completely failed, the temperature was recorded and the time of failure, which ends the experiment and the sample is allowed to cool, weighted and compressive strength is then tested. The results obtained is used to draw temperature-time curve.

2.6 Mix proportions

The preparation of the concrete specimens was in accordance with B.S 1881: Part 116 (1983). The materials for all specimens were hand mixed and 100mm×100mm×100mm cube samples were prepared from MBF moulds for the test. The cement replacement with SBA was mixed for 5%, and 10%. Three (3) samples each were produced for compressive strength tests and also three (3) samples for each test were produced for water absorption test and a total of 12 cubes were produced for fire resistance test. The concrete mix proportion was 1:1:2 with water cement ratio of 0.60. The control mixture was proportioned for a target concrete strength of 25 N/mm^2 at 56-day curing. Samples were prepared to conform to minimum compressive strength for structural concrete in accordance with BS: 8110. The mix had a cementations material of 1440 Kg/m^3, fine aggregate of 1521 kg/m^3 and coarse aggregate of 1693Kg/m^3 bulk densities. To achieve workable mix, batching by volume was adopted.

Table 1: Properties of Binding Materials

Material	Bulk Density Kg/m^3	Specific Gravity
Cement	1440	3.22
SBA	556	1.84
Sand	1521	2.07
Gravel	1693	2.93

Table 2: Material Quantities for Control Specimen

Material	Dry Bulk Densities 1:1:2	Ratio Weights With Respect to Cement	Material Quantities In 1m^3 (Kg/m^3)	Material Quantities per 150mm Cube Specimens (Kg)	Total Material Quantities in45 Specimens (Kg)
Cement	1440.00	1	458.16	0.50	24.00
Fine Aggregate	1521.50	1	483.93	0.53	25.44
Coarse Aggregate	3386.00	2.5	1076.68	1.18	56.64
Water	-	-	284.06	0.31	14.88

Table 3: Material Quantities used in SBA Blended Concrete and the Slump Values.

Percentage Replacement (%)	**Cementitious Material (Kg)**		**Slump (mm)**
	Cement	SBA	
0	24.00	0	25
5	22.80	1.20	76
10	21.60	2.40	110

Table 4: Compressive Strength of SBA Blended Cement Concrete and Densities

Curing age (days)	**SBA (%)**	**Compressive Strength (N/mm²)**			**Mean Strength (N/mm²)**	**Attainment of Design Strength (%)**	**Densities of Concrete (Kg/m³)**
		Specimen 1	Specimen 2	Specimen 3			
7	0	20.65	21.02	21.84	21.17	84.68	2500.00
	5	16.12	16.06	16.33	16.17	64.68	2456.70
	10	7.82	8.29	7.89	8.00	32.00	2553.33
14	0	10.70	11.13	11.17	11.00	44.00	2815.00
	5	12.96	13.49	13.54	13.33	53.32	2488.33
	10	9.86	10.29	9.85	10.00	40.00	2441.70
28	0	28.71	28.64	28.66	28.67	114.69	2474.33
	5	14.79	14.86	14.84	14.83	59.32	2406.70
	10	13.98	14.16	14.37	14.17	56.68	2476.70
56	0	29.35	28.99	29.65	29.33	117.32	2480.00
	5	24.30	23.75	23.95	24.00	96.00	2430.00
	10	15.23	15.08	15.20	15.17	60.68	2413.44

Table 5: Compressive strength and Density of fired cubes

% Replacement of SBA	**Duration**	**Density**	**Compressive Strength (N/mm²)**
0	56	2320	5.00
5	56	2020	4.50
10	56	2480	6.50

Table 6: Percentage Decrease of compressive strength

% Replacement of SBA	**Duration (days)**	**Compressive strength Unfired cubes(C2) (N/mm²)**	**Compressive strength fired cubes (C1) (N/mm²)**	**% compressive strength decrease $[(C_2-C_1)/C_2]\times100$**
0	56	29.33	5.00	82.95
5	56	24	4.50	81.25
10	56	15.17	6.5	57.15

Table 7: Percentage Decrease weight

SBA%	**Weight Of Unfired cube(W2)**	**Weight of fired Cube (W1)**	**Decrease weight =[(w_2-w_1)**	**%weight decrease [(w_2-w_1)/w_2]×100**
0	2.44	2.32	0.12	4.92
5	2.26	2.02	0.24	10.62
10	2.82	2.48	0.34	12.06

Table 8: Water absorption test

SBA%	**Dry weight Before immersion w_1**	**Wet weight After immersion w_2**	**Absorption again w_2-w_1**	**% gain of water [(w_2-w_1)/w_1]x100**
0	2.40	2.46	0.06	2.5
	2.26	2.30	0.04	1.77
	2.68	2.72	0.04	1.49
5	2.40	2.46	0.06	2.5
	2.56	2.62	0.06	2.34
	2.24	2.28	0.04	1.79
10	2.34	2.40	0.06	2.56
	2.78	2.82	0.04	1.43
	2.32	2.38	0.06	2.59

Table 9: Fire resistance observation

Time (minute)	**Temperature (℃)**	**Remark**		
0	30	0%	5%	10%
60	502		smoke	
101	600	Single hairy crack	Double hairy crack	
144	700			Double hairy crack
214	800	multiple cracks		
288	900	failed		
311	930	Completely failed and breakage	Failed	
330	980			Failed

Table 10: The fire resistance test is carried out according ASTM E119

Design no	%SBA	Exposure Time	Failure time	Rating
A	0	5hr11min	4hr 48min	4hr
B	5	5hr 11min	5hr 11min	5hr
C	10	5h30min	5h30min	5hr

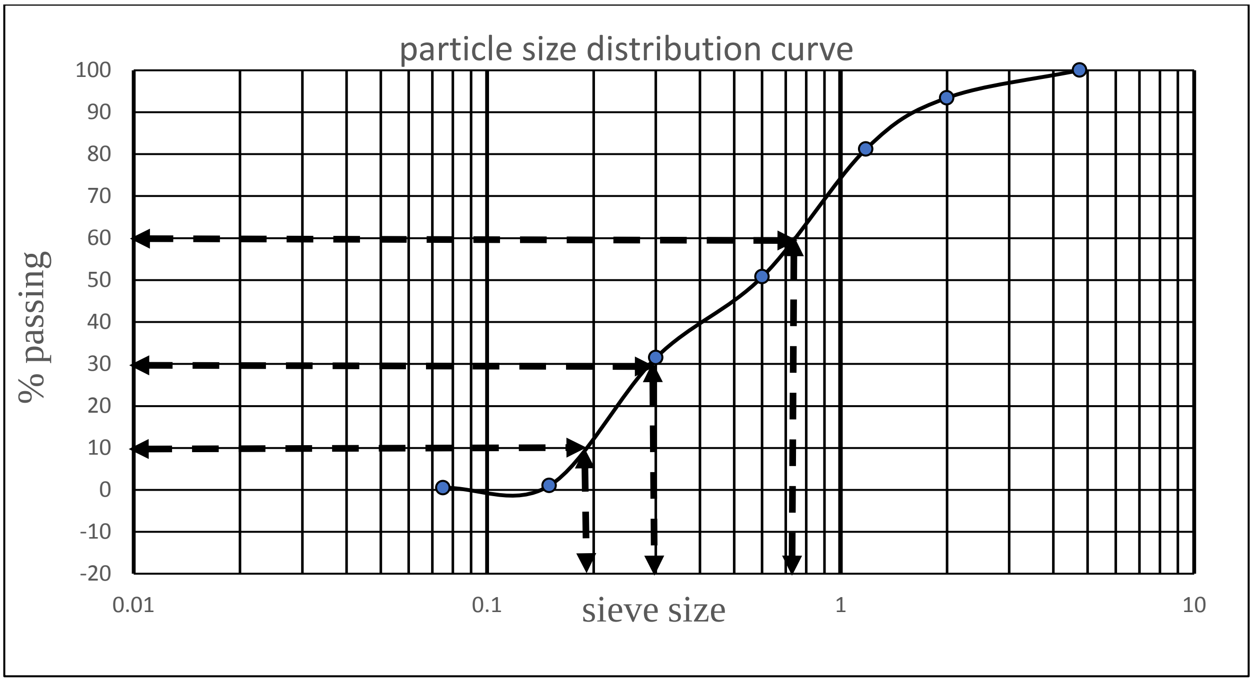

Figure 1: Fine Aggregate Distribution Curve

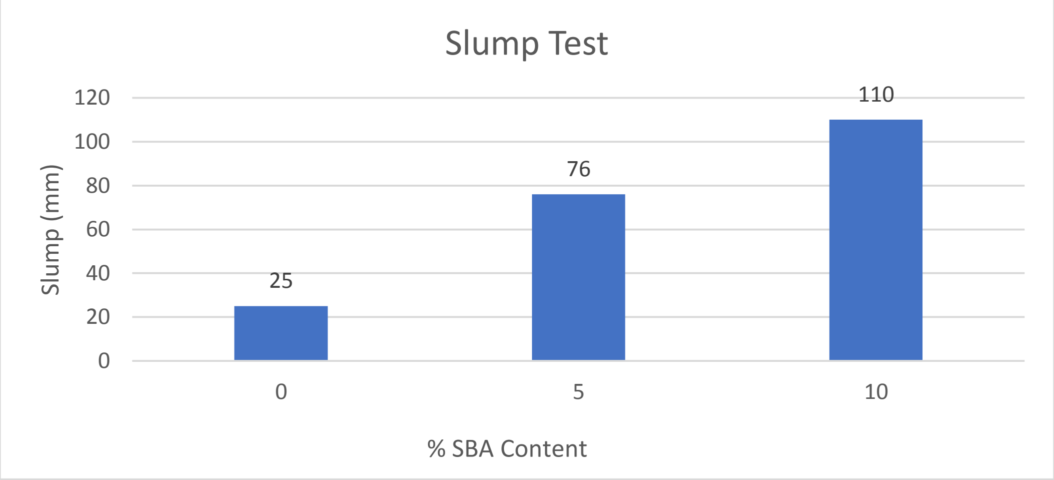

Figure 2: Slump Test

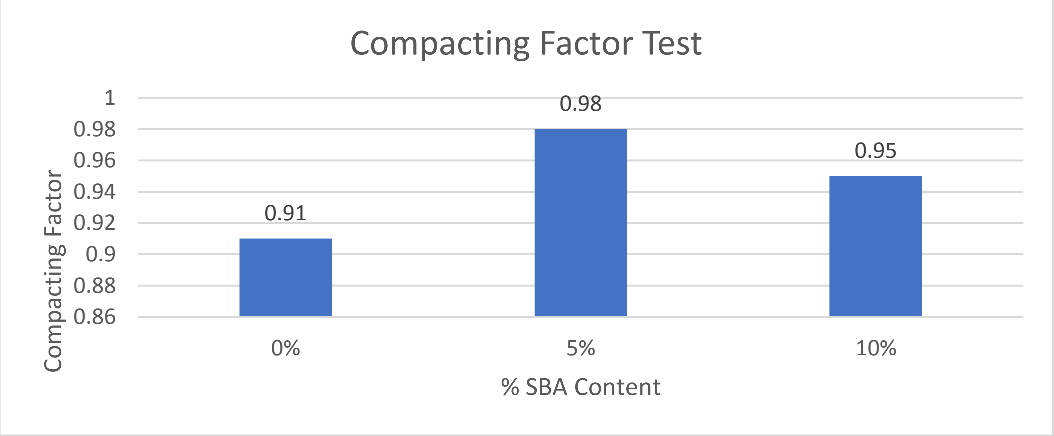

Figure 3: Compaction Factor Test

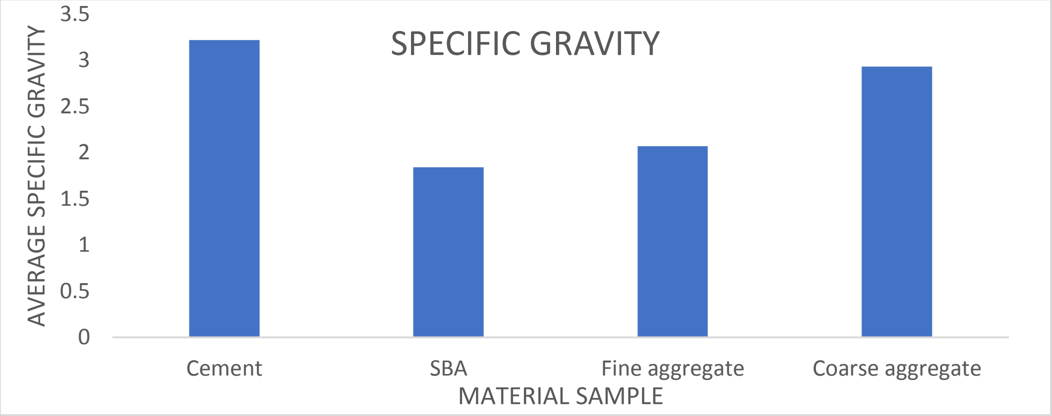

Figure 4: Specific Gravity of materials

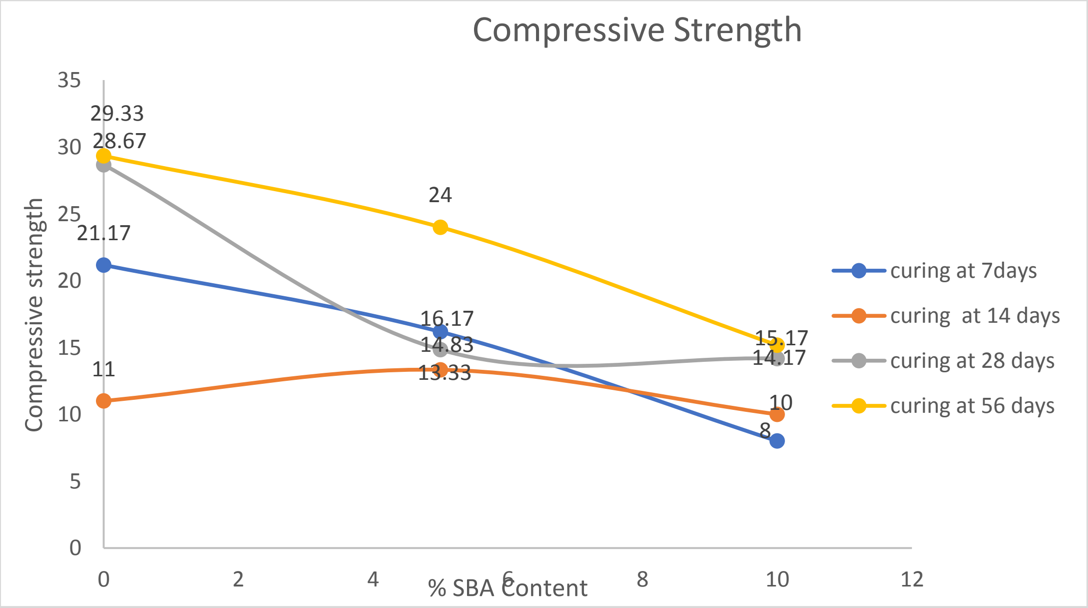

Figure 5: Compressive Strength

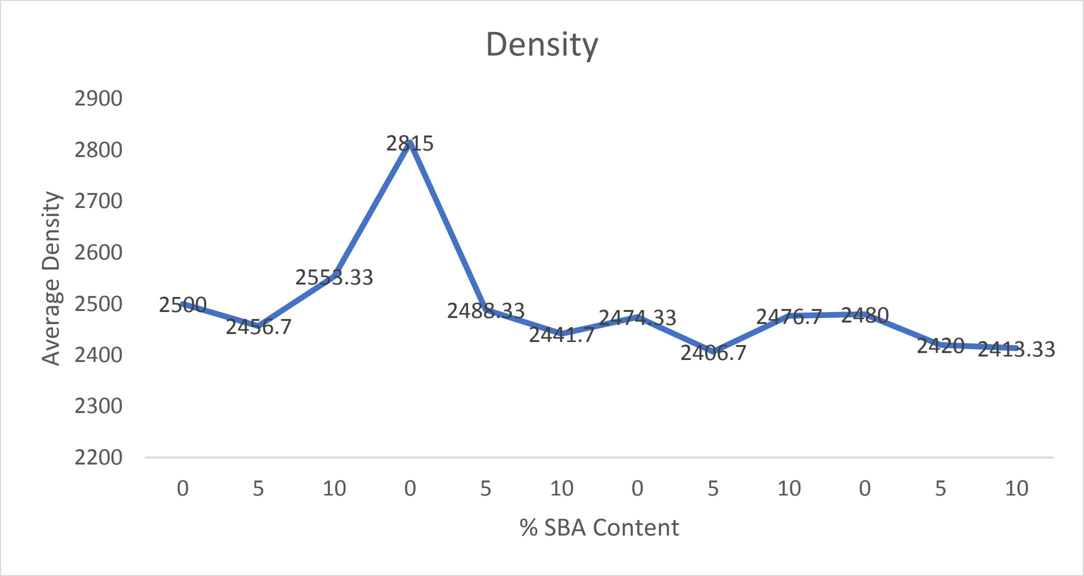

Figure 6: Density

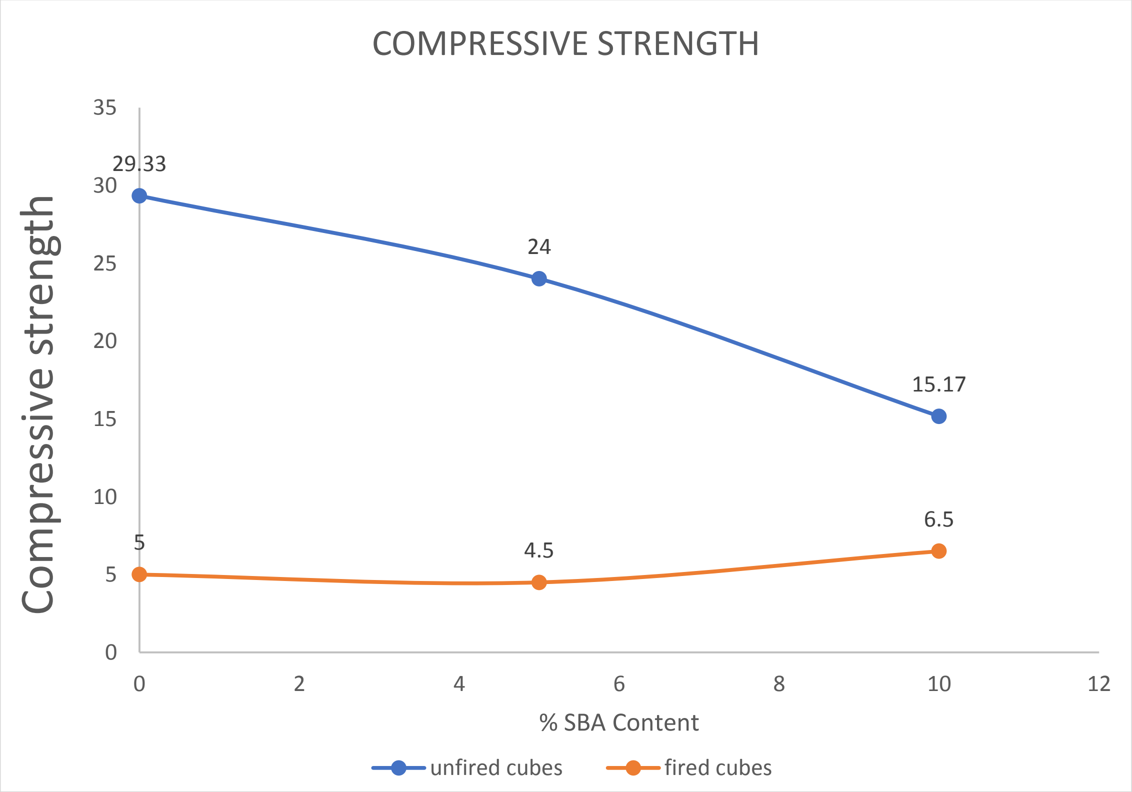

Figure 7: Compressive Strength of Fired Cubes

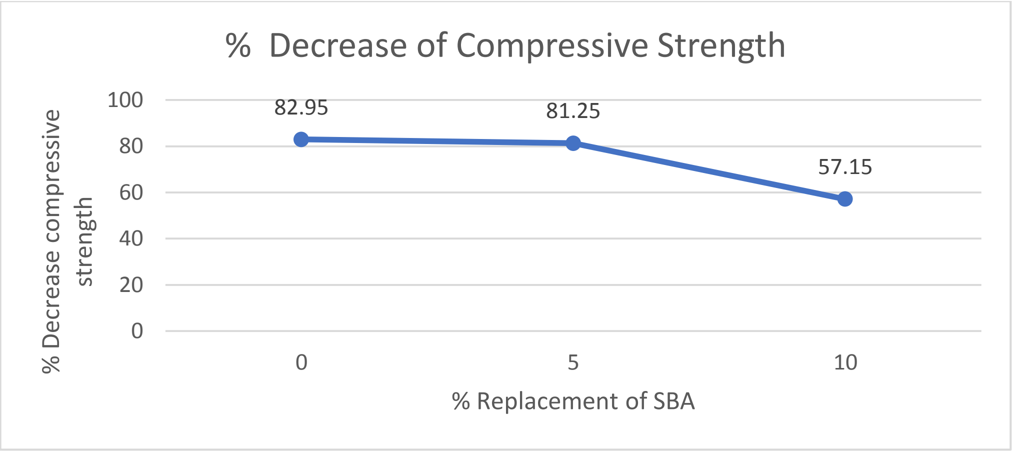

Figure 8: Percentage Decrease of Compressive Strength

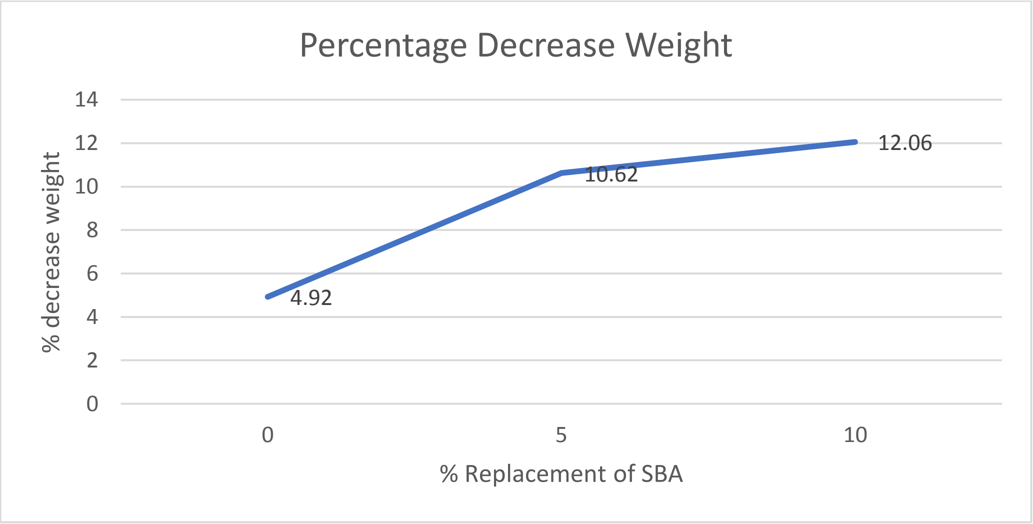

Figure 9: Percentage Weight Decrease

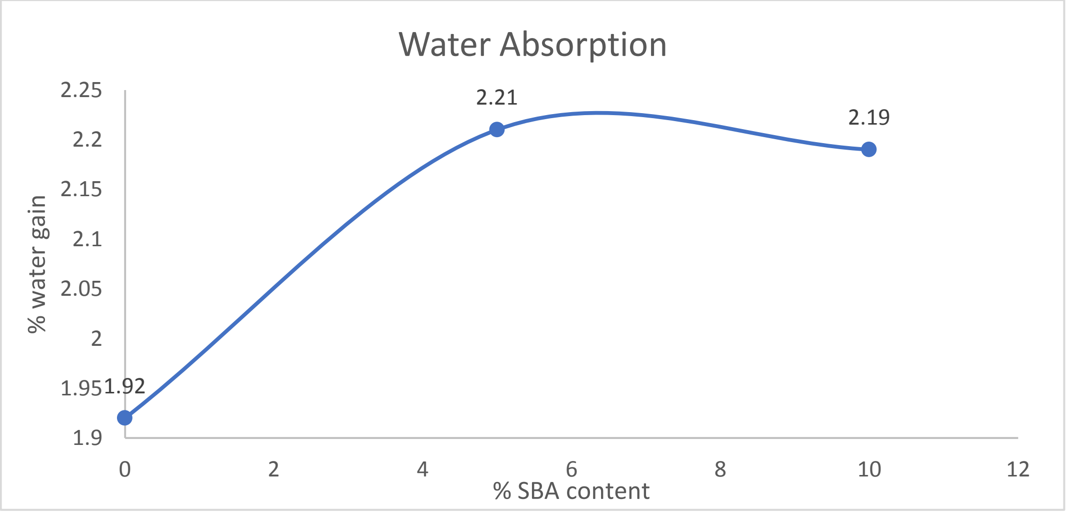

Figure 10: Water Absorption

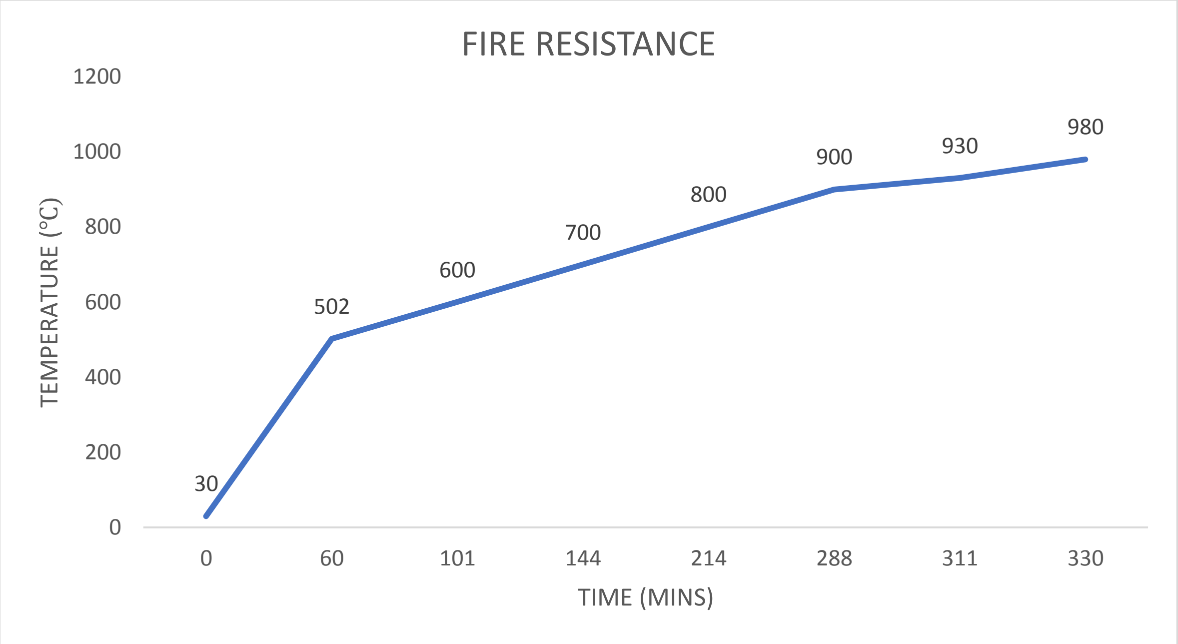

Figure 11: Fire Resistivity curve

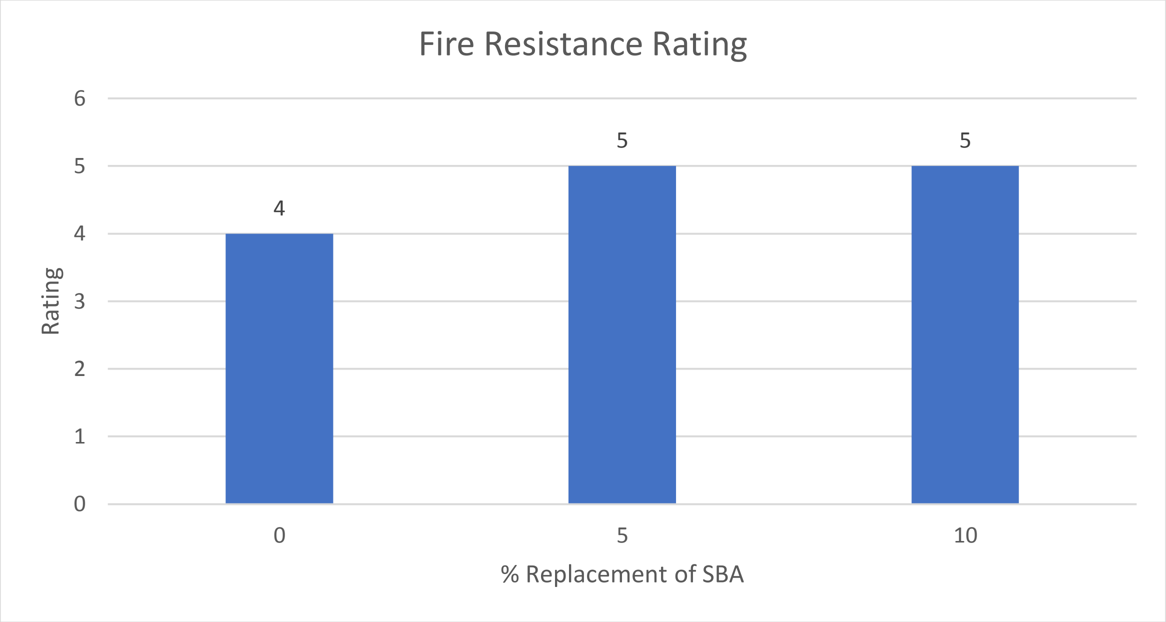

Figure 12: Percentage Fire Resistance Ratings

3.0 RESULT AND DISCUSSION

3.1 Sieve Analysis of Fine Aggregate

Sieve analysis was done to determine the proportion of various sizes of the particle in the aggregate as to ascertain the particle distribution. The particle sizes were passed through openings ranging from 4.75-0.075 by using mechanical sieve shaker in accordance to BS 812:1985 and BS 882. The sand particles passed through the 4.75mm BS sieve, with the greatest percentage of 50.76% retained on sieve 600µm. This shows that the sand is mostly of uniform grading. The percentage retained on the different sieves are: 4.75mm: 1 00% (90-100%), 2.00mm: 93.40% (75-100%), 1.18mm:

81.22% (55-90%), 600µm: 50.76% (35-59%), 300µm: 31.47% (8-30%), 150µm: 1.02% (0-10%), the sand therefore falls within Zone 2 of the grading Zones (BS 882:1978) for the grading requirement of fine aggregate in NIS 87:2004, since the sand consists of 0.00% coarse material and 100% fines. The result is shown in the particle distribution in Figure 1.

3.2 Specific Gravity Test

Specific gravity is the ratio of weight of a given volume of a material to the weight of an equal volume of water discharged. The test was done in accordance with BS 812 (1975). The specific gravity of cement shows the result in Table 1 which indicates that cement has specific gravity of 3.22, greater than the standard specific value (3.15) by the American System of Testing Materials having a difference of 0.07. The specific gravity result of SBA was 1.84 determined in order to compare it with that of the pozzolan specific gravity range (1.9 - 2.4) having a difference of 0.06. The specific gravity result of fine aggregates (sand) showed in Table 1 was 2.07 and the specific gravity result of coarse aggregate is shows 2.93. This shows that the specify gravity of cement obtained is relatively inclined with the standard specific gravity cement recommended. while the SBA specific gravity falls within the range of standard specific gravity of pozzolans and this shows that as the specific gravity of material decrease there will be increase in the volume of material required or to be used. Neville & Brooks (S2010) says that the partial replacement of Portland cement by pozzolan has to be carefully defined because it has specific gravity (1.9 - 2.4) which is lower than that of cement (3.15).

3.3 Fresh Concrete

The test conducted on fresh concrete are slump test and compacting factor test for concrete workability. Table 3, Figure 2 and Figure 3 show the slump and compacting factor values for 0%, 5% and 10% replacement of sugarcane bagasse ash with water/cement ratio of 0.60 The results show that at 0% replacement, slump is 25mm and compacting factor 0.91; at 5% replacement, slump is 110mm and compacting factor of 0.98 and at 10% replacement, slump is 76mm and compacting factor 0.95. Workability of each mix was assessed using the slump and compacting factor test in accordance with the provision of BS: 1881(1970). Shetty (2005) states that low to medium workability concrete can be compacted manually on mass concrete foundations without vibration. It was noted from the results that the slump and unit weight of concrete mixtures decreases with increase in percentage replacement of sugarcane bagasse ash.

3.4 Hardened Concrete Test

The test conducted on hardened concrete includes compressive strength

3.4.1 Compressive Strength Test

Table 4 shows the result of the compressive strength development of concrete cubes produced with sugarcane bagasse Ash, using a water-cement ratio of 0.60 and a mix ratio of 1:1:2 at percentage replacements of 0%, 5% and 10%, and also at curing durations of 7, 14, 28 and 56 days. Based on Table 4, the compressive strength for the cubes increased with increase in curing duration and decreased with increase in percentage replacement of SBA. This is due to the fact that insufficient portlandite is produced by the hydration of the cement to react with all of the pozzolana. At 0% (control sample), the compressive strength increased from 21.17 N/mm^2 (day 7) to 29.33 N/mm^2 at 56 days. At 5% percentage replacement, the compressive strength decreased from 16.17 N/mm^2 (day 7) to 13.33 N/mm^2 (14days) then the strength increases to 14.83 N/mm^2 (28 days) and to 24.00 N/mm^2(56 days). At 10% percentage replacement, the compressive strength increased from 8.00 N/mm^2 (7days) to 10.00 N/mm^2 (14 days), to 14.17 N/mm^2 (28 days) and 15.17 N/mm^2(56 days). The improvement in the strength in pozzolanic concrete has been observed to be proportional with the curing age and SBA made concrete follows this precedence as seen in the results

3.4.2 Compressive Strength After Firing

After the firing, the compressive strength of samples decreased to 5.0N/mm^2, 4.5N/mm^2 and 6.5N/mm^2 for 0%, 5% and 10% SBA replacement respectively. Figure 7 shows that when concrete cubes are fired, it causes the material to have less strength than when they were not fired. Ali & Masoud (2009) observed strength loss for all concrete exposed to 600°C especially the concrete that contained silica fume despite their good mechanical properties at room temperature and also noted that the effect of the temperature on mass loss of Ground Granulated Blast Furnace Slag (GGBFS) concrete was less than 8% below 700°C, which was similar to the ordinary Portland cement (OPC) concrete. According. Rashwan, Diab, & Gad (2014) test results indicate that, for all sample series there was a decrease in compressive strength with increase in temperature but test sample C2, S2 and G3 performed better at elevated temperatures compared to the control mix. Figure

8 shows that the control mix lost the greatest compressive strength at 82.95% while the 10% SBA replacement lost the least strength at 57.17%. The results of SBA replacement of 10% shows that it performed better than both the control and the 5% mix indicating and improved fire resistivity.

3.5 Density and Weight of Fired Samples

The samples of concrete became light in weight when they were fired. The result shows for 0% and 5%, the weight after firing is 2.32kg and 2.02kg while before firing it was 2.44kg and 2.26kg weight was recorded. According to studies by Rashwan, Diab, & Gad, November (2014) the specimen unit weights decrease with increasing temperature. Furthermore, for the control mix, the percentage of loss in weight at 300°C, 600°C and 800°C was 1.31%, 3.29% and 5.23% respectively and for other specimen series at any temperature, there is increase in percentage loss in weight with increase in replacement ratio of GGBFS. Figure 9 shows 4.92% 10.62% 12.06% decrease in weight of 0%, 5%, 10% SBA fired samples respectively. Figure 6 shows that the density of SBA made concrete were lower than the control mix for both unfired an fired samples. The study of Yew M. K. et al 2021 on the Fire resistance of Lightweight Foam Concrete LWFC opined that the principal role of inclusion of Oil Palm Shell OPS has constantly reduced the density of LWFC and the inclusion of OPS is used to provide better fire resistivity of LWFC. It can be deduced, therefore that light weight and density of concrete tends to increase fire resistivity of concrete as observed in the production of concrete with SBA.

3.6 Water Absorption Test of Concrete Samples

The result of water absorption obtained is shown in Figure 10 shows that plain concrete absorb less water than the concrete produce with SBA. At 100 % cement content, the percentage of absorption was 1.92% for plain concrete and the absorption increase as the percentage of replacement of sugarcane bagasse ash increase when cured in water. At 5% replacement, water absorption was 2.21% while at 10% there was a decrease in the water absorption of the concrete from 2.21% to 2.19 respectively.

3.7 Fire Resistance Test

Figure 11 and Figure 12 show the results of Fire testing. The cubes place in the oven are heated from room temperature to 502°C in which it remains in its original state but on reaching to 600°C the control shows a long thin hairy crack while on the 5% sample double or two hairy crack was observed which show that the sign of failure but both samples failed completely at 930°C showing multiple hairy on the samples and the control sample was failing off or breaking due the effect of fire. The fire resistance test of 10% started from 30°C at 0mins, the temperature continued to increase and at 500°C after 1hour of heating the sample was still stable. At 600°C the sample was observed to Still be without any sign of failure but at 700°C double hairy cracks are notice on the sample while the sample failed at 980°C. This proofs that the 10% SBA cube sample has better fire resistivity compare to Ali & Masoud(2009) study which observed strength loss for all concrete exposed to 600°C, especially the concrete that contained silica fume despite their good mechanical properties at room temperature.

4.0 CONCLUSION

The aim of this study was to investigate the Fire resistance properties of concrete made from 0.6 water/cement ratio, 0%, 5% and 10% by weight of cement replacement with Sugarcane Bagasse Ash (SBA) and then subjected to elevated temperatures. Based on findings of the experimental studies of the applicability of SBA in normal strength concrete, the following conclusions were made

1. Concrete produced with SBA has better workability based on the slump result and the workability decrease as the percentage replacement of SBA increases.

2. After observing the compressive strength of 0%, 5% and 10% SBA replacement of cement with SBA, it is concluded that the concrete produced with SBA at 5% can be used where grade M20 concrete is required and where M15 grade concrete is required, a 10% SBA replacement maybe suitable. However, SBA made concrete shows signs of increase in strength with age. This is consistent with strength development in concrete made with pozzolan's as concrete age increases.

3. Fire resistivity of both 5% and 10% SBA content is better than for 100% cement content mix. Therefore SBA at 5% and 10% is recommended as material that has better fire resistivity than plain concrete.

REFERENCES

Al Kourd, A., & Hammad, A. (2009/2010). Cement and Concrete Technology. Civil Engineering Department, faculty of Engineering, Islamic university of Gaza. https://onlineaavedan.com/study_material/1546679142.pdf

Aldefae, A. H., Fadhel, A., & Edan, A. S. (2020). Fire resistance of selected construction materials. Conference: 2nd International Conference On Materials Engineering & Science (IConMEAS 2019).

Ali, B., & Masoud, G. (2009). Comparison Of Compressive and Splitting Tensile Strength of High- Strength Concrete with and without Polypropylene Fibres Heated to High Temperatures. Fire Safety Journal, 44.

Bangar, S. S., Phalke, S. N., Gawade, A. Y., Tambe, R. S., & Rahane, A. B. 2017) . A Review Paper on Replacement of Cement with Bagasse. International Journal of Engineering Sciences & Management, ISSN 2277 – 5528, p 7(1)

B. E. (2002). Testing of hardened Concrete, Compressive strength of test specimens. London: British Standard Institute.

BS 8110-2, 1. (1985). Structural use of concrete for special circumstances. London: Bristish Standard Institute.

BS EN, 1.-3. (2002). Testing hardened concrete, Compressive strength of test specimens. London: British Standard Institute.

BS5588-1. (1990). Fire precautions in the design, construction and use of buildings. London: Bristish Standard Institute.

BS5588-5. (1991). Fire precautions in the design, construction and use of buildings for firefighting stairs and lifts. London: British Standard Institute.

Chudley, R., & Greeno, R. (2010). Concrete production-materials. In R. Chudley, & R. Greeno, Building Construction Handbook (p. 284). Elsevier.

Fire Resistance. (2013). In N. Z. Inc., New Zealand concrete masonry manual (p. 7). New Zealand Concrete Masonry Association Inc.

Hailu, B., & Dunku, A. (2012). application of sugarcane ash as partial cement replacement of material.

Hull, T. R. (2008). Challenges in fire testing: reaction to fire tests and assessment of fire toxicity. Advances in Fire Retardant Materials.

Kumar, L. V., & Vignesh, B. J. (2017). Experimental Investigation on Replacement of Bagasse Ash in Bricks. International Journal of Innovative Research in Science, Engineering and Technology.

Madurwar, M., Mandavgane, S. A., & Ralegaonkar, R. V. (2014, September). Use of sugarcane bagasse ash as brick material. Research Communications Current Science.

Maneela, M., Ariff, S., P, M., V, R. G., M, M., & Srinivasa. (2019). Compressive Strength of Fly Ash Bricks with Addition of Bagasse Ash. International Journal of Current Engineering and Scientific Research (IJCESR), 5.

Modania*, P.O., & Vyawahare, M. R. (2012). Utilization of Bagasse Ash as a Partial Replacement of Fine Aggregate in Concrete. Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference on Engineering (NUiCONE 2012) (p. 5). INDIA: ELSEVIER Ltd.

Neville, A. M., & Brooks, J. J. (2010). Concrete Technology. UK: Pearson Education Limited.

Otoko, G. R. (2014). Concrete, Use of Bagasse Ash as Partial Replacement of Cement in concrete. International Journal of Innovative Research & Development, 285.

Rashwan, M. M., Diab, H. M., & Gad, A. F. (2014). Elevated Temperature resistance concrete using Non- Traditional Materials. Journal of Engineering Sciences Assiut University, Faculty of Engineering, Vol. 42 No. 6, 11.

Yew, M.K., Yew, M.C., Beh, J.H., Saw, L.H., Lee, Y.L., Lim, J.H., and C. Y. T. (2021). Fire Resistance of Lightweight Foam Concrete by Incorporating Lightweight Bio-based Aggregate. IOP Conference Series: Earth and Environmental Science; 2021. Doi:10.1088/1755-1315/920/1/012009

Yohannes, L. Y., Raymond, H. W., and Lamb, D. L. (2017). Chemical technologies for modern concrete production. Science Direct: Modern Building Materials, Structures and Techniques, MBMST 2016, Procedia Engineering 172 (2017) 1270 – 1277. Published by Elsevier Ltd. Available online at www.sciencedirect.com.