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Investigation on Strength Characteristics of Pervious Concrete produced with Coarse Aggregate sizes

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***ABSTRACT*: *Pervious Concrete is a unique kind of concrete with high porosity that reduces the water runoff from particular site. This study evaluated the effect of coarse aggregate sizes on the properties of pervious concrete. Granite was collected on an ongoing construction site at Ajayi Crowther University, Atiba Local Government Area, Oyo State. Production of pervious concrete was carried out by using aggregate sizes with the mixing ratio 1:4 and water cement ratio 0.55 which later increased to 0.65. Slump and compacting factor test were carried out to check the effect of coarse aggregate sizes on the workability of fresh concrete. A total of Twenty Seven (27) cubes of size 150 x 150 x 150 mm^3 were cast. The pervious concrete were tested for compressive strength, density, water absorption, permeability, abrasion resistance and void contents at the ages 14, 21 and 28 days. The slump value increased from 85 mm for 12.7 mm granite to 105 mm with 25.40 mm of granite, as the size of aggregate increased indicating that pervious concrete becomes less workable as the aggregate size increased while the compacting factor value varied from (0.975-0.995). The compressive strength of pervious concrete at 28 days ranges from 14.95 - 16.25 N/mm2, Bulk density ranges from 1725 to 1830.05 Kg/m^3, water absorption ranges from 2.29-1.01%, void content ranges from 18.20-23.25%, permeability ranges from 8.50-12.15 mm/s, and Abrasion resistance range 0.21-1.90 Kg. It was observed that only coarse aggregate size shows high degree of water permeable. Pervious concrete exhibit better porosity properties than ordinary Portland cement concrete, pervious concrete is therefore recommended for the construction of farm structure for irrigation purposes.*

***KEYWORDS**: Concretes, Aggregates, Granites, Cement, Compressive strength*

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I. INTRODUCTION

Concrete is the widely used number one structural material in the world today. The demand to make this material lighter, has been the subject of the study that has challenged scientists and engineers alike (Chandra *et al*., 2011). The challenge in making lightweight concrete is decreasing the density while maintaining strength and without adversely affecting cost. Introducing new aggregates into the mix design is a common way to lower a concretes density. Normal concrete contains four components such as cement, granite, sand and water. The granite and sand are the components that are usually replaced with lightweight aggregates (Adewole, 2014).

Aggregates which are prominent material in concrete constitute 60-80% of total concrete constituent (Adesanya and Ejeh, 2014). The most effective properties of aggregate utilization in concrete properties against environmental effects and against static and dynamic loads on concrete by its own capacity. The composition, shape, characteristics, size of aggregate and source of aggregate have significant impact on the workability, durability, strength, fire resistance and shrinkage limited of the properties of concrete. Thus, the sources aggregate can have influence on the characteristics and properties of concrete produced thereof (Brook and Neville, 2012).

Pervious concrete is a unique kind of concrete with high porosity that reduces the water runoff from particular site and promote to ground water recharge (Atoyebi *et al.,* 2018). Pervious concrete has little aggregate and sufficient cementations paste to coat coarse aggregate particles on preserving the interconnectivity of voids which drains quickly. Pervious concrete is used in residential streets, parking areas, pedestrian walkways, areas with light traffic and greenhouses (Sadiq and Atoyebi, 2015). It is an important application to protect water quality. The proper use of pervious concrete is recognized by the United States environmental protection agency for providing storm-water management pollution control (Osuolale *et al.*, 2019).

The advantage of pervious concrete over normal cement concrete is that it is for water treatment by pollution removal, less need for curbs and storm sewers, better skid resistance in pavements, recharge to local aquifers (Mujedu *et al.*, 2014). Pervious concrete is a type of concrete which consist of coarse aggregate, Portland cement and water. Absence of fine aggregate defines its difference from the convectional concrete, its single sized aggregates are bonded together with cement-water paste (Adesanya and Ejeh, 2014), which resulted into a concrete with highly interconnected voids which allows rapid percolation of water through it in its function state. Pervious concrete has void ratio ranging from 15 to 40% depending on its application. It is also different to the convectional concrete with lower unit weight, higher permeability and lower compressive strength (Akinwumi, 2016).

Many places around the world have been reported to have experienced flooding resulting from a combination of increased rainfall and reduced permeability in urban regions. To solve this problem, it is necessary to reduce various environmental problem occurring around residential regions. Different approaches have been used to address this issue of environmental problem. Therefore, to overcome this difficulties, pervious concrete is considered a best management practice because of its capability to reduce excessive storm-water runoff (Adewole *et al.,* 2014). At present, no attention is paid on production of pervious concrete using different coarse aggregates, this call for concerted effort to investigate properties of pervious concrete using different coarse aggregates.

II. MATERIALS AND METHODS

A. Materials

The material used was granite of three (3) different sizes as coarse aggregate, and Dangote brand of ordinary Portland cement of 32.5 grades was used. The granite was obtained from quarry sites at Atiba Local Government Area, Oyo, Oyo State. Fine aggregate and water was obtained locally in Oyo land Nigeria. The concrete mix ratio used is 1:4. The 150 x 150 x 150 mm3 cube specimens was produced and tested for compressive strength density, permeability, void ratio, abrasion resistance test in accordance with BS 1881: part 116:1970 and BS 1881: part 117:1983. Using Vary – Denison Universal Testing Machine at Ajayi Crowther University Structural Laboratory, Oyo, Oyo State. For each concrete produced from three (3) different sizes of granite samples experiment on fresh concrete and hardened concrete test were obtained to know which sizes of granite use, in the production of pervious concrete.

Sieve analysis was done to determine the particle size distribution of the coarse aggregates. This was done by sieving the aggregates in accordance with the provisions of BS 812: (Part 1) – 1985. Furthermore, Compacting factor test was carried out by using the compacting factor apparatus. The upper hopper was filled with concrete in such a way that no work done to produce compaction, the bottom door of the hopper was released so that the concrete will falls to lower hopper. The bottom door of the lower hopper was released so that the concrete falls to the cylinder; excess concrete was cut off by two floats slid, across the top of the mold. The net weight is then known and the volume of the cylinder was determined. Compacting factor was determined by comparing the weight of concrete in the cylinder to the weight of the fully compacted concrete by using the following equation

$$C.F = \frac{weight\ of\ partially\ compacted\ concrete}{weight\ of\ fully\ compacted\ concrete}$$

proceeding. The aggregate was mixed and cast at the structural laboratory and it was cured and tested at expected curing age.

Fig. 1: Samples Casting

Fig. 2: Curing Samples

In addition, after 28 days curing, pervious concrete specimen was taken out from storage for density test according to ASTM C 642, for testing at particular day. The specimens was turned to Saturated Surface Dry (SSD) condition by removing water from the surfaces. Then SSD weight of samples in air (C) was measured. The specimens was placed in oven at a temperature of 100 to 1100C for 24 hours. After which the weight of the specimen was measured. This is oven dry weight of samples in air (A). After that, the specimens was placed under water in a bucket and weight under water (D) was obtained. Temperature of water at test day (T) was also recorded and water density (p) was calculated for that temperature. The density of concrete was calculated using equation below.

$$Dry\ Density\ (Bulk\ Density), g_1 = \frac{Ap}{(C-D)}$$

Where:

A = mass of oven-dried sample in air, (gram)
C = mass of saturated surface-dry sample in air, (gram)
D = mass of sample in water after immersion, (gram)
P = density of water at T^0C (kg/m^3)

The pervious concrete specimen was made ready for compressive strength test at required age according to ASTM C 39. The diameters of the cylinders was measured and cross-sectional areas was estimated according to ASTM C 39. Universal testing machine was used to compress the load on specimens at a required loading rate. The cylinders were placed within the bearing blocks, the axis of the specimens were aligned properly and compression was applied. The compressive strength of the specimen was calculated by dividing the maximum load attained during compression test by the cross-sectional area of the specimen, this was determined using Equation below.

$$Compressive\ Strength\ (N/mm^2)\ =\ \frac{failure\ load \times 1000}{gross\ area\ of\ cube}$$

Fig. 3: Compression of Sample cubes

Furthermore, Permeability test on Pervious Concrete was done using a falling head apparatus to measure the permeability of pervious concrete. The specimen was prepared by coating the four (4) sides of pervious concrete sample with bitumen insulation to prevent water from throwing out sideways. The coated sample was placed at the bottom of standpipe with inner diameter of 110mm. Test was initiated by allowing water to saturate the pervious concrete sample to release an entrapped air in the samples. At an initial head of pervious concrete immersion, the time was recorded till the water level reached the final head. This was repeated thrice for each sample under falling head for water permeability to improve the accuracy of the results. The coefficient of water permeability (K) was computed using Equation below.

$$K = \frac{\alpha L}{At} L\left(\frac{h_0}{h_1}\right)$$

Where:
K = Permeability coefficient
A = Cross section area of standpipe
L = Vertical distance of measuring point of sample
t = Time taken for the head to fall from h0 to h1
h0 = Initial Water Head
h1 = Final Water Head

Water absorption test was carried out by weighing the pervious concrete specimen after the curing age of 28 days for each batching of pervious concrete specimen. The specimen was then immersed in water for 24 hours and the new weight of each specimen was measured. The water absorption rate was determined as the ratio of difference between the soaked and dry weight of the pervious concrete to that of dry weight.

This was done by sun drying pervious concrete specimen at the curing age of 28 days, the specimen was then immersed in water for 24 hours. The specimen were then removed from the curing tank and allowed to drain. The pervious concrete specimen was engaged in direct scratching of all the sizes of the specimen with ten backward and forward stroke of iron rod. The resulting scratched particle difference of the pervious concrete were weighed to give the amount of abrasion resistance of pervious concrete specimen

III. RESULTS AND DISCUSSION

A. Slump and Compacting Factor Test

The slump and compacting factor of the specimen were examined for each of different aggregate sizes of granite and the results were presented in Table 1 and Fig. 4. It was observed that the slump and compacting factor values of 12.70 mm granite fall below the standard 120 mm requirement for concrete, had the lowest value for slump and highest value of compacting factor value. The slump value for 12.70, 19.05 and 25.40 mm granite varied from (45-105) mm while the compacting factor value varied from (0.975-0.995).

Table 1: Slump and Compacting Factor Values

Aggregate Sizes (mm)	Slump	Compacting Values
12.70	85	0.995
19.05	90	0.982
25.40	105	0.975

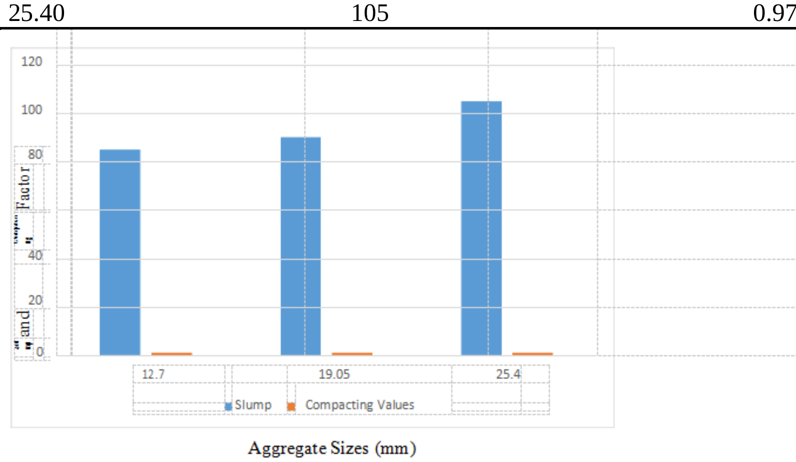


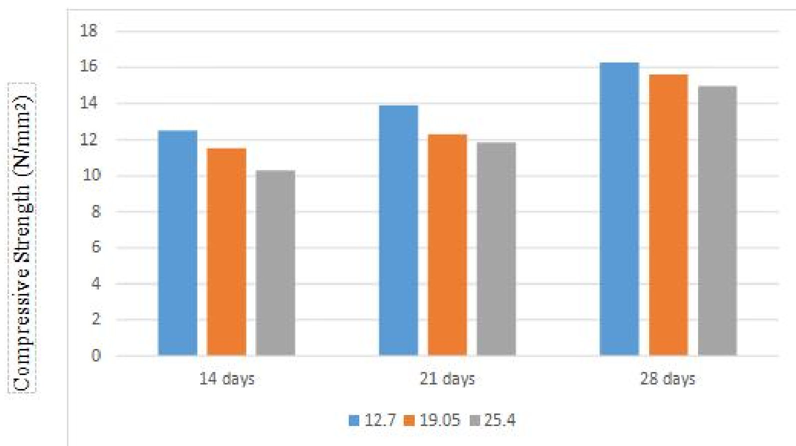
Fig.4: Slump and Compacting Values of different Aggregate Sizes

B. Compressive Strength of Pervious Concrete

Compressive strength test was carried out on a total of Twenty Seven (27) concrete cubes. Three cubes from the batch were tested after 14, 21 and 28 days of curing. The result were presented in Table 2 and Fig.5 respectively. The Fig. indicates that the compressive strength generally increases with increased number of curing ages. At 14 days, 12.70 mm aggregate was observed to lead other aggregates in terms of compressive strength with 12.50 N/mm^2. The compressive strength obtained decreases as the aggregate size of granite increased. While the compressive strength value increases as the curing age increases. Invariably, it is advisable for the curing to attain a minimum curing age of 28 days.

Table 2: Slump and Compacting Factor Values

Aggregate Sizes (mm)	Compressive Strength Values (N/mm^2)		
	14 days	21 days	28 days
12.70	12.50	13.90	16.25
19.05	11.50	12.25	15.60
25.40	10.25	11.80	14.95



Aggregate Sizes (mm)

Fig.5: Average Compressive Strength for different Aggregate Sizes

C. Bulk Density of Pervious Concrete

The result and Fig. presented below revealed that the density of the pervious concrete ranged from 1725.00 to 1830.05 kg/m^3, with 12.70 mm aggregate size giving the pervious concrete with the highest density. All densities within the lower range of light weight in the grade of concrete on the order of 1000 to 2000 kg/m^3. This is in accordance to BS EN206-1:2000.

Table 3: Average Density of Pervious Concrete

Aggregate Sizes (mm)	Bulk Density (Kg/m^3)		
	14 days	21 days	28 days
12.70	1762.05	1805.25	1830.05
19.05	1730.20	1780.10	1795.25
25.40	1725.00	1770.15	1782.06

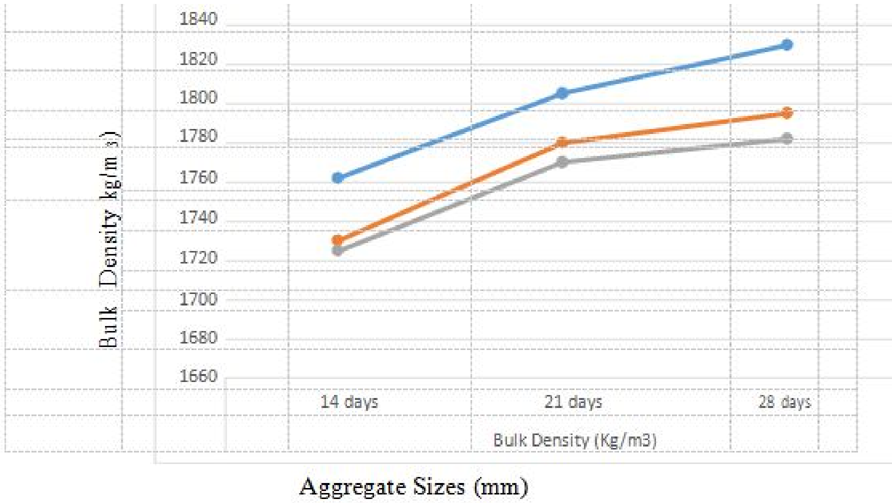


Fig.6: Graphical Illustration of Bulk Density

It was observed from Fig. 6 that the density of pervious concrete produced with 12.70 mm granite is denser than the pervious concrete produced with 19.05 and 25.40 mm granite. This is as a result of small sizes of the 12.70 mm granite which make it easy to fill the spaces in the pervious concrete produced during compaction at 25 blows in three layers. The highest density was observed in pervious concrete with 12.70 mm at 28 days with 1830.05 kg/m^3.

D. Water Absorption of Pervious Concrete

The result obtained from the water absorptivity of pervious concrete cubes is presented in Table 4. The result indicates that the water absorption decreased from (2.29-1.01) % at an average of 1.48%. This implies that the pervious concrete becomes more workable as the water absorption value is lesser than 3% as recommended by British Specification values.

Table 4: Water Absorption of Pervious Concrete

Aggregate Sizes (mm)	Water Absorption (%)
12.50	2.29
19.05	1.15
25.40	1.01

E. Void Content in Pervious Content

The percentage of voids present in each sample from different pervious concrete produced with different aggregate sizes of granite presented in Table 5. It was observed that the highest void content of 23.25% was noticed in pervious concrete produced with 12.70 mm granite, followed by 19.05 mm granite. It was also observed that the density and void content are inversely proportional i.e the higher the density, the lower the void content. According to Hirschi et al., pervious concrete contains no fine aggregate and has its air as void content varying between 15 and 30%. Therefore, the void content of pervious concrete samples produced by all aggregate sizes are adequate, as a minimum of 15% is needed to provide sufficient permeability.

Table 5: Relationship between Density and Void Content of Pervious Concrete

Aggregate Sizes (mm)	Average Mass (Kg)	Average Density (Kg/m^3)	Void Content (%)
12.50	7.20	1830.05	18.20
19.05	6.90	1795.25	21.80
25.04	6.95	1782.06	23.25

F. Permeability of Pervious Concrete with Aggregate Sizes

The result of permeability of pervious concrete produced with different aggregate sizes is present in Table 6 and Fig. 7 respectively.

Table 6: Permeability of Pervious Concrete

Aggregate Sizes (mm)	Permeability (mm/s)
12.50	8.50
19.05	10.60
25.40	12.15

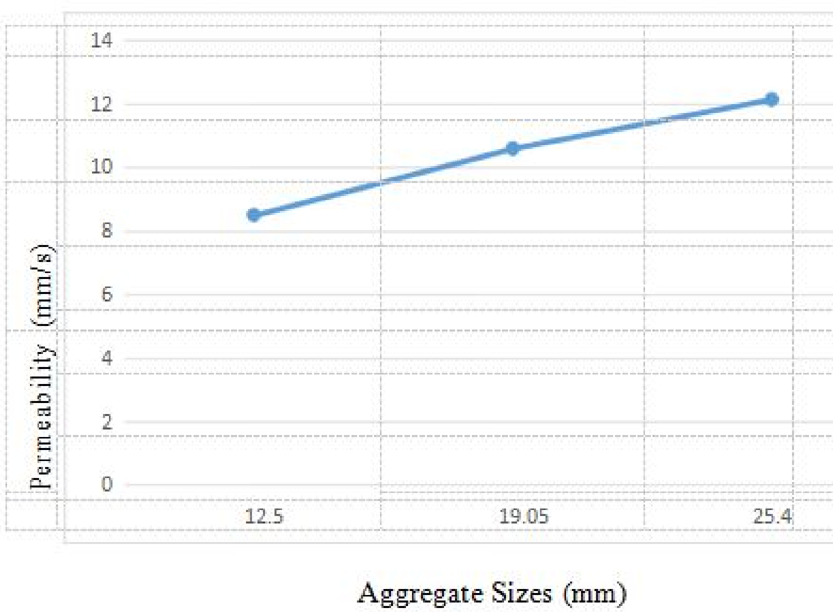


Fig. 7: Illustration of Aggregate Sizes against their Permeability

It was observed from Fig. 7 that 25.40 mm granite produced the most permeable sample with 10.60 mm/s value. Followed closely with 19.70 mm granite with 10.60 mm/s and 12.50 mm granite had 8.50 mm/s.

G. Abrasion Resistance on Pervious Concrete

The result of the abrasion resistance carried-out on pervious concrete produced from 12.70, 19.05 and 25.40 mm granite is presented in Table 7 and Fig. 8.

Table 7: Abrasion Resistance of Pervious Concrete

Aggregate Sizes (mm)	Abrasion Resistance (Kg)
12.70	0.21
19.05	1.12
25.40	1.90

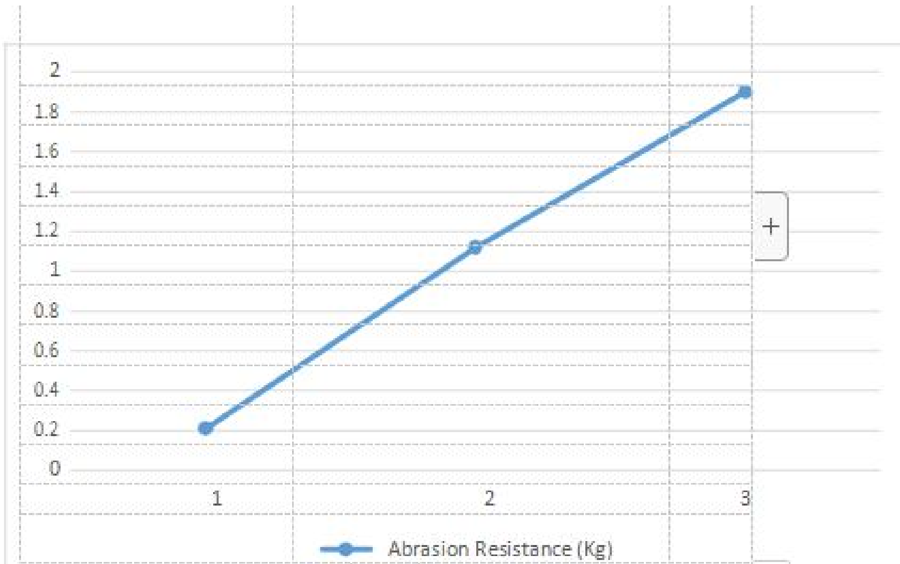


Fig. 8: Illustration of Abrasion against Aggregate

Table 7 and Fig. 8 show the influence of Aggregate Sizes on the abrasion resistance of pervious concrete. It indicated that the increases from 0.21 to 1.90 kg as the size of the aggregate increased from 12.70, 19.05 and 25.40 respectively. The result from the Fig. indicated that the abrasion resistance value of pervious concrete increased as the sizes of granite increases. This is as a result of interstitial spaces amongst the larger size of the granite, this made it more difficult for the fine aggregate (cement) to hold it firmly enough. The result suggested that abrasion resistance of pervious concrete increased with increase in course aggregate sizes.

IV. CONCLUSION

The aggregate granite of 12.7 mm had the highest compressive strength. The aggregate size of 25.40 mm is the most permeable concrete with 12.15 mm/s. By visual inspection, all brands of cement produced pervious concrete with very similar aesthetics. The densities of pervious concrete were between 1725 to 1830 kg/m^3. Aggregate size 12.70 mm of granite had the highest resistance to Abrasion.

REFERENCES

Adesanya, A.U. and Ejeh, S.P. (2014). Effect of the Incorporation of Sawdust Waste Incineration Fly Ash in Cement Paste and Mortars. *Journal of Asian Architecture and Building Engineering, 3(1):1-7.*

Adesanya D.A., Raheem, A.A. (2009). Development of Corn Cob Ash Blended Cement, Construction and Building Materials, *23(4):347-352. doi:10.1016/j.conbuildmat. 2007.11.013.*

Adewole, K.K., Olutoge, F.A., Habib, H. (2014). Effect of Nigerian Portland-Limestone Cement Grades on Concrete Compressive Strength. *International Journal of Civil Environmental Engineering, 8(1):199-202.*

Atoyebi, O.D., Odeyemi, S.O., Bello, S.A and Ogbeifun, C.O. (2018), Splitting Tensile Strength Assessment of Lightweight Foamed Concrete Reinforced with waste Tyre Steel Fibre. *International Journal of Civil Engineering Technology, 9(11):29-37.*

Atoyebi, O.D., Aladegboye, O.J., Odeyemi, S.V. (2018), Evaluation of Laterized Earth Moist Concrete in Construction Works. *International Journal of Civil Engineering Technology, 9(32):7-33.*

Atoyebi, O.D, Sadiq O.M. (2018). Experimental Data on Flexural Strength of Reinforced Concrete Elements with Waste Glass Particles as Partial Replacement for Fine Aggregate. *Data Br, 18(8):46-59. doi:https://doi.org/10.1016/j.dib.2018.03.104.*

American Society for Testing and Materials (ASTM C618-92a). *Chemical and Physical Specifications (2009).*

ASTM C1688/1688M-12. American Society for Testing and Materials (ASTM). Standard Test Method for Density and Void Content of Fresh Mixed Pervious Concrete. *Philadelphia, USA:2012.*

ASTM C 618 (2005). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete, *Annual Book of ASTM Standards, Philadelphia, USA.*

Osuolale, O.M., Atoyebi, O.D., Tunde, O.V. (2019). Experimental Study of the Strength Performance of Sawdust Ash Pervious Concrete. *Journal of Engineering and Applied Science, 14(832):1-8.*

Mujedu, K.A., Adebara, S.A., Lamidi, I.O. (2014), The use of Corn Cob Ash and Saw Dust Ash as Cement Replacement in Concrete Works. *International Journal of Engineering Science, 3(42):2-8.*

