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Effect of *Acacia Nilotica* Seed Powder on the Properties of Concrete

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Concrete is universally a vital building material due to its outstanding strength and durability. This makes it superior to other building materials such as wood and timber. Concrete, under moderate environmental exposure, has the ability to resist processes of deterioration. However, when exposed to aggressive environment, concrete deteriorates. Thus, an addition of a supplement is desirable to improve its resistance to the deteriorating processes of the environment; such as weathering actions, chemical attacks and abrasions. This study evaluated the compressive strength and the durability of concrete containing an agricultural waste - *Acacia Nilotica* Seed Powder (ANSP) in 0.25%, 0.50%, 0.75% and 1% addition to the concrete mix design. The standard and specification and sourcing of the Portland cement and aggregates were same as for the control cubes. The concrete specimens were made by the addition of 0.25% or 0.50%, 0.75% and 1% of ANSP materials and using a concrete mixer. The control and specimens' cubes were evaluated at 7, 14, and 28-days curing. Results indicated that the summation of the major oxides of SiO_2 (27.7%), Al_2O_3 (4.04%) and Fe_2O_3 (6.21%) was about 38% indicating a Class C pozzolan. The soundness of the Portland pozzolans concrete increase from 1 mm to 7.4 mm. Resistance to absorption rate increases from 2.4% to 7.4%. Outcome of the compressive strength of concrete cubes containing 0.25% addition of ANSP at 28 days curing period showed an increase of $1N/mm^2$ ($19N/mm^2$) above the control specimen ($18N/mm^2$). It is conclusive that addition of 0.25% ANSP into concrete mix has effect on the compressive strength and durability properties of the concrete. It is therefore recommended that 0.25% of ANSP can be added in concrete production as a retarder since it delays final setting time for about 8 hours; similarly increases the compressive strength of the concrete and improved the water absorption capacity from 2.4 to 7.4%.

Key Words: *Acacia nilotica,* supplementary cementitious material, pozzolan, concrete durability, cement

INTRODUCTION

Hossain *et al* (2011) asserted that concrete is the most widely used construction materials globally due its outstanding strength, durability, versatility and flexibility in production and ease of application in construction. It is the durability and flexibility in production and usage characteristic that makes its usage superior to materials such as wood and steel. The American Concrete Institute (ACI, 2001) defined Durability of concrete as the ability of a concrete structure to 'resist deteriorations processes such as weathering, chemical attack and abrasion and or any other any processes of deterioration while retaining its original form, quality, and serviceability'

Despite the strength and durability cement concrete; it offers weak resistance to deterioration attack when use in seawater, salt and acid environment. But Hossain1*et al* (2015) asserted that concrete containing volcanic ash exhibited better performance in terms of the strength and durability compared to normal concrete when situated in an aggressive chemical environment. Kurtis (2002) attributed these strength and durability enhancement to hydraulic and or pozzolanic activity of the volcanic ash. Dadu (2012) explained further that SCM are materials that, when used in concrete mix design and in conjunction with cement contributes to the compressive strength and durability properties of the hardened concrete. Massazza (1993) reported that the key property of concrete containing pozzolanic cements are their greater resistance to chemical attacks than the cement concrete, hence addition of Supplementary Cementitious Material (SCMs) such as pozzolans to concrete mix design would improve the resistance of the concrete to the deterioration processes particularly of chemical attack.

The pozzolans are materials that chemically react with calcium hydroxide to form strong compounds of CSH. ASTM C 618 (2005) defined the pozzolans as siliceous or siliceous and aluminous materials, which in themselves possess little or no cementitious values but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at in the presence of moisture at ordinary temperatures to form compounds possessing cementitious properties. Dadu (2010) stated further that the pozzolans are classified into natural and artificial. The Natural Pozzolans (NP) are products of volcanogenic activities; made up materials such as volcanic ash, volcanic tuff, volcanic lava and pumice. While Artificial Pozzolanas are by-products of main industrial processes wastes. These include Silica Fume (SF), Fly Ash (FA), Rice Husk Ash (RHA) and *Acacia Nilotica* Seed Powder (ANSP).

The ANSP is an innovative agricultural waste that are environmentally friendly cementitious materials for use in concrete as an admixture. Thus, this study investigated the characteristics of concrete containing ANSP as a supplement to the Portland cement concrete. The workability, compressive strength and the durability characteristics of concretes containing ANSP was evaluated.

LITERATURE REVIEW

Concrete Strength and Durability

Concrete is the most widely used construction materials globally. Dadu (2012) asserted that this is due its versatility and flexibility in usage and application as a building material and that its outstanding features include strength, durability and ease of production. ACI (2001) states that the Durability Concrete is its ability to resist wearing action, chemical attack, occasional resistance to mild acids exposures; and any process that lead to deterioration; it asserted further that in practice when concrete is exposed to aggressive chemical environment, concrete deteriorate often due to distress mechanisms such as physical salt attack, seawater exposure, acid attack and carbonation.

Cement is an essential building material though cement is only a fractional constituent in concrete mix production, the manufacture of Ordinary Portland Cement (OPC) affects the sustainability of the environment. The production of cement is responsible to the emission of CO_2 and other hazardous gases to the atmosphere. SCMs are introduced into concrete mix design to not only as an environmentally friendly cementitious material but to also improved durability of the concrete products. There is a need therefore for innovative and environmentally friendly cementitious materials for concrete production. Thus, the potentials of agricultural waste materials such as ANSP are potential materials for cement blending.

Supplementary Cementitious Material

The OPC is very expensive and its production is harmful to the environment. The global trend is the reduction of the Portland cement contents in the concrete mixtures with cheaper SCM to improve certain properties of concrete. Dadu (2011) explained that the SCMS are classified as hydraulic and pozzolanic based on their reacting mechanisms. The Hydraulic SCMs react directly with water to form compounds possessing cement properties. Slag, a by- product of iron production is an example of such material. While the pozzolanic materials such as volcanic ash, materials react chemically with calcium hydroxide $Ca(OH)_2$ to form compound possessing cementitious properties.

Admixtures

Chemical and Mineral Admixtures

There are chemical and mineral admixtures. Admixtures are natural or manufactured chemicals which are added to the concrete before or during mixing. The most often used admixtures are air entraining agent, water reducers, retarders and accelerator. Admixtures are used to give special properties to fresh or hardened concrete. Admixtures may enhance the durability, workability or strength characteristics of a given concrete mixture. Admixtures are used to overcome difficult construction situations, such as hot or cold weather placements, pumping requirement, early strength requirement, or very low water-cement ratio specifications.

Acacia Nilotica Seed Powder

However, *acacia nilotica* seed powder contains the chemical composition of a pozzolanic materials but with lower content of silicon oxide, thus it can be used as an admixture rather than replacing cement content. Therefore, using mineral admixtures are less expensive compare to chemical admixtures.

Acacia Nilotica:

Plate I showed the *Acacia nilotica* tree and the dried seeds.

***Plate I* (a): *Acacia Nilotica* tree**

Plate I (b): *Acacia Nilotica* seeds

The *acacia nilotica* seeds (Plate I (b)) were harvested from its tree (Plate I (a)) in Kafur Local Government, Katsina state. *Acacia nilotica* popularly known as "bugarija" in Hausa language is a multi-purpose nitrogen fixing tree legume that is widespread in Africa and Asia, and occurs in Australia. It has been recognized worldwide as a multipurpose tree National Academy of Sciences (NAS, 1980). The most significant in use is the leaf, followed by the flower extract and then the gum (Meena *et al*., 2006). The chemical composition includes: sodium, potassium, calcium, magnesium, iron, manganese, copper, silicone and iron, aluminum, zinc, sulphate and phosphorous. This implies that the acacia *nilotica* seed powder has the properties of pozzolanic material, hence it is used as admixture rather than cement replacement. This study was aimed to use ANSP as admixture in concrete. Thus, the primary objective of this study was to understand the possibilities of use of ANSP in concrete.

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MATERIALS AND METHODS

The materials and methods used in this research are as follows:

Materials

In this research, Portland cement, fine aggregate, coarse aggregate, water and *acacia nilotica* seed powder was used.

Production of acacia nilotica seed powder

The ANSP was obtained from different Local Government Areas in three different states of Nigeria. Prior to the use of *acacia nilotica* seed, it was dried under the sun for two weeks to remove the moisture content. After sun the dried, the seeds were grinded mechanically. The grinded seed powder was then sieved manually to remove the ungrounded particles. *Acacia nilotica* seed powder passing through 150-micron sieve was used the project research. The sieving was carried out in accordance with the ASTM C 136 (2006).

Cement and Aggregates

Dangote cement was used for the concrete cubes. The crushed granite stones were obtained from a local quarry in Zaria; and sand were from a river at the outskirt of Zaria. The Crushed stones and sands used met ASTM C33 (2002) specifications. Water fit for drinking was used was used for both production and curing of the concrete cubes.

Methods

Energy Dispersive X-Ray Fluorescence (EDXRF) Techniques

The determination of the oxides SiO_2, Fe_2O_3, Al_2O_3, MgO, CaO, SO_3, TiO_2, Na_2O, Mn_2O_3, CrO, Y_2O_3, and SrO were carried out by the use of Energy Dispersive X-Ray Fluorescence (EDXRF) techniques. According to Omotola and Onojah (2009), the EDXRF technique provides one of the simplest, most accurate and economic analytical methods for the determination of the oxides of glass, ceramics and building materials; it is non-destructive and reliable for solids, liquids and powdered samples analysis. Dadu (2012) further reported that the X-Ray Fluorescence (XRF) method is based on the measurement of x-rays intensities emitted by components of a target sample when excited by Silver-Potassium (Ag-K) X-rays (22.1 keV) from an annular excitation source of 25 milicurie (25 mC_i) Cadmium 109 (^{109}Cd). The system consists of the excitation source and a Silicon (Si)-Lithium (Li) semiconductor detector coupled to a computer-controlled Analog to Digital Control (ADC) Card.

The samples were prepared into pellets of 19 mm diameter. The measurements of the elements were performed using the Excitation Source by introducing the pellets of each of the samples into the X-ray fluorescence generator detector source emitting Silver (Ag)-Potassium (K) X-ray (22.1keV) in which all elements with lower characteristic excitation energies were accessible for detection in the samples for the analysis. The elements with the characteristic excitation energies were accessible for detection in the samples.

The quantification of the elements was then carried out using the Emission-Transmission Method. This method involved the use of Molybdenum (Mo) as a target material as the source of monochromatic X-rays, which is excited through the sample by primary radiation and then penetrate on the way to the detector. The spectra for the samples were collected with the Cadmium 109 source and evaluated using the analysis of X-ray Spectra by Iterative Least Squares Fitting (AXIL) a software program used for the analysis of the oxides of SiO_2, Fe_2O_3, Al_2O_3, MgO, CaO, SO_3, TiO_2, Na_2O, and Mn_2O_3.

Pozzolanic Activity Index with Portland Cement

The strength activity index of pozzolanic materials was evaluated following procedures stated by ASTM C 311 (2005). This was done by evaluating the strength of the concrete with zero pozzolan with the specific replacements at 28days for all the samples investigated.

The concrete cubes were prepared in 100 mm steel mold and tested in accordance to ASTM C 109 / 109M (2001) standards. Three test and reference cubes were cast and crushed at curing periods of 7, 14 and 28days.

Samples Preparation

The concrete cubes were prepared in 100mm steel mold and tested in accordance with C 109/C 109M (2001). The materials were batched by volume. The water/cement ratio of 0.6 was used for all the mixes based on trial mixes. The control cubes specimens were also treated identically to the test specimens. The specimens were made by replacing cement with

0.25%, 0.50%, 0.75% and 1% of the ANSP materials in the concrete mixtures and compressive strengths of all the cubes were determined at 7, 14 and 28-days curing.

Tests on Fresh and Hardened Concrete Samples
Slump test, consistency test and soundness test were conducted on fresh concrete for all percentage replacements of the ANSP with cement in accordance with BS 1881: part 2(2002) and BS4550: part 3(2001) while the compressive and tensile strengths were based on BS 1881: part116(2002) respectively.

Durability Properties
Some of the durability tests carried out during the experiment were abrasion and water absorption capacity properties details of which are as follows

Abrasion resistance
Because of lack of instrument for carrying out the abrasion test, method improvised by Ibrahim (2014) was adopted where the cubes after been cured for 28 days were dried and weighed. A 3.5kg load was tied on a metal brush and the brush was used to brush the surface of the specimen cubes to and fro for about 60 counts per minute. The samples were then re-weighted to find the new weight and the percentage loss in weight was then calculated as

$$\text{Abrasion resistance (\%)} = \frac{Wb - Wa}{Wb} X\ 100$$

Where, Wb = weight of specimen before brushing (g).
Wa = Weight of specimen after brushing (g)

Water absorption test
The test procedure according to BS 1881-122 (2005) was adopted which involves drying a specimen to a constant weight in an oven at 105^0C for 72 hours. The sample was allowed to cool in the oven, weighed and the mass recorded (W1). Each sample was then immersed in water for 30 minutes. After that, the specimens were removed from the water and dried with a cloth as rapidly as possible until all free water was removed from the surface and re-weighed again (W2). The increase in weight as a percentage of the original weight is expressed as its absorption as shown below.

$$Water\ absorption\ (\%) = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{W1}} \times 100$$

Where, W1 = Oven dry weight of cubes in grams.
W2 = Wet weight of cubes in grams

RESULTS AND DISSCUSSION

Fresh Properties
Consistency Test
Table 1 shows the consistency test result of the control, 0.25%, 0.5%, 0.75% and 1.0%. It can be observed that the plunger penetration increases from 5mm to 7mmand then decreases. The control, 0.25%, 0.5%, 0.75% and 1.0% have plunger penetration of 5mm, 6mm, 7mm, 5mm and 5.5mm respectively. BS EN197-1 (2009) states that when the plunger penetrates the paste to a point 5-7 mm above the bottom of the mold, the paste is considered to be at "normal consistency". Therefore, the control and the specimens containing ANSP are at normal standard consistency. More so, this indicate that the paste met the requirement since all plunger penetration values range between 5mm to 7m. However, the higher the quantity of ANSP, the higher the water content. This indicate that the admixture is a water absorbing material.

Table 1: Consistency Test Result

S/No.	Specimens (%)	Weight of cement (g)	Weight of ANSP (g)	W/C (ml)	Plunger penetration (mm)
1.	Control	400	0	120	5.0
2.	0.25	400	1	121	6.0
3.	0.5	400	2	124	7.0
4.	0.75	400	3	126	5.0
5.	1.0	400	4	126	5.5

Setting Time Test
Table 2 shows the setting time result of the control, 0.25%, 0.5%, 0.75% and 1%. It can be observed that the initial and final setting time of the specimens (control, 0.25%, 0.5%, 0.75% and 1%) increases with increasing ANSP content. According to BS 4550 part 3 (2001), the initial-setting time of ordinary Portland cement (OPC) should not be less than 45 minutes and the final setting time should not exceed 10 hours. The reaction between water and cement which causes the stiffening of the cement is exothermic which produces heat and evaporation of moisture. Initial and final setting times respectively for the cement paste are: 1hr 55minutes and 3hrs

18minutes for control sample; 3hrs 11minutes and 8hrs 23minutes for 0.25% ANSP; 4hrs 2minutes and 11hrs 51minutes for 0.50% ANSP; 4hrs 30min and 12hrs 50minutes for 0.75% ANSP; 5hr and 13hrs 23 minutes for 1% ANSP as shown in the table above. The results suggest that ANSP delays the setting times of cement paste and this will be suitable in hot weather as well as in mass concreting. The delay was due to the dilution of cement with ANSP and slower pozzolanic reaction of ANSP. The final setting times for 0.50%, 0.75%, and 1% ANSP does not comply with the standard because it exceeded the recommended 10hrs.

Table 2: Setting Times Test Result

S/No.	Sample (%)	Initial setting time (min)	Final setting time (min)	Time delayed (hours)
1.	Control	75	198	3hhrs 18min
2.	0.25	191	503	8hhrs 23min
3.	0.50	242	711	11hhrs 51min
4.	0.75	270	770	12hhrs 50min
5.	1.0	300	803	13hhrs 23min

Soundness Test

Table 3 shows the soundness test result of the concrete specimens (control, 0.25%, 0.5%, 0.75% and 1%. It can be observed that the increase of ANSP in the mix increases the expansion of the apparatus thereby reducing the tendency of expansion and contraction which may lead to possible defects along the life span of the specimen. According to BS 4550 part 3 (2001), value for soundness test performed on any cement paste sample should not exceed 10mm. The results obtained show that the pastes were within the acceptable limit.

Table 3: Soundness Test Result

S/No.	Sample (%)	After 24 hrs (mm)	After 90min boiling (mm)	Soundness value (mm)
1.	Control	2.5	3.5	1.0
2.	0.25	4.5	9.0	4.5
3.	0.50	7.0	12	5.0
4.	0.75	7.8	14	6.2
5.	1.0	9.0	16.2	7.2

Slump test

Table 4 shows the slump result of the concrete specimens (control, 0.25%, 0.5%, 0.75% and 1%). The control, 0.25% and 0.5% ANSP samples recorded medium slump while 0.75% 1% ANSP recorded low slump values. The result shows that the higher the quantity of ANSP, the lower the slump value. It shows that the workability at constant water cement ratio is decreasing as the percentage of ANSP is increasing. Hence, medium workable concrete is suitable for reinforced concrete while low workable concrete is suitable for Mass concrete.

Table 4: Slump Test Value for Concrete

S/No.	Sample	Slump value (mm)	W/C	Degree of workability
1.	Control	75	0.6	Medium
2.	0.25%ANSP	70	0.6	Medium
3.	0.50%ANSP	58	0.6	Medium
4.	0.75%ANSP	49	0.6	Low
5.	1.0%ANSP	40	0.6	Low

Compressive Strength Test

Figure 1 shows the compressive strength of the control, 0.25%, 0.5%, 0.75% and 1% ANSP specimens. Increase in strength can be observed with increase of age in all the specimens. However, there is decrease in strength with increase in the % of ANSP from 0.25% to 1%. At 7 days, control recorded the highest strength (15N/mm^2) while 1% recorded the least strength (4N/mm^2). Similarly, same trend is observed across the ages. At 28 days, 0.5% recorded the highest strength (19N/mm^2) by about 5% and 37% than the control and 1% ANSP respectively. This means that the 0.5% ANSP has positive by impacting positively on the compressive strength property of the concrete through micro filling effect.

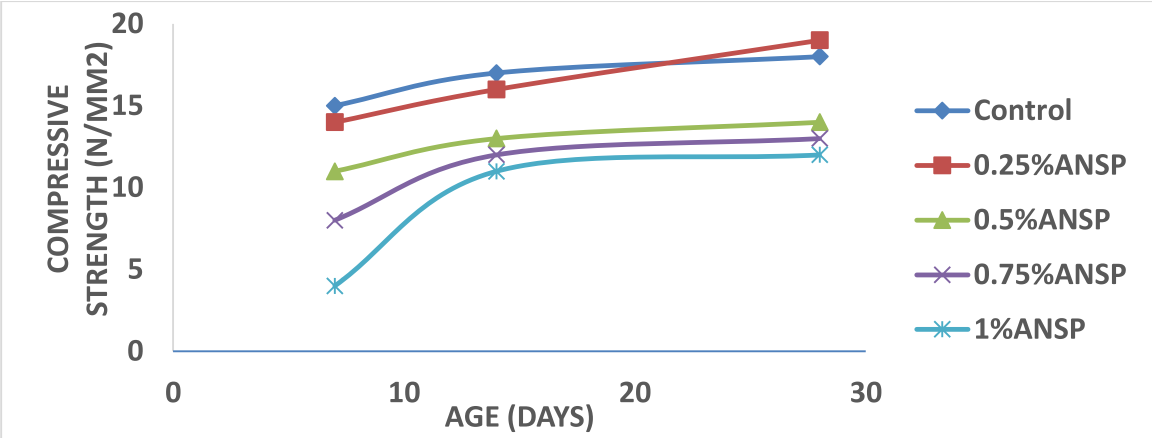

Figure 1: Compressive Strength Test for concrete specimens

Durability Properties

Durability properties assessed are water absorption capacity and abrasion resistance as follows:

Water absorption test result

Figure 2 shows the water absorption capacity of the control, 0.25%, 0.5%, 0.75% and 1% ANSP specimens. Increase in water absorption capacity can be observed with increase in the % of ANSP from 0% to 1%. The control has 2.4% water absorption capacity which is the lowest while 1% recorded 7.4% water absorption capacity which is the highest. This shows that ANSP affected the concrete specimens' structures by increasing their porosity.

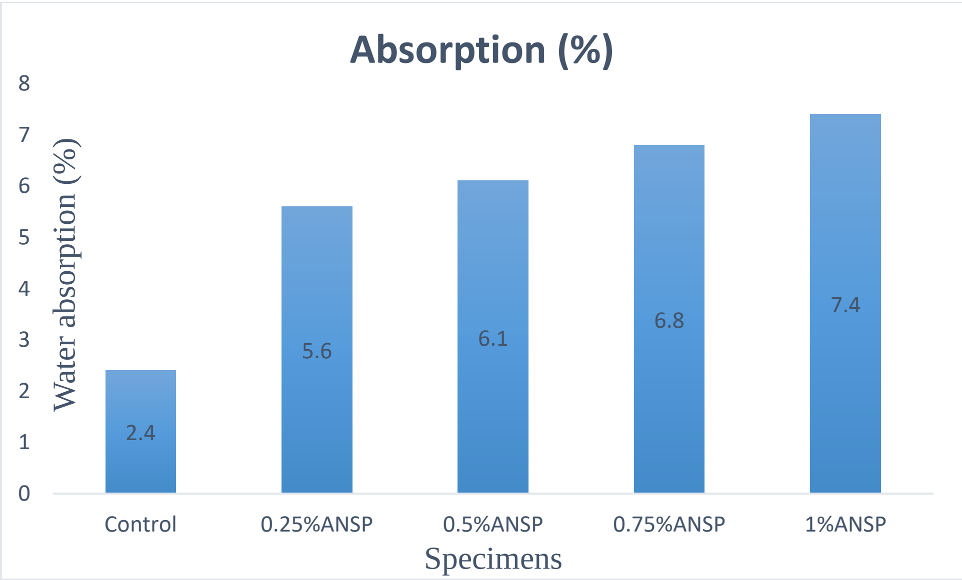

Figure 2: Water absorption capacity

Abrasion

Figure 3 shows the abrasion resistance of control, 0.25%, 0.5%, 0.75% and 1% samples. It can be observed that the abrasion resistance of the control, 0.25%, 0.5% and 0.75% have relatively same (0.04%) abrasion resistance. However, 1% recorded 0.78% abrasion resistance. Therefore, this suggest that all the concrete samples are durable but it is less accurate method compared to water absorption test since it was carried out manually.

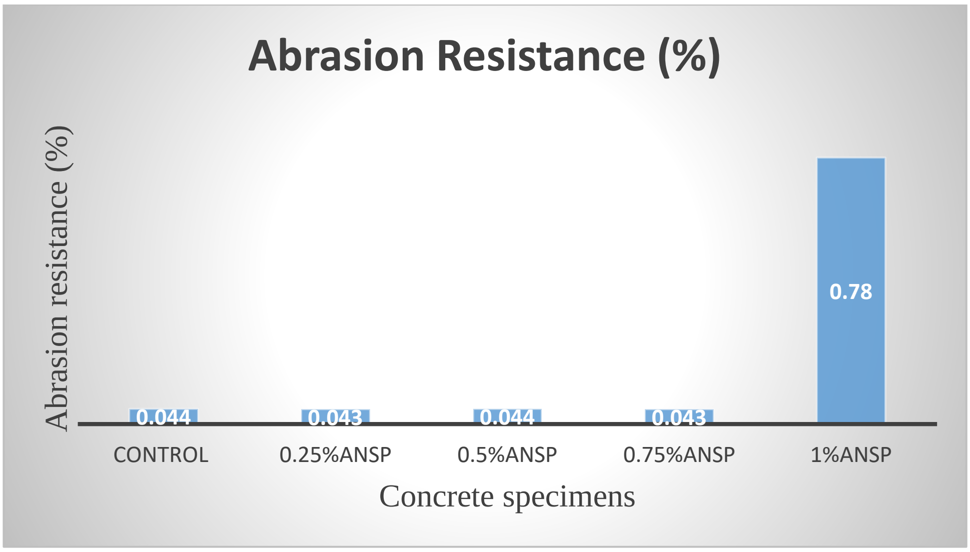

Figure 3: Abrasion resistance

CONCLUSION

Base on the outcomes of the experiment, *acacia nilotica* seed powder is a Class C Pozzolan. Concrete sample produced with *acacia nilotica* seed powder of 0.25% has the highest compressive strength of 19N/mm^2 greater than that of the control sample. Therefore, ANSP can be used as an admixture in concrete to achieve durability and optimum compressive strength by adding up to 0.25% ANSP in the concrete mix while adding more than 0.25% causes reduction in strength and durability.

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