PERMEABILITY PROPERTIES OF CONCRETE PRODUCED WITH ORDINARY PORTLAND CEMENT (OPC) BLENDED WITH COW DUNG ASH (CDA)

Fredrick J. O., Dambring E. D., Molwus J. J., and Amos N. G
Building Department University of Jos, Nigeria
Corresponding E-mail: ezydeb2016@gmail.com

Abstract - This research is aimed at to study the permeability properties of CDA concrete with a view of producing durable blended concrete in terms of water permeability and sorptivity. Concrete cube samples with mix design strength of 25Nmm-2 and water to cement ratio of 0.6 were produced with OPC and partially replaced with CDA at 0, 10, 20 and 30% to OPC content. The research observed that the control samples had greater early strength as compared with that of the CDA samples. This low strength development is as a result of the presence of CDA as filler in the concrete, as pozzolanas are known to reduce the early strength of concrete due to its slow rate of hydration. In both cases, there was an increase in strength with the age of curing. The test results indicated that the flexural strength decrease as CDA percentage content was increased. CDA increases the sorptivity of concrete hence, increasing the ingress of water which could affect the durability of the concrete negatively. There was decrease in the permeability with increase in curing period but increases with increase in the quantity of CDA. The optimum replacement was 10% research for compressive strength, flexural strength sorptivity and water permeability. It can therefore be concluded that CDA is a very good pozzolana which can attain up to 93.64% design strength at 28 days curing period but increase the ingress of moisture into concrete when used but at 10% partial replacement the effect will not be of great concern.

Index Terms- Permeability, Sorptivity, Cow dung Ash

1.0 INTRODUCTION

High cost of building materials has been the bane of construction industry in the developing countries of the world as a result of importation of most of the building materials. As prices increase sharply, there is a growing awareness to relate research to local materials as alternatives for the construction of functional but low-cost dwellings both in the urban and rural areas of Nigeria (Lasisi & Ogunjimi, 1984). It is well accepted by everyone that concrete executes outstanding responsibilities for the construction of modern infrastructures and industrialization (Ojedokun, Adeniran, Raheem & Aderinto, 2014). Attempt has been made by various researchers to maintain the durability, strength and stability of concrete structure while also reducing the cost of production. The cement industry has one of the highest carbon footprints which make traditional concrete unsustainable in the future. Materials such as Cow Dung Ash (CDA), Fly Ash, Slag, and Silica Fume, can be used as partial replacement for cementing material (Ojedokun, *et al.*, 2014). Besides the exorbitant cost of cement, its production requires very high temperature of about 1500°C which requires enormous amount of energy which is expensive to attain and maintain (Singh, Das, and Dwivedi, 2006). The activities of cement producing companies have depleted the natural environment and huge amount of poisonous gasses such as CO_2 and $NO_2$are released into the atmosphere causing environmental pollution. These gasses are also responsible for the depletion of the ozone layer which is responsible for global warming (Shalini, Prem & Dahiya, 2006).

All the aforementioned challenges have necessitated the need to intensify the search for supplementary cementeous materials (SCMs) for utilization as partial substitutes for cement. Several notable researchers have proven that the utilization of SCMs like saw-dust-ash (SDA), rice-husk ash (RHA), as partial replacement of cement in concrete and mortar is successful (Abalaka and Ugbome, 2010; Matawal and Duna, 2002). Cow dung is the undigested residue of plant matter which has passed through the animals' (cow) gut. In many parts of the world, cow dung is predominantly used as green manure for farming. It is also used with adobe in brick production, insect repellent and more recently used to produce biogas for electricity and heat generation. It can be duely noted that despite its application in the aforementioned areas, its production outweigh the usage (Olusegun and Sam, 2012; Marek, 2012).

Pavan Kumar and Polu Raju (2012) studied the effect of cow dung ash in cement paste and concrete. Their results revealed a decrease in compressive strength with increasing ash content. The workability, setting times and standard consistency increased as the CDA content increase. Another study investigated the possibility of using CDA as partial cement replacement material in the production of concrete (Ojedokun, et al., 2014). Their findings showed that cement replacement with CDA beyond 10% adversely affected its

compressive strength. All the aforementioned study did not cure concrete specimens beyond 28 days which is essential for assessing the pozzolanic potential of CDA (Ojedokun, et al., 2014).

It should be highlighted that the initial and final setting time increases as the percentage of Cow Dung Ash is added, (CDA) has an advantage that offers lightness of weight and low thermal conductivity, Cow Dung Ash requires more quantity of water as the percentage increases in the concrete therefore it has a serious limitation that must be understood before it is put to use. Cow Dung Ash concrete is recommended for use only when a ten percentage (10%) of Cow Dung Ash is added. The aforementioned researchers predicated their research on strength properties of CDA blended concrete. However, durability of concrete is not only a function of the strength but also permeability properties (Neville, 1991). Permeability is described as the property that governs the rate of flow of fluid into a porous solid. Permeability of cement concrete is of particular significance in structures which are intended to retain water or which come into contact with water. Besides functional considerations, permeability is also intimately related to the durability of concrete, specially its resistance, against progressive deterioration under exposure to severe climate, and leaching due to prolonged seepage of water, particularly when it contains aggressive gases or minerals in solution. The determination of the permeability characteristics of concrete, therefore, assumes considerable importance (Indian Standard, 2002).

2.0 MATERIAL AND METHOD

2.1 Experimental Design

Cow dung was obtained from three (3) different cow excreta points between Rayfield and New-Abuja Dadin-Kowa areas of Jos-South Local Government of Plateau State. Binary concrete of mixed design strength of 25N/mm^2 for normal weight concrete was produced at 10, 20 and 30% replacement of cow dung ash on concrete specimens cured between 7 to 90 days. Laboratory test were carried out to test density, compressive and flexural strengths, water absorption, porosity and sorptivity for cubes cured under different curing condition at ATBU Bauchi.

2.2 Materials

The materials that were used for this research are be ordinary Portland cement, fine aggregate of fine river sand, coarse aggregate of crushed stones and potable water. Cow Dung and other materials will locally be sourced from Jos, Plateau state, Nigeria.

2.2.1 Cement

The Dangote-Obajana brand of ordinary Portland cement conforming to BS 12 (1996) and ASTM-C 150 (1994) was used. This type of cement is majorly found in the Nigerian markets.

2.2.2 Fine Aggregate

Natural river sand from a river around Bauchi town was procured and used as fine aggregate. The properties of sand to be used were obtained from tests conducted in accordance to BS 812 (1991).

2.2.3 Coarse Aggregate

The coarse aggregate of crushed granite will be procured from a local quarry Bauchi metropolis, Bauchi state, Nigeria. The properties of the coarse aggregate will be obtained from tests conducted in accordance to the provisions of BS 812 (1991) and BS 882 (1992).

2.2.4 Cow Dung Ash (CDA)

Cow dung ash that was used for this project work was obtained in Jos, Plateau state, Nigeria. The cow dung was exposed to sunlight to dry in order to have dung cakes which were then subjected to burning after it is dried to have the cow dung ash which is obtained in black colour. The resultant ash was sieved using a sieve of 300μm and stored in an air tight container to prevent it from absorbing moisture.

2.5 Batching of materials

The batching will be done by weight according to the properties of each material determined earlier and inputted for the concrete mix design calculations for mix design strength of 25Nmm^{-2} at 28 days curing period.

2.6 Fresh concrete mix

The concrete was hand mix on a clean hard and none adsorbent metal surface. The procedure for the mixing was as follows:

i. The required quantities of materials as calculated from the Mix Design were measured and used with a partial replacement of OPC with CDA at 0, 10, 20 and 30% replacement.

ii. The constituents were mix together dry, until the mixture is of uniform colour. Water to cement ratio of 0.6 is measured for each batch and added and mixed thoroughly until a uniform colour was obtained.

2.6.1 Workability Test

Slump test was carried on fresh concrete to determine the workability of fresh concrete using the slump test method in accordance to BS 1881: Part 102 (1993)

The compaction factor test (Powers 1968; Neville 1981; Bartos 1992; Bartos, Sonebi, and Tamimi, 2002) measures the degree of compaction resulting from the application of a standard amount of work. The test was developed in Britain in the late 1940s and has been standardized as British Standard 1881-103.

The compaction factor test was carried out on fresh concrete to determine the workability of fresh concrete using the compaction factor test method in accordance with BS 1881-103.

2.7 Hardened concrete

The hardened concrete cubes were tested for compressive strength at various hydration periods (curing ages 7, 21, 56 and 90days). The beams were also tested for flexural strength at 56 days hydration period.

2.7.1 Compressive strength test

The compressive strength was carried on 100mm cube specimen of the various batch mix cured at 7, 28, 56 and 90 days. This test was done in accordance to the recommendations of BS 1881: Part 116 (1983) to determine the compressive strength of hardened concrete cubes.

2.7.2 Flexural Strength Test

The flexural strength was carried on 500 x 100 x 100mm beam specimen of the various batch mix cured at 56 and 90 days. This test will be done in accordance to the recommendations of BS 1881: Part 118 (1983) to determine the flexural strength.

2.9 Concrete durability tests

The sorptivity and water permeability tests were conducted at the ATBU, Bauchi, Bauchi State, Nigeria.

2.9.1 Water Permeability

The method used for the water permeability of the concrete is the falling Head Permeability Test method and in accordance to BS 1377-5: 1990. The Concrete were cylindrical in shape having a diameter of 75mm and 100mm height. The specimen were tested at 28days, 56days and 90days curing period both interrupted and uninterrupted. The specimen were placed into the permeameter cell and water tight with candle wax and then placed in the permeameter (The Permeameter is made of non-corrodible material with a capacity of 1000 ml, with an internal diameter of 100±0.1 mm and effective height of 127.3±0.1 mm) in the bottom tank and filled the tank with water for concrete to get saturated. After saturation is attained the inlet nozzle of the mould was connected to the stand pipe and the water was allowed to flow until steady flow was obtained. The time interval ‘t’ for a fall of head in the stand pipe ‘h’ was noted and repeated three times to determine ‘t’ for the same head. The permeability Kt is calculated as follows

m/s

Where Kt = Permeability (m/s)

a = cross section area of manometer tube used (mm^2)
A = cross section area of specimen in permeameter cell (mm^2)
t = measured time interval (s)
L = length of specimen (m)
h1 = start level manometer tube = y1- h0 (m)
h2 = end level manometer tube = y2- h0 (m)

2.9.1 Sorptivity test

The sorptivity was determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting were cured in water for 28 and 56 days curing. The specimen size 100mm diameter x 50 mm height after drying in oven at temperature of 100 + 10 °C and placed in water with level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating (candle wax). The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a digital balance. Surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds.

Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t) I=S.t½

Therefore S=I/ t½

Where; S= sorptivity in mm,

t= elapsed time in mint.

I=Δw/Ad

Δw= change in weight = W2-W1

W1 = Oven dry weight of cylinder in grams

W2 = Weight of cylinder after 30 minutes capillary suction of water in grams.

A= surface area of the specimen through which water penetrated.

d= density of water

3.0 RESULTS, ANALYSIS AND DISCUSSION

3.1 PROPERTIES OF AGGREGATES

Sieve analysis, specific gravity and bulk density tests were done on the aggregates used in the production of the concrete. The specific gravities of fine and coarse aggregate obtained are 2.6 and 2.7 while bulk densities were 1610kg/m^3 and 2535 kg/m^3 respectively. The Aggregate Impact Value (AIV) and Aggregate Crushing Value (ACV) were determined for the coarse aggregate of nominal size of 20mm. The AIV of the coarse aggregate obtained was 12.82% and the ACV was 9.55% which are all adequate as stipulated by BS 812:112 (1990). The results obtained are presented appropriately below.

3.2 PROPERTIES OF CDA

The properties of the CDA to be used were checked through various tests to ascertain it suitability to be used as a pozzolana. The physical and chemical properties are discussed.

3.2.1 Physical Properties

The specific gravity of CDA obtained was 2.28. This is less than that of OPC having a value of 3.15 and lies between 2.0-2.40 conforming to the requirement stipulated in ASTM C618 (1978) for pozzolana. This implies that there will be considerable weight reduction in the concrete produced with partial amount of CDA compared to that with 100% OPC

3.2.2 Chemical Properties

The total combination of Al_2O_3, SiO_2 and Fe_2O_3 was 77.66% which greater than 70% as minimum according to ASTM C618 (2001), calcium trioxocarbonate of 23.65% was detected which contributed in strength attainment. The percentage composition of sulphur as MgO is 2.11% which is less than 5% specified in the standard and Na_2O was detected at 0.61% less than 1.5% which conforms to ASTM C618 (2001) and will show a high pozzolanic activity.

Chemical Composition												
Elemental Oxide (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	P_2O_5	Mn_2O_5	TiO_2	$CaCO_3$
	69.75	4.74	3.17	13.25	2.11	0.89	2.70	0.61	1.37	0.62	0.38	0.19

Table 1: Chemical and Physical Properties of CDA

3.6 HARDENED CONCRETE

The various tests conducted on the hardened concrete samples are presented in this section to show the level of compressive strength gain, flexural strength gain and the density of samples with their age of curing. The samples were tested after 7, 28, 56 and 90days of curing.

3.4.1 Compressive Strength

The research observed that the control samples had greater early strength as compared with that of the CDA samples. A compressive strength of 13.58 N/mm^2 for control at 7 days curing while for 10, 20 and 30% are 10.09, 8.61, 5.19 N/mm^2 respectively. At 28 days, the compressive strength obtained are 23.41, 14.56, 10.81 and 7.39 N/mm^2 for control, 10, 20 and 30% CDA respectively. The values are 24.06, 17.13, 13.24 and 9.75 N/mm^2 for control, 10, 20 and 30% CDA respectively at 28 days curing period. At 90 days 24.82, 19.10, 15.50, 11.59N/mm^2 for control, 10, 20 and 30% CDA respectively. This data is illustrated in figure 1.

This slow rate of strength development is as a result of the presence of CDA as filler in the concrete, as pozzolanas are known to reduce the early strength of concrete due to its slow rate of hydration. In both cases, there was an increase in strength with the age of curing.

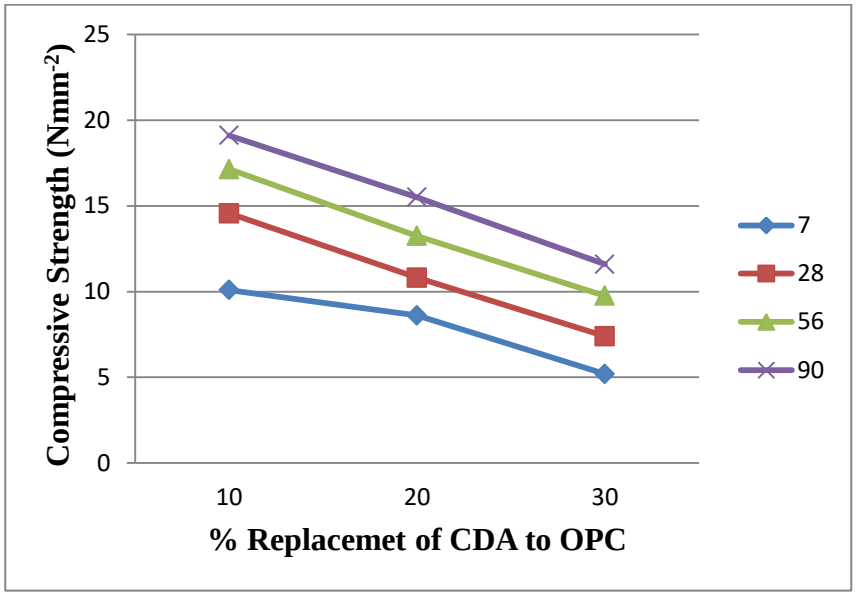

Figure 1: Compressive Strength Test Results with curing age

3.6.2 Flexural Strength

The values obtained for the indirect tensile strength as measured by the flexural strength test for the various beams cured at hydration period of 28 and 56 days are shown in Table 3. The test results indicated that the flexural strength decrease as CDA percentage content was increased.

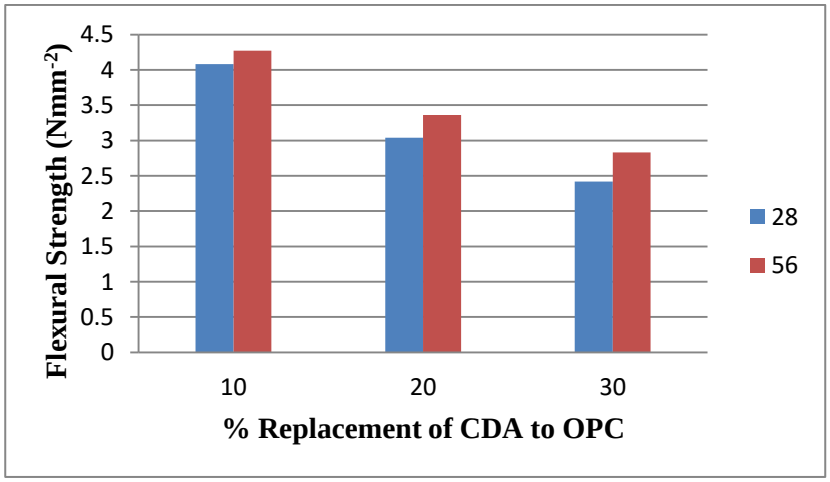

Figure 2: Flexural strength result with curing age

3.6.3 Sorptivity of Concrete

The values of sorptivity are shown in tables 16 obtained after 90 days of curing. Sorptivity values for increases with increase in CDA. For control a value of 5.31 x 10^{-8} mm/min$^{0.5}$ was obtained. For 10, 20, and 30% of CDA the values are 8.21, 10.44, 12.10 x 10^{-8} mm/min$^{0.5}$ respectively. This implies that CDA increases the sorptivity of concrete hence, increasing the ingress of water which could affect the durability of the concrete negatively.

Percentage CDA replacement to OPC	W2-W1 (g)	A*d x 10^6	I x 10^6	Sorptivity x 10^{-8} mm/min$^{0.5}$
0	10.8	7.85	1.38	5.31
10	16.7	7.85	2.13	8.21
20	21.24	7.85	2.71	10.44
30	24.62	7.85	3.14	12.10

Table 2: Sorptivity at 90 days curing

3.6.4 Water Permeability

The water permeability was taken at 7, 14, 28, 56 and 90 days curing period and the results are shown in Table 20 and represented in figure 4. There was decrease in the permeability with increase in curing period but increases with increase in the quantity of CDA. This implies that water permeability is affected by quantity of CDA ie creating voids to allow for water movement.

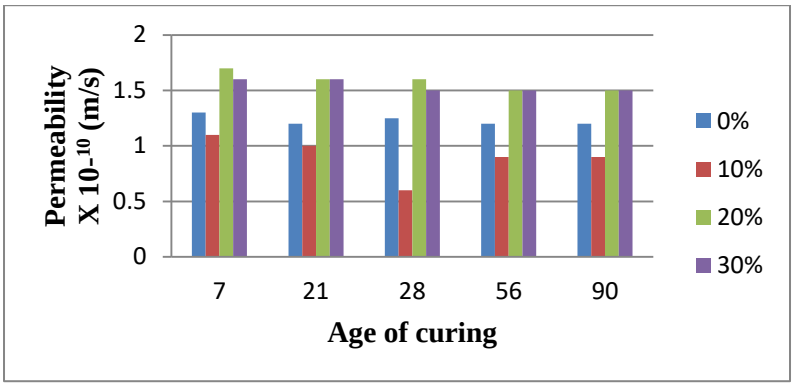

Figure 3: Permeability Test Results with curing age

5.0 CONCLUSION

From the findings of this research it can be concluded that:

CDA used meets all requirement stipulated in ASTM C618 (2001) and BS 12 (1971). The optimum replacement was 10% which confirms previous research for compressive strength and flexural strength. CDA concrete show low sorptivity and water permeability with optimum replacement still at 10% CDA. It can therefore be concluded that CDA is a very good pozzolana which can attain up but increase the ingress of moisture into concrete when used but at 10% partial replacement the effect will not be of great concern.

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