Effect of different brands of Nigerian cement on the properties of pervious concrete

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A J Gana[1], O D Atoyebi[1*] and R B Ichagba[1]

[1]Department of Civil Engineering, Landmark University, Omu-Aran, Kwara State, Nigeria

Corresponding Author; atoyebi.olumoyewa@lmu.edu.ng

Abstract. Pervious concrete can be immensely used in the construction of farm structures for irrigation purposes in agriculture. This study evaluated the effects of different brands of Nigerian cement on the properties of pervious concrete. Four different brands of Portland cement; Dangote Falcon(grade 32.5), Elephant Supaset (grade 42.5), Elephant Lafarge (grade 32.5) and Dangote 3*(grade 42.5) were used to produce pervious concrete of mix ratio 1:4 and tests such as compressive strength, permeability and density were tested, the void content was also analyzed. The densities of pervious concrete produced were between 2000 kg/m^3 – 1948 kg/m^3 , with Elephant Supaset being the densest. All brands produced PC of compressive strength higher than 6 N/mm^2 which is the minimum strength requirement in BS 5224 Dangote Falcon cement had the highest compressive strength followed by Elephant Supaset, Elephant Lafarge and Dangote 3* in that order after a 21 day curing period with values 16.39 N/mm^2, 13.97 N/mm^2, 13.54 N/mm^2 and 13.11 N/mm^2 respectively. Elephant cement PC was most permeable with a 10.1 mm/sec value, followed by Dangote 3* with 9.98 mm/sec then Dangote and Elephant S had 9.89 and 8.46 mm/sec respectively. Density is inversely proportional to porosity and permeability. Elephant Lafarge cement had the highest void content with 20.43% followed by 20.13%, 19.52%, 18.31% respectively for Dangote 3*, Dangote Falcon, Elephant Supaset.

1. Introduction

The numerous properties of concrete like strength, durability, fire resistance, low maintenance, ease in usage etc. has made it the most widely used construction material on earth. It's progressively increasing compressive strength (curing) and affordability gives it an edge over other materials [1–3]. Concrete is used in buildings for constructing load bearings elements such as beams, columns, staircase etc. A variety of cement types can be used in the production of concrete but the most common is Portland cement; other types include Portland Pozzolana Cement (PPC) [4], rapid hardening cement [5], Sulphate resistant cement etc. [6]. The required type of concrete to be produced determines the type of cement to be used [7]. One of the types of cement which only harden by reaction with water is the Portland cement, it forms a water-resistant product from clinker pulverization which involves calcium silicates and calcium sulphate. Portland cement is one of the low-cost materials used in the construction world in the last century due to the widespread availability of its raw materials which is shale and majorly limestone

[8]. Portland cement originates with color and quality similarities from Portland stone, a limestone gotten from quarry activities on the isle of Portland in Dorset, England [9].

Pervious concrete is a type of concrete which consist of coarse aggregate, Portland cement, and water [10]. Absence of fine aggregate defines its difference from the conventional concrete, its single-sized aggregate are bonded together with cement-water paste [11,12], which result into a concrete with highly interconnected voids which allows rapid percolation of water through it in its function state. Pervious concrete has void ratios ranging from 15 to 40% depending on its application. It is also different to the conventional concrete with lower unit weight, higher permeability and lower compressive strength. This study aims to evaluate the effects of different Nigerian cement brands on the properties of pervious concrete.

2. Methodology

The materials used in this study are water, different brands of Portland cement (Dangote Falcon (grade 32.5), Elephant Supaset (grade 42.5), Elephant Lafarge (grade 32.5) and Dangote 3*(grade 42.5), coarse aggregate (20mm). Concrete cubes were cast using the different brands of cement and cured for 28 days. Laboratory tests such as specific gravity, density, permeability, water absorption and compressive strength test were carried out 7, 14, 21 and 28 days. The compressive strength (fc) is given and presented as equation 1 [13]:

$$F_{ck} = {Fc}/{A_c} \quad (1)$$

Where,
f_{ck}=Compressive Strength in (N/mm^2).
F= Maximum load at failure, in Newton (N).
A_c= Cross-sectional area of the specimen on which the compressive force acts.

The weight of the concrete cubes was measured after 28 days of curing. The density is then obtained by using equation 2:

$$D = {M}/{V} \quad (2)$$

Where M= weight in kg, V = volume in m^3

The void content was determined according to [14], the void content is defined as the total percentage of voids present by volume in a specimen as shown in equation 3.

$$\text{Void content (\%)} = \frac{T-D}{T} \times 100 \quad (3)$$

Where T = Theoretical Density, D = Density

Falling head permeability test was performed to ascertain the hydraulic conductivity of the pervious concrete samples. The specimen was pre-conditioned by allowing water to drain out through the pipe until it was saturated. A total of 12 samples were used for water absorption test. After drying the samples they were immersed in water for intervals of 2 and 24 hours at which they were weighed again.

3. Result and discussions

3.1. Specific Gravity

The specific gravity of the specimen were examined for each of the different brands of cement and the results were presented in table 1 and figure 1. It shows that the specific gravity of Elephant S cement although below the standard 3.15 requirement for cement, had the highest value for specific gravity at 2.46; followed by Dangote 3*, Elephant and Dangote with a specific gravity of 2.4, 2.4, 2.33 respectively.

Table 1. Average specific gravity of Cement Brands.

Brand of cement	SG 1	SG 2	SG 3	Average SG
Dangote 3*	2.33	2.41	2.45	2.4 ± 0.06
Elephant S	2.59	2.61	2.18	2.46 ± 0.24
Elephant	2.37	2.55	2.28	2.4 ± 0.14
Dangote	2.2	2.52	2.28	2.33 ± 0.17

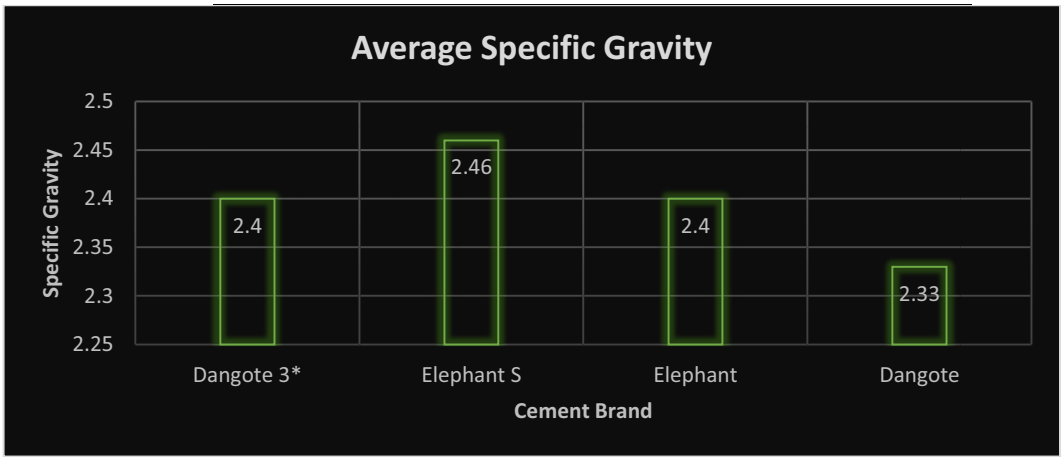

Figure 1. Specific Gravity of different brands of Cement.

3.2 Compressive Strength

Compressive strength test was carried out on a total of 54 concrete cubes. Three cubes from the batch were tested after 7, 14, 21 and 28 days of curing.

Table 2. Compressive Strength at 7 Days.

Cement Brand	Average Compressive Force (kN)	Average Compressive Strength (N/mm^2)
Dangote	219	9.73
Elephant S	196.33	8.73
Elephant	229.67	10.21
Dangote 3*	187.33	8.33

Elephant was observed to lead the other brands in terms of compressive strength with 10 N/mm^2 then Dangote, Elephant S and Dangote 3* respectively.

Table 3. Compressive Strength at 14 Days.

Cement Brand	Average Compressive Force (kN)	Average Compressive Strength (N/mm^2)
Dangote 3*	236.33	10.5
Elephant S	249.67	11.1

Elephant	241.67	10.74
Dangote	256.67	11.41

Dangote cement had the highest compressive strength on day 14 of curing, with a compressive strength of 11.41N/mm^2 followed by Elephant S, Elephant and Dangote 3* having 11.10N/mm^2, 10.74 $N/mm^2$and 10.50 N/mm^2 $r$espectively.

Table 4. Compressive Strength at 21 Days.

Cement Brand	Average Compressive Force (kN)	Average Compressive Strength (N/mm^2)
Dangote 3*	275.33	12.24
Elephant S	292.33	12.99
Elephant	283.00	12.58
Dangote	319.67	14.21

Dangote cement had the highest compressive strength on day 21 of curing, with a compressive strength of 14.21 N/mm^2 followed by Elephant S, Elephant and Dangote 3* having 12.99N/mm^2, 12.58 N/mm^2 and 12.24 N/mm^2 respectively.

Table 5. Compressive Strength at 28 Days.

Cement Brand	Average Compressive Force (kN)	Average Compressive Strength (N/mm^2)
Dangote 3*	295.00	13.11
Elephant S	314.33	13.97
Elephant	304.67	13.54
Dangote	368.67	16.39

After 28 days of curing, the final compressive strength test was carried out with Dangote cement still leading with the highest compressive strength of 16.39 N/mm^2 followed by Elephant S, Elephant and Dangote 3* having 13.97 N/mm^2, 13.54 N/mm^2 and 13.11 N/mm^2 respectively. At this point, it can be inferred that Dangote cement produced the samples with the highest strength after the 28 days curing period. Generally, the samples increased in strength as the curing days increases as shown in Figure 2.

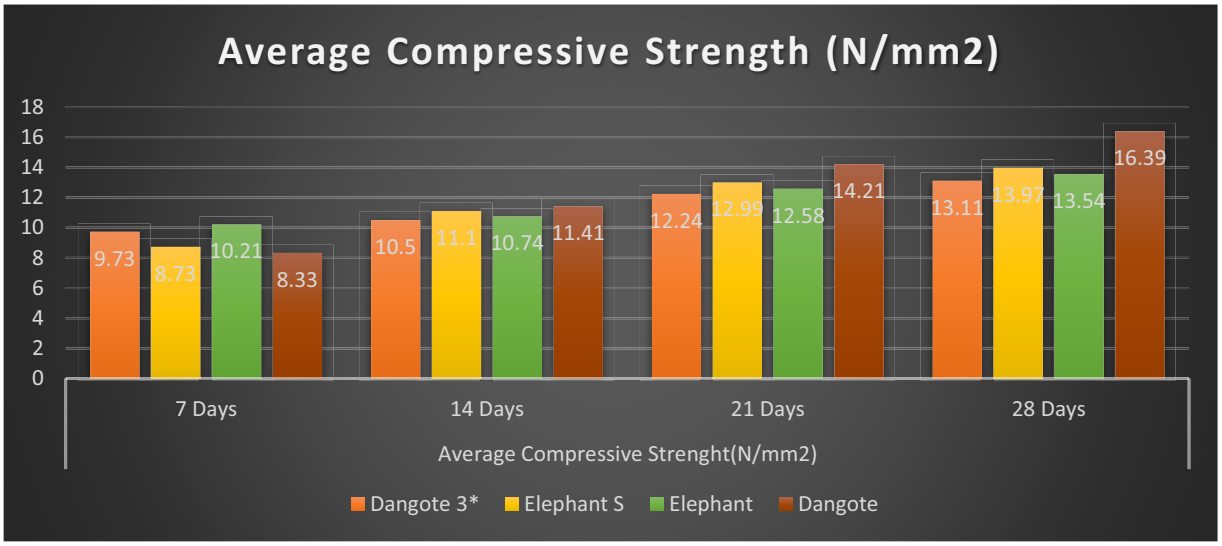

Figure 2. Average Compressive Strength for different brands of Cement.

3.3 Density

Table 6 reveals that the density of the pervious concrete ranged from 1948.14 kg/m^3 to 2000 kg/m^3, with Elephant cement giving the pervious concrete with the highest density. All densities fall within the lower range of lightweight concrete on the order of 800 to 2000 kg/m^3 [15].

Table 6. Average Density of Pervious Concrete.

Cement Brand	Average Density (kg/m^3)
Dangote 3*	1955.56
Elephant S	2000
Elephant	1948.14
Dangote	1970.37

3.4 Void Content

The percentage of voids present in each sample from the different brands of cement illustrated in table 7 shows that Elephant pervious sample had the highest void content of 20.43% followed by Dangote 3*, Dangote Falcon, Elephant Supaset with 20.13%, 19.52% and 18.31% respectively.

It is 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 void content varying between 15 and 30% [1]. Therefore the void content of pervious concrete samples produced by all brands is adequate, as a minimum of 15% is needed to provide sufficient permeability.

Table 7. Relationship between Density and Void Content.

Cement Brand	Average Mass (Kg)	Average Density (Kg/m^3)	Void Content (%)
Dangote 3*	6.6	1955.56	20.13
Elephant S	6.75	2000	18.31
Elephant	6.575	1948.14	20.43
Dangote	6.65	1970.37	19.52

3.5 Permeability

Table 8. Permeability of Pervious Concrete by various Cement Brands.

Cement Brand	Permeability (mm/sec)
Dangote 3*	9.98
Elephant S	8.46
Elephant	10.1
Dangote	9.89

Elephant cement produced the most permeable samples with a 10.1 mm/sec value as presented in table 8, followed closely behind by Dangote 3* with 9.98 mm/sec then Dangote and Elephant S had 9.89 and 8.46 mm/sec respectively.

3.6 Water Absorption

From Table 9, the Dangote 3* cement samples gave the highest water absorption of 5.43 and 7.75 % for 2 and 24 hours respectively. It was followed by Elephant brand and Dangote in that order, with Elephant S producing samples with water absorption as low as 0.38 and 1.14 % after the respective 2 and 24 hours' time intervals.

Table 9. Water Absorption Values after 2 and 24 Hours.

Cement brand	Average Initial Weight (kg)	Average Weight after 2 hours (kg)	Average Weight after 24 hours (kg)	Water Absorption after 2 hours (%)	Water Absorption after 24 hours (%)
Dangote 3*	6.45	6.8	6.95	5.43	7.75
Elephant S	6.575	6.6	6.65	0.38	1.14
Elephant	6.3	6.5	6.6	3.17	4.76
Dangote	6.45	6.55	6.575	1.55	1.93

4. Conclusion

Based on the results of the experimental study, It is discovered that Dangote Falcon cement had the highest compressive strength followed by Elephant Supaset, Elephant Lafarge and Dangote 3* in that order after 28 days curing period with values 16.39 N/mm^2, 13.97 N/mm^2, 13.54 N/mm^2 and 13.11 N/mm^2 respectively. All specimens met the minimum strength of 6N/mm^2 after 28 days of curing recommended by BS-5224 [16]. Elephant Lafarge cement was the most permeable with 10.1mm/sec followed by 9.98 mm/sec, 9.89 mm/sec, 8.46 mm/sec respectively for Dangote 3*, Dangote Falcon, Elephant Supaset. By visual inspection, all brands of cement produced pervious concrete with very similar aesthetics, the finest being Elephant Supaset then Elephant Lafarge, Dangote Falcon and Dangote 3* in that order. Elephant Lafarge cement had the highest void content with 20.43% followed by 20.13%, 19.52%, 18.31% respectively for Dangote 3*, Dangote Falcon, Elephant Supaset. The densities of pervious concrete produced were between 2000 Kg/m^3-1948 Kg/m^3. Elephant Supaset cement had the highest density with 2000Kg/m3 followed 1970.37 Kg/m^3, 1955.56 Kg/m^3, 1948.14

Kg/m^3 respectively for Dangote Falcon, Dangote 3* and Elephant Lafarge. Permeability is proportional to porosity and density is inversely proportional to void content.

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