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Effect of Curing Age on Concrete Grade 20 Produced with Groundnut Shell Ash (GSA) Blended Calcium Chloride ($CaCl_2$)

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Abstract – This research investigates the effect of Groundnut Shell Ash (GSA) and Calcium Chloride ($CaCl_2$) as partial replacement of cement in concrete. The objective is to determine the highest strength of concrete grade 20 based on Curing Age as a result of partial replacement of cement. Groundnut Shell Ash (GSA) is obtained by the combustion of groundnut shell. The replacement levels of Ordinary Portland Cement (OPC) with Groundnut Shell Ash (GSA) were 0%, 5%, 10%, 15% and 20%. 1% of Calcium Chloride was blended with OPC/GSA in all the test specimens except from the control mix. Concrete cubes of sizes 150mm x 150mm x 150mm were cast and cured in water for 7,14, 28 and 56 days respectively. Slump test were conducted on fresh concrete while density test and compressive strength test were conducted on hardened concrete. The slump results revealed that the concrete becomes less workable (stiff) as the OPC/GSA and OPC/GSA/$CaCl_2$ percentage increases. The compressive strengths result at 28 days shows that 0% have the highest strength of 24.29N/mm^2 followed by 5%GSA/1%$CaCl_2$ (24.07N/mm^2), 10%GSA/1%$CaCl_2$ (23.26N/mm^2), 15%GSA/1%$CaCl_2$ (21.18N/mm^2) and 20%GSA/1%$CaCl_2$ (19.56N/mm^2). However, the compressive strengths result at 56 days shows that 0% have the highest strength of 26.52 N/mm^2 followed by 5%GSA/1%$CaCl_2$ (26.82N/mm^2), 10%GSA/1%$CaCl_2$ (24.74N/mm^2), 15%GSA/1%$CaCl_2$ (23.11N/mm^2) and 20%GSA/1%$CaCl_2$ (21.63N/mm^2). The compressive strengths increase as the number of curing age increases for each percentage of OPC/GSA/$CaCl_2$ replacement. Integration of 5%GSA+1%$CaCl_2$, 10%GSA/1%$CaCl_2$ and 15%GSA/1%$CaCl_2$ can be used for concrete grade 20 while 20%GSA/1%$CaCl_2$ replacement can be used for concrete below grade 20. This indicates that concrete produce with GSA should be extended beyond 28 days curing age..

Keywords: Calcium Chloride, Cement, Compressive Strength, Concrete, Curing Age, Groundnut Shell Ash.

1. Introduction

Concrete is the most versatile construction material because it is designed to withstand the harsh environments, with adequate strength and durability (Swathi & Gnanadevi, 2015). It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions (Ashish, 2010). Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry (Amudhavalli et al., 2012). The need to reduce the high cost of Ordinary Portland Cement in order to provide accommodation for the populace has intensified research into the use of some locally available materials that could be used as partial replacement for Ordinary Portland Cement (OPC) in Civil Engineering and Building Works.

Supplementary cementitious materials have been proven to be effective in meeting most of the requirements of durable concrete and blended cements are now used in many parts of the world (Obilade, 2014). Supplementary cementing materials (SCMs) are materials that when used with portland cement contribute to the properties of the hardened concrete through hydraulic or pozzolanic activity or both (Nabil et al., 2005). Some of the commonly used supplementary cementing materials are fly ash, Silica Fume (SF), Ground Granulated Blast Furnace Slag (GGBFS) and Rice Husk Ash (RHA) etc (Alireza et al., 2010). Other pozzolanic materials that can be used as supplementary cementing materials are groundnut shell ash (GSA), locust bean waste ash (LBWA), bagasse ash (BA) etc. Groundnut shell ash (GSA) is the supplementary cementitious material that was used in this research in addition with calcium chloride.

Groundnut shell is a waste from groundnut pod which is usually burnt, dumped or left to decay naturally. It constitutes about 25% of the total pod (husk and seeds) mass. Due to the growing environmental concern and the need to conserve energy and resources, efforts have been made to properly burn the shell to ash and to examine the ash with a view to utilizing it for useful purposes (Egbe – Ngun et al., 2014). Groundnut Shell Ash (GSA) is obtained by the combustion of groundnut shell. Various research works have been carried out on the use of GSA in cement or concrete as supplementary cementing materials. Ndefo (2013) investigated properties of cement - groundnut shell ash concrete. He concluded that cement ash concrete at 10% partial replacement level at 0.35% water cement ratio can be used for structures that are non-load bearing.

Buari et al. (2013) characterized strength of groundnut shell ash (GSA) and ordinary Portland cement (OPC) blended concrete in Nigeria. They concluded that the compressive strength value of the GSA/OPC blended concrete at 10% replacement level performed better and would be acceptable and considered as a good development for construction of masonry walls and mass foundations in low - cost housing in Nigeria. Raheem et al. (2013) studied the strength properties of groundnut shell ash (GSA) blended concrete. They recommended that superplasticicer (water-reducing admixture) should be introduced so that early strength could be generated and lower water/cement ratio is maintained. It was observed that super plasticizer (Water-Reducing Admixture, High-Range) have been recommended and used with supplementary cementitious materials (pozzolans) by several researchers to reduce water-cement ratio and also increase strength of concrete but in this present study, calcium chloride (Accelerating Admixture) was used in addition with groundnut shell ash (GSA) to improve strength of concrete.

2. Materials and Method

2.1. Materials

Ordinary Portland Cement (OPC) – Dangote cement brands 42.5R was used and the specific gravity (tested) was 3.13. Portable water which is free from suspended particles was used. The aggregates used in this research were fine aggregate (natural sand) that pass through sieve 5.0mm and coarse aggregate (crushed stone) of maximum size 19.0mm both of which conform to 882:1992. Calcium Chloride Anhydrous ($CaCl_2$, 95% Assay), which conformed to ASTM C494 (1999) were used as accelerating admixture.

Groundnut Shell Ash (GSA) - The groundnut shells (locally available materials) were collected from a milling store at Tsaragi, Edu Local Government of Kwara State. The groundnut shells were burnt to ashes at a temperature of by Thermolyne Furnace at Foundry and Forging Workshop, Mechanical Engineering Department Federal Polytechnic Offa. The ashes were further grounded to a require level of finer particles with milling machine and allow to pass through sieve No.200 (75 µm). The Groundnut Shell, Groundnut Shell Ash and Grinded Groundnut Shell Ash are shown in Figure 1 a, b and c respectively.

Fig. 1. (a) Groundnut Shell, (b) Groundnut Shell Ash and (c) Grinded Groundnut Shell Ash

2.2. Method

The experimental program was designed to investigate influence of Groundnut Shell Ash (GSA) and Calcium Chloride ($CaCl_2$) on strength of concrete. The replacement levels of OPC with GSA were 0%, 5%, 10%, 15% and 20%. 1% of Calcium Chloride was blended with OPC/ GSA in all the test specimens except from the control mix. Concrete cubes of sizes 150mm x 150mm x 150mm were cast and cured in water for 7,14, 28 and 56 days respectively. A total of 60 cubes were produced (12 cubes for the control and 48 cubes for concrete with groundnut shell ash/calcium chloride). A mix ratio of 1:2:4 was adopted for the concrete production and batching was done by weight. At the end of each different curing age, the cubes were crushed using a 2000KN capacity compression testing machine to determine their compressive strengths.

3. Results and Discussion

3.1. Chemical (Oxides) Composition of OPC and GSA

The results of oxides composition of OPC and GSA tested are shown in Table 1.

Table 1. Oxides Composition of OPC and GSA

OXIDES (%)	**OPC**	**GSA**
SiO_2	19.63	19.69
Al_2O_3	5.84	0.95
Fe_2O_3	3.98	0.68
CaO	57.75	1.23
MgO	1.44	0.59
K_2O	0.16	1.67
Na_2O	0.27	1.77
SO_3	0.13	0.08
Loss on Ignition (LOI)	1.64	14.36

From Table 1, the values of SiO_2, Al_2O_3, Fe_2O_3, and MgO (of OPC) fell within the limit specified by SP:23 (1982) and Neville, A.M. (2011) but the value of CaO is below the required limit. However, the values of SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO corresponds with the one reported by Faleye *et al.*, (2009). ASTM C-618 (2005) specifies that the sum of SiO_2, Al_2O_3, and Fe_2O_3 of a pozzolanic material should not be less than 70%. The sum of SiO_2, Al_2O_3, and Fe_2O_3 of the groundnut shell ash (GSA) tested as shown in Table 2 is 21.32% which is low to that of Alabadan *et al.*, (2006), Buhari *et al.*, (2013) and 70% specified by ASTM C-618 (2005). However, the result of the groundnut shell ash (GSA) tested shows that silicon dioxide (SiO_2) have the highest percentage of oxide composition.

3.2. Specific Gravity of Aggregate

The result obtained from specific gravity of fine and coarse aggregate are shown below in Table 2.

Table 2. Specific gravity of Fine and Coarse Aggregate

S/No.	**Test Samples**	**Specific Gravity**
1.	Fine Aggregate	2.65
2.	Coarse Aggregate	2.63

The range of specific gravity of aggregates as specified by ACI Education Bulletin E1 (2007) ranges from 2.30 to 2.90. The results of specific gravity of fine and coarse aggregate shown in Table 2 are within the acceptable limits for fine and coarse aggregates.

3.3. Fineness Modulus of Aggregate

The fineness modulus was conducted in accordance with ACI Education Bulletin E1 (2007). From the sieve analysis, the following fineness modulus as shown in Table 3 was obtained.

Table 3. Fineness modulus of Fine and Coarse Aggregate

S/No.	**Test Samples**	**Fineness modulus**
1.	Fine Aggregate	2.9
2.	Coarse Aggregate	6.3

ACI Education Bulletin E1 (2007) reports that fineness modulus is most commonly computed for fine aggregates, while the fineness modulus of coarse aggregate is needed for some proportioning methods. However, for fine aggregate used in concrete, the fineness modulus (FM) generally ranges from 2.3 to 3.1. The result of fineness modulus in Table 3 falls within the acceptable limits for fine aggregates.

3.4. Tests on Fresh Concrete

Slump Test - The slump test was conducted on all replacement level of GSA by weight of cement (both OPC/GSA and OPC/GSA/$CaCl_2$) and the results are shown in Table 4. The test conformed to ASTM C192/C192M (2006).

Table 4. Results of Slump Test of concrete with Different Percentages of GSA

S/N	Replacement (%)	Slump Height (mm)	Replacement (%)	Slump Height (mm)
1	0%	40	0%	40
2	5% GSA	30	5 GSA%, 1% $CaCl_2$	20
3	10% GSA	25	10 GSA%, 1% $CaCl_2$	15
4	15% GSA	20	15 GSA%, 1% $CaCl_2$	15
5	20% GSA	15	20 GSA%, 1% $CaCl_2$	10

True slump was exhibited by the concrete in the fresh concrete mix. Table 4 shows that the slump height values reduce as the OPC/GSA and OPC/GSA/$CaCl_2$ content increases. These results indicate that the concrete becomes less workable (stiff) as the OPC/GSA and OPC/GSA/$CaCl_2$ percentage increases. The slump values of OPC/GSA/$CaCl_2$ at all replacement level are less than that of OPC/GSA. However, the result shows that more water is required to make the mixes more workable as the percentage increases. The results are represented in Figure 2.

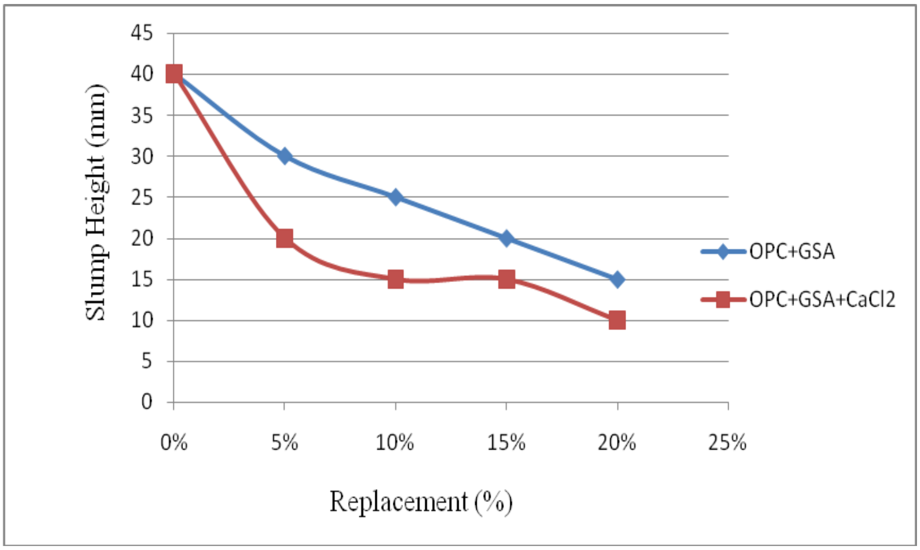

Fig. 2. Slump Height against GSA-Replacement

3.5. Tests on Hardened Concrete

Hardened concrete assumes important properties that are retained for the life of the concrete and these properties include density, strength and deformation under load and durability among others.

Density Test - The densities of concrete cubes made with different replacement level of OPC/GSA/$CaCl_2$ for age 7, 14, 28 and 56 days hydration period are given in Table 5. The test was done in accordance with BS EN 12390-7:2009 and CS1:2010.

Table 5. Summary of Densities of Concrete Cubes

Age (Days)	Mean Densities of Concrete Cube (Kg/m^3)				
	0%	5 GSA%, 1% $CaCl_2$	10GSA%, 1% $CaCl_2$	15GSA%, 1% $CaCl_2$	20 GSA%, 1% $CaCl_2$
7	2480	2483	2468	2409	2350
14	2480	2459	2450	2421	2361
28	2495	2450	2468	2361	2361
56	2489	2489	2489	2450	2439

All concrete cubes produced fell within the range of 2300Kg/m^3-2500Kg/m^3. The densities of all the samples tested fell within the normal range of concrete specified by Jones (1999).

Compressive Strength Test - The compressive strength tests on the concrete cubes were carried out with compression testing machine. This was done in accordance with BS EN 12390-3:2009 and CS1:2010. The results of all concrete cubes strength are shown in Table 6.

Table 6: Compressive Strength of Concrete Cubes

Age (Days)	Mean Compressive Strength (N/mm^2)				
	0%	5 GSA%, 1% $CaCl_2$	10GSA%, 1% $CaCl_2$	15GSA%, 1% $CaCl_2$	20 GSA%, 1% $CaCl_2$
7	13.93	13.63	12.59	11.41	10.52
14	19.71	17.33	16.59	14.37	12.82
28	24.29	24.07	23.26	21.18	19.56
56	26.52	26.82	24.74	23.11	21.63

The results of the compressive strength of concrete cubes show that the compressive strengths reduced as the percentage OPC/GSA/$CaCl_2$ increases. However, the compressive strengths increase as the number of days of curing increases for each percentage of OPC/GSA/$CaCl_2$ replacement. Table 7 shows that for the control cube (conventional concrete i.e., 0% replacement), the compressive strength increased from 13.93N/mm^2 at 7 days to 26.52 N/mm^2 at 56 days (strength gained of 53% at 7days). The 28 day strength

(24.29N/mm^2) was above the specified value of 20N/mm^2 for grade 20 concrete (BS 8110-2:1985) as shown in Table 7.

The strength of 5% replacement by Groundnut Shell Ash/1% Calcium Chloride showed increase in compressive strength from 13.63N/mm^2 at 7 days to 26.82N/mm^2 at 56 days (strength gained of 51% at 7days). The 28 day strength (24.07N/mm^2) was above the specified value of 20N/mm^2 for grade 20 concrete (BS 8110-2:1985) as shown in Table 7. The strength of 10% replacement by Groundnut Shell Ash/1% Calcium Chloride showed increase in compressive strength from 12.59N/mm^2 at 7 days to 24.74N/mm^2 at 56 days (strength gained of 51% at 7days). The 28 day strength (23.26N/mm^2) was above the specified value of 20N/mm^2 for grade 20 concrete (BS 8110-2:1985) as shown in Table 7.

The strength of 15% replacement by Groundnut Shell Ash/1% Calcium Chloride showed increase in compressive strength from 11.41N/mm^2 at 7 days to 23.11N/mm^2 at 56 days (strength gained of 49% at 7days). The 28 day strength (21.18N/mm^2) was above the specified value of 20N/mm^2 for grade 20 concrete (BS 8110-2:1985) as shown in Table 7. The strength of the 20% replacement by groundnut shell ash/1%calcium chloride showed increase in compressive strength from 10.52N/mm^2 at 7 days to 21.63N/mm^2 at 56 days (strength gained of 49% at 7days). The 28 day strength (19.56N/mm^2) was below the specified value of 20N/mm^2 for concrete 20 (BS 8110-2:1985) as shown in Table 7.

At 7 days, the compressive strength results of 0% and 5%GSA/1%$CaCl_2$ met the minimum required compressive strength of 13.5 N/mm^2 for grade 20 concrete specified by BS8110 Part 2 (1985). The compressive strengths result at 28 days shows that 0% have the highest strength of 24.29N/mm^2 followed by 5%GSA/1%$CaCl_2$ (24.07N/mm^2), 10%GSA/1%$CaCl_2$ (23.26N/mm^2), 15%GSA/1%$CaCl_2$ (21.18N/mm^2) and 20%GSA/1%$CaCl_2$ (19.56N/mm^2). However, the compressive strengths result at 56 days shows that 0% have the highest strength of 26.52N/mm^2 followed by 5%GSA/1%$CaCl_2$ (26.82 N/mm^2), 10%GSA/1%$CaCl_2$ (24.74N/mm^2), 15%GSA/1%$CaCl_2$ (23.11N/mm^2) and 20%GSA/1%$CaCl_2$ (21.63N/mm^2). The results are presented in Figure 3.

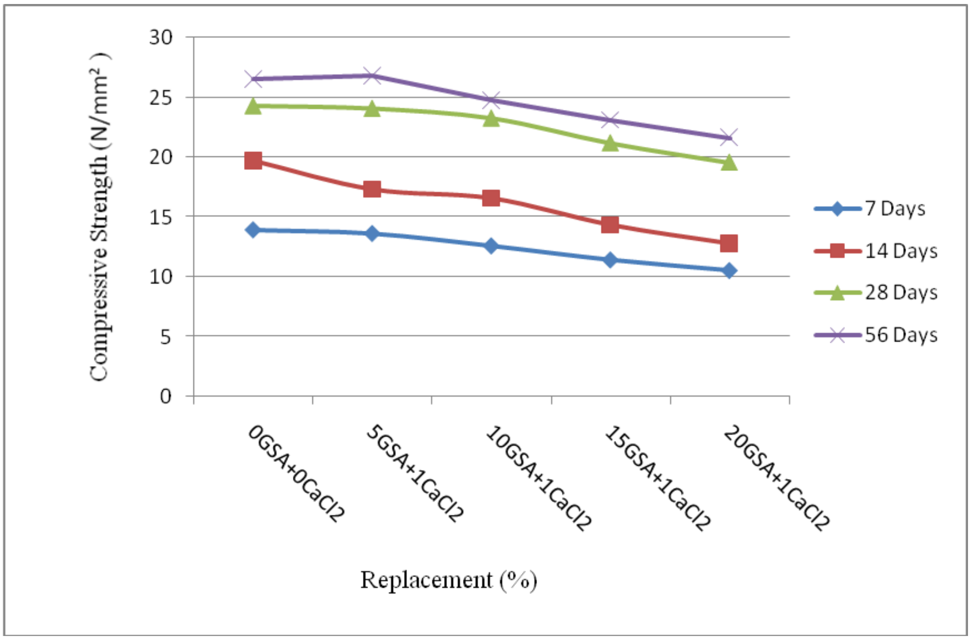

Fig. 3. Relationship between Compressive Strength and GSA/$CaCl_2$ - Replacement

Table 7. Required/Recommended Strength of Concrete (BS8110 Part 2, 1985)

Grade	Characteristic Strength, f_{cu} (N/mm^2)	Cube Strength at an age of:				
		7 days	2 months	3 months	6 months	1 year
20	20.0	13.5	22	23	24	25
25	25.0	16.5	27.5	29	30	31
30	30.0	20	33	35	36	37
40	40.0	28	44	45.5	47.5	50
50	50.0	36	54	55.5	57.5	60

4. Conclusion and Recommendations

4.1. Conclusion

The slump values indicate that the concrete becomes less workable (stiff) as the OPC/GSA and OPC/GSA/$CaCl_2$ percentage increases. However, the slump values of OPC/GSA/$CaCl_2$ at all replacement level are less than that of OPC/GSA. Likewise, the compressive strengths of concrete reduced as the percentage of OPC/GSA/$CaCl_2$ replacement increased at all curing ages while the compressive strengths increases as the number of days of curing increased for each percentage of OPC/GSA/$CaCl_2$ replacement. This indicates that concrete produce with GSA should be extended beyond 28 days curing age.

4.2. Recommendations

i. Water/cement ratio should be increase as the percentage replacement of GSA increases in order to improve the workability of fresh concrete.

ii. The integration of 5%GSA+1%$CaCl_2$, 10%GSA/1%$CaCl_2$ and 15%GSA/1%$CaCl_2$ can be used for concrete grade 20 while 20%GSA/1%$CaCl_2$ replacement can be used for concrete lesser than grade 20.

iii. Integration of 5%GSA+1%$CaCl_2$ replacement would produce a concrete of higher strength compared to conventional concrete for grade 20.

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