Effect of sorghum husk ash and calcium chloride on compressive strength of grade 20 concrete

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Abstract. This study examined the influence of sorghum husk ash (SHA) and calcium chloride (CaCl$_2$) as fractional substitution of cement in grade 20 concrete. Sorghum husk Ash (SHA) was gotten by burning of sorghum husk at a regulated temperature. The substitution of cement by SHA were 0, 5, 10, 15, 20 and 25%. A fixed amount of 1% CaCl$_2$ was mixed with Cement/SHA in all the test samples apart from control mixture. Sample sizes of 150 x 150 x 150 mm concrete cubes were cast and healed in water respectively for 7 as well as 28 days. The tests carried out on prepared fresh and hardened concrete were slump and compressive strength. The result of slump showed that the concrete turn out to be stiffer with increase in proportion of SHA. The 28 day compressive strengths result shows that 5%SHA/1%CaCl$_2$ have the maximum strength of 26.45 N/mm$^2$ followed by 10% (25.01 N/mm$^2$), 0%SHA/1%CaCl$_2$ (23.11 N/mm$^2$), 15%SHA/1%CaCl$_2$ (22.45 N/mm$^2$), 20%SHA/1%CaCl$_2$ (20.90 N/mm$^2$) and 25%SHA/1%CaCl$_2$ (18.13 N/mm$^2$). This implies that the best addition of SHA/CaCl$_2$ as fractional substitution for cement in concrete is in the range 0 - 20% since their compressive strength results were above 20 N/mm$^2$ specified for grade 20 concrete. Incorporation of 5%SHA/1%CaCl$_2$ and 10%SHA/1%CaCl$_2$ substitution would yield a concrete of greater compressive strength than standard grade 20 concrete.

1. Introduction
Increasing buildings cost in developing countries like Nigeria have been ascribed to several factors [1], among which are incapability of manufacture companies to meet the enormous building materials demand, high cost of transportation and national currency depreciation. Others include overwhelming building materials prices and over-dependency on building materials importation that is frequently proportional to inflation. The most dominant construction material is concrete. It be made up of cement, coarse aggregate, fine aggregate, water and at times admixture in a certain prescribed proportion [2], [3]. Research inclinations in materials engineering have recently concentrated on giving choices to subdue the significant expense of conventional concrete materials. The most recently trending research exercises on proffering the alternatives are centered on the utilization of pozzolanas from agricultural wastes as admixtures or additives in concrete [4].

Some of the agricultural waste products that has been confirmed as pozzolanic materials include palm oil fuel ash, rice husk ash, palm kernel shell ash, sawdust ash, sorghum husk ash as well as guinea corn husk ash. These materials are readily available in Nigeria to partially replace cement...
without economic implications [5]. They are supplementary cementitious materials (SCMs) which improves the properties of hardened concrete when used with Portland cement through hydraulic or pozzolanic operation or both [5, 6, 7, 8, 9, 10, 11, 12, 13, 14].

USDA [15] stated that Nigeria is the world's second-largest manufacturer of sorghum, with almost 6.6 million tons of sorghum manufactured annually in the country. Approximately 11 per cent SHA content is obtained from proper sorghum husk burning [6]. Studies have shown that a mixture of SHA’s chemical constituents suits it as a strong pozzolana [14, 16]. Most authors who worked on suitability of supplementary cementitious materials recommended high range water reducing admixture (e.g superplasticizer) to reduce water/cement ratio and improve concrete strength. However, this study adopted an accelerating admixture (calcium chloride) as addition with SHA to improve the concrete strength.

2. Materials and methods
2.1. Materials
Portland lime cement of grade 42.5R with specific gravity 3.14 was adopted for this study. Natural sand that passes 4.75 mm sieve having 2.57 specific gravity and 0.57 water absorption capacity was utilized as fine aggregate. The crumpled stone (granite) utilized as concrete coarse aggregate has 19 mm maximum size, 2.72 specific gravity and 0.3% water absorption respectively. Individually, the fine and coarse aggregates utilized conformed to [17] while the calcium chloride conformed to [18]. The sorghum husk utilized was collected from Amoloko, Minna, Niger State, Nigeria. It was calcinated into ashes (SHA) in regulated furnace for 3 hours at 700°C. The SHA was then powdered after allowing to cool utilizing ceramic mortar and pestle. The ash was sieved using 75 µm sieve to obtain ash that is fine enough to react perfectly with ordinary cement. Ash specific gravity was tested to be 2.2. The chemical constituents of SHA as presented by Tijani et al. [16] is given in Table 1. The combined fraction of silica, alumina and ferric oxide is 77.3 percent, which fulfills the pozzolana condition of ASTM [19].

| Chemical constituents of SHA | %  |
|------------------------------|----|
| SiO₂                         | 55.3|
| Al₂O₃                        | 10.1|
| Fe₂O₃                        | 11.9|
| SO₃                          | 0.5 |
| MgO                          | 1.2 |
| K₂O                          | 4.5 |
| Na₂O                         | 0.7 |
| CaO                          | 10.4|
| SiO₂ + Al₂O₃ + Fe₂O₃         | 77.3|

2.2. Methods
The weight method of batching was adopted using design mix for normal strength concrete of proportion 1:2:4 and 0.6 water/cement ratio. The weight of concrete was calculated based on the volume of mould that was used and the number of cubes for each test sample. The SHA was varied with cement in the order 0, 5, 10, 15, 20 and 25%. 1% CaCl₂ by weight of cement was blended with
cement/SHA mixes. A total of 36 concrete cubes of 150 x 150 x 150 mm were produced and preserved in water for 7 as well as 28 days. The slump test which conformed to [20] was carried out on fresh concrete while the hardened concrete were tested for density and compressive strength in accordance with [21] and [22] respectively. Figure 1 displays the compressive strength test setup.

3. Results and Discussion

3.1. Slump of SHA-CaCl₂ Concrete

Figure 2 displayed the outcomes of slump test. The figure shows that slump of concrete becomes lower as the SHA percentage risen. The reduction in slump when likened to the slump of control mix was substantial. The slump falls between 38.8 and 2.5 mm. The concrete was observed to become less workable as the proportion of SHA becomes higher. The implication of this is that a workable mixture will requires additional water. The amplified amount of silica in the mix might be the reason for additional water demand as SHA proportion becomes high. The silica-lime reaction necessitates more addition of water to the water needed in the course of hydration of cement [6, 16, 23].
3.2. Density of SHA-CaCl₂ Concrete

Figure 3 presents the results of 7 and 28 day density of SHA-CaCl₂ concrete mixtures at different substitution levels. It could be detected that hardened densities (both 7 and 28 day) slightly decreased as the amount of SHA addition increased from 0 to 25%. The respective values obtained at 7 as well as 28 days were 2577, 2502, 2485, 2450 and 2397 kg/m³ and 2554, 2492, 2479, 2450, 2419 and 2360 correspondingly for 0%SHA/0%CaCl₂, 5%SHA/1%CaCl₂, 10%SHA/1%CaCl₂, 15%SHA/1%CaCl₂, 20%SHA/1%CaCl₂ and 25%SHA/1%CaCl₂. This implied a decrease of 2.91, 3.57, 3.88, 4.93 and 6.98% at 7-day with reference to control and 2.43, 2.94, 4.07, 5.29 and 7.60% at 28-day with reference to control. The decrease in densities with increase in the amount of SHA might be credited to the lesser specific gravity of SHA (2.20) than that of cement (3.14). Furthermore, a slight decrease in densities could be observed at 28 day when compared with 7 day results. This decrease could be due to the fact the some water are still present in the concrete which have not been fully used for hydration at 7 day of curing.
3.3. Compressive Strength of SHA-CaCl₂ Concrete

The 7 as well as 28-day compressive strength outcomes of SHA-CaCl₂ concrete are represented in Figure 4. The result indicated that the compressive strengths rises as the SHA/CaCl₂ percentage upsurge from 0% to 5% and reduces as the percentage increases from 5% to 25%. Conversely, as the amount of curing days increased, the compressive strengths increased for each percentage of SHA/CaCl₂ replacement. The figure shows that for the control cube (plain concrete i.e., 0% replacement), the compressive strength amplified from 15.20 N/mm² at 7-day to 23.11 N/mm² at 28-day. The 28-day compressive strength was more than the stated value of 20 N/mm² for concrete grade 20 [24, 25]. The compressive strength of the 5% replacement by SHA/1% CaCl₂ revealed rise in compressive strength from 18.46 N/mm² at 7-day to 26.45 N/mm² at 28-day. The 28-day compressive strength was more than the stated value of 25 N/mm² for concrete grade 25 [24, 25].

The compressive strength of the 10% substitution by SHA/1% CaCl₂ revealed rise in compressive strength from 16.25 N/mm² at 7-day to 25.01 N/mm² at 28-day. The 28-day compressive strength was more than the stated value of 25 N/mm² for concrete of grade 25 [24, 25]. The compressive strength of the 15% substitution by SHA/1% CaCl₂ indicated rise in compressive strength from 15.56 N/mm² at 7-day to 22.45 N/mm² at 28-day. The 28-day compressive strength was more than the stated value of 20 N/mm² for concrete grade 20 [24, 25].

The strength of the 20% substitution by SHA/1% CaCl₂ revealed compressive strength rise from 13.31 N/mm² at 7-day to 20.90 N/mm² at 28-day. The 28-day compressive strength was more than the stated value of 20 N/mm² for concrete grade 20 [24, 25]. The strength of the 25% substitution by SHA/1% CaCl₂ revealed compressive strength rise from 11.95 N/mm² at 7-day to 18.13 N/mm² at 28-day. The 28-day compressive strength was less than the stated value of 20 N/mm² for concrete grade 20 [24, 25].

At 7-day, the results of compressive strength of 0%SHA/0%CaCl₂, 5%SHA/1%CaCl₂, 10%SHA/1%CaCl₂ and 15%SHA/1%CaCl₂ met the lowest indicated compressive strength of 13.5N/mm² for grade 20 concrete stated by [25]. Nonetheless, the compressive strengths result at 28-day shows that 5%SHA/1%CaCl₂ have the maximum strength of 26.45 N/mm² followed by 10% (25.01 N/mm²), 0%SHA/1%CaCl₂ (23.11 N/mm²), 15%SHA/1%CaCl₂ (22.45 N/mm²), 20%SHA/1% CaCl₂ (20.90 N/mm²) and 25%SHA/1%CaCl₂ (18.13 N/mm²). This implies that the optimal addition of SHA/CaCl₂ as fractional substitution for cement in concrete is in the range 0 - 20% since their compressive strength values were above 20 N/mm² specified for concrete grade 20.

![Figure 4. Compressive Strength of SHA-CaCl₂ Concrete](image-url)
4. Conclusion
The influence of SHA and CaCl₂ as fractional substitution of cement in concrete grade 20 was investigated in this study. Sorghum husk Ash was gotten by calcination of sorghum husk at a regulated temperature. The substitution of cement by SHA were 0, 5, 10, 15, 20 and 25%. A fixed amount of 1% CaCl₂ was mixed with Cement/SHA in all the test samples apart from control mixture. Sample sizes of 150 x 150 x 150 mm concrete cubes were cast and preserved in water respectively for 7 as well as 28 days. The tests conducted on prepared fresh and hardened concrete were slump and compressive strength. The slump values indicated that concrete becomes less workable as the SHA/CaCl₂ proportion rises. The compressive strengths of concrete declined as the proportion of SHA/CaCl₂ substitution upgraded at all curing ages. The compressive strengths result at 28 days shows that 5%SHA/1%CaCl₂ possess the maximum strength of 26.45 N/mm² followed by 10% (25.01 N/mm²), 0%SHA/1%CaCl₂ (23.11 N/mm²), 15%SHA/1%CaCl₂ (22.45 N/mm²), 20%SHA/1%CaCl₂ (20.90 N/mm²) and 25%SHA/1%CaCl₂ (18.13 N/mm²). This implies that the most favorable addition of SHA/CaCl₂ as partial substitution for cement in concrete is in the range 0 - 20% since their compressive strength values were above 20 N/mm² specified for concrete grade 20. Combination of 5%SHA/1%CaCl₂ and 10%SHA/1%CaCl₂ substitution would yield concrete of greater compressive strength than standard grade 20 concrete.

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