

Cost Analysis of partially replaced Ordinary Portland Cement (OPC) with Groundnut Shell Ash in a Concrete Mix

Afolayan J. O, Oriola F. O. P., Sani J. E.

Abstract— The cost analysis of partially replaced cement with groundnut shell ash (GSA) was conducted to ascertain the percentage reduction in price of cement in concrete. Researchers have revealed that agricultural wastes are viable replacement materials, especially for cement in concrete. GSA was used in this research and the percentage level of cement replacement adopted were 0%, 5%, 10%, 15%, 20%, 25% and 30%. Workability was measured in the fresh concrete by the Slump test and 100mm x 100mm x 100mm cube specimens were tested for compressive strength at 7, 14 21 and 28days using a concrete mix ratio of 1:2:4 and water cement ratio of 0.55. Results showed that workability reduced with increase in percentage of GSA replacement with an acceptable value of 15mm for 15% replacement, if mechanical vibrator is to be employed. Compressive strengths of 32.01 N/mm² and 31.78N/mm² were obtained at 5% and 10% of replacement of cement respectively. While the maximum strength of the specimen with 0% replacement was 34.22N/mm². Compressive strength values of 32.01 N/mm² and 31.78N/mm² for the 5% and 10% cement replacement also satisfied the provisions for minimum structural grade concrete of 25N/mm². This leads to economy of material and enhances the alternative usage of agricultural wastes. The use of 10% GSA replacement leads to a decrease in the cost of cement in concrete to a value of 10% of the total cost of cement required. The cost saving becomes significant when large volume of concrete is involved in construction.

Index Terms— Groundnut shell ash, Cement, Concrete

I. INTRODUCTION

The continuous increase in the price of Portland cement is attributed to the insufficient production rate of the raw materials when compared with the demand rate in the construction industries. Nowadays there is a scarcity of concrete materials, so we are in need to find out the alternative materials to concrete. In this situation we should utilize the larger amount of waste products which is available. For example plastic wastages, agriculture wastages, rice husk ash etc., (Navaneetha & Mohamed, 2016). It then becomes extremely difficult for majority of the people to own their own houses or many collapse structures in attempt to reduce cost. A way out is either by reducing the energy costs in the burning of clinker or by increasing the production of the composite cement. The later involves replacing a proportion

of the clinker-high calorie consuming portion by other products that are suitable and do not require further heat treatment (Alabadan, Olutoye, Abolarin, & Zakariya, 2005). Thus, the possible use of agricultural waste (such as Groundnut Shell Ash - GSA) will considerably reduce the cost of construction and as well as reduce or eliminate the environmental hazards caused by such waste. Groundnut shell is an agricultural waste obtained from milling of groundnut. Nigeria contributes about 7 percent of world groundnut production which makes Nigeria the 3rd largest producer of groundnut in the world (Oriola & Moses, 2010). In 2002, about 2,699,000 Mt of groundnut were produced in about 2,783,000 Hectares of Land. Meanwhile, the ash from groundnut shell has been categorized under pozzolana (Alabadan, Olutoye, Abolarin, & Zakariya, 2005), with about 8.66% Calcium Oxide (CaO), 1.93% Iron Oxide (Fe₂O₃), 6.12% Magnesium Oxide (MgO), 15.92% Silicon Oxide (SiO₂), and 6.73% Aluminum Oxide (Al₂O₃). This research is aim at finding the effect of partial replacement of ordinary Portland Cement with groundnut shell ash on the compressive strength of concrete mix and finding the comparative analysis of the cost of both the natural concrete and the partially replaced cement content.

II. MATERIALS AND METHODS

2.1 Materials

2.1.1 Cement

Dangote cement was used for all the tests. The quality of the cement was considered by checking its consistency, setting time, soundness and strength. These tests were carried out in accordance with (BS12, 1991). Tests were also carried out on the qualities of the cement with, 10%, 15%, 20 and 30% replacement of the cement with groundnut shell ash. This was used to find out to what extent these qualities comply with the requirement of (BS12, 1991).

2.1.2 Aggregates (Gravel and Sand)

Sharp river sand gotten within Kaduna was used for the experiment. Gravel is gotten from a supplier from quarry in Kaduna state, 3/4inch size of gravel was considered. Particle size distribution and tests like specific gravity tests and silt content test were carried out on the fine aggregate in accordance with the (BS812, 1985) to find out their suitability for the test. Particle size distribution and other quality assurance tests of the coarse aggregates were also carried out in accordance with (BS812, 1985).

2.1.3 Groundnut Shell Ash

The groundnut shell ash was obtained from the burning of groundnut shells which is a byproduct of groundnut processing industry and it is considered an agricultural waste from groundnut milling process. The burnt ash was passed

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through a BS sieve of 150 microns. The portion passing through the sieve which has the required fineness of 0.063 mm was used for the test while the residue was discarded.

2.1.4 Water

The water used for the concrete work is of drinkable quality obtained from Concrete laboratory of the Department of Civil Engineering Nigerian Defence Academy permanent site, Kaduna.

2.2 Method

2.2.1 Concrete Work

The slump values of the concrete produced with the cement at different level of replacement were measured and recorded. This was done first with a water cement ratio of 0.55 as prescribed in BS 8110 (1997). The concrete at different replacement of cement with groundnut shell ash were moulded, demoulded and cured for 7, 14, 21, and 28 days. The concrete were mixed at a mixed ratio of 1:2:4 and water cement ratios of 0.55.

2.2.2 Production of Concrete Cubes

Groundnut shell ash (GSA) was used to replace ordinary Portland cement at 0%, 5%, 10%, 15%, 20 and 30% by weight of cement. Concrete cube with 0% of groundnut shell ash serve as the control experiment. A 100mm x 100mm x 100mm steel moulds was used to produce concrete cubes of mix ratios 1:2:4 with constant water cement ratio of 0.55. The cube steel moulds were assembled prior to mixing and properly lubricated with engine oil for easy removal of hardened concrete cubes. Each mould was then filled with prepared fresh concrete in three layers and each layers was tamped with taping rod using twenty-five (25) strokes uniformly distributed across the seldom of the concrete in the mould. The top of each mould was smoothed and leveled with hand trowel and then the outside surfaces cleaned. The moulds and their contents were left in the open air for 24 hours. The concrete cubes were demoulded after 24 hours of the concrete setting under air and later in storage curing tank filled with clean tap water only for periods of 7, 14, 21, and 28 days respectively.

III. RESULTS AND DISCUSSION

3.1.1 Oxide Composition of Cement and Groundnut shell ash

The oxide composition obtained from the Chemical Analysis of Groundnut Shell Ash (GSA) and cement is summarized in Table 1. As may be observed from Table 1, the oxide composition of GSA shows that it contains 33.36% silica which is higher than 21.55% for cement and this is an important ingredient as it imparts strength to the cement due to the formation of Dicalcium and Tricalcium Silicates (Saurabh, 2013).

Table 1: Oxide compositions of groundnut shell as compared with Ordinary Portland cement

Oxide	Groundnut shell ash (%)*	Cement (OPC) (%)**
CaO	10.91	64.45
SiO ₂	33.36	21.55
Al ₂ O ₃	6.73	5.28
Fe ₂ O ₃	2.16	3.95
MgO	4.72	1.85
K ₂ O + Na ₂ O	25.38	-
TiO ₂	-	-
SO ₃	6.40	1.50
CO ₃	6.02	-

* After (Alabadan, Olutoye, Abolarin, & Zakariya, 2005)

** (Afolayan, Amartey, & Oriola, 2015)

3.1.2 Compacting factor (cf) and slump tests

The result for the compactive factor and slump tests is shown in Table 2. From the results it is observed that slump value decreases with increase in the percentage replacement of GSA in the concrete mix and also, the compacting factor test shows a decrease in value as the percentage replacement of GSA is increased in the concrete mix. This observed trend may be attributed to the fact that the density of the GSA is lower than that of Cement and the particle size finer. Therefore, the volume of GSA is higher than that of the replaced cement leading to higher water requirement for wetting and mixing GSA proportion when compared to that of similar weight of Cement. Similar trend was recorded by (Afolayan, Amartey, & Oriola, 2015)

Table 1: Compacting factor (cf) and slump tests

Percentage Replacement Of GSA (%)	Specimen ID	Weight Of Partially Compacted Concrete (g)	Weight Of Fully Compacted Concrete (g)	Compacting Factor (CF)	Slump (mm)
0	A1 – A12	14235	16740	0.85	30
5	1B – 12B	14680	16830	0.87	23
10	1C – 12C	14680	16939	0.88	18
15	1D – 12D	15840	17800	0.89	15
20	1E – 12E	14896	17321	0.86	0
25	1F – 12F	14364	17101	0.84	8
30	1G – 12G	13853	16895	0.82	5

3.1.3 Compressive Strength Test

Effects of curing age (days) on compressive strength

The results of the Compressive strength test at various curing age is shown in Figure 1. It shows increasing strength with age for all the blends. Higher strength values were obtained at 28 days curing period therefore the target of 25N/mm² were obtained at curing at beyond 21 days.

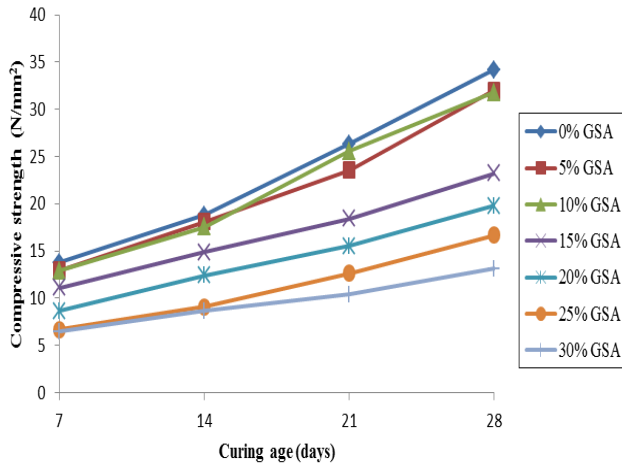


Figure 1: Variation of concrete compressive strength with age at different percentages of cement replacement with GSA

3.1.4 Effects of Groundnut shell ash on compressive strength

The variation of concrete compressive strength with groundnut shell ash at varying curing period is shown in Figure 2. The general trend is that compressive strength steadily decreases with increase in the percentage of replacement of cement with GSA in the concrete. However, the target value of 25N/mm² was achieved at replacement value not higher than 10% GSA. At 28 days curing period the compressive strength values recorded are; 34.22N/mm² for 0% GSA replacement, 32.01N/mm² for 5% GSA replacement and 31.78N/mm² for 10% replacement. Replacement above this percentage recorded values lower than that of the target strength. Similar trend were recorded by (Mahmoud, Belel, & Nwakaire, 2012), (Afolayan, Amartey, & Oriola, 2015) and (Navaneetha & Mohamed, 2016).

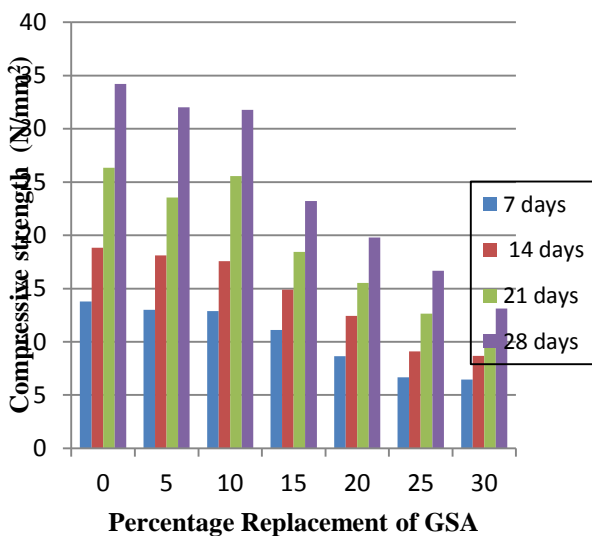
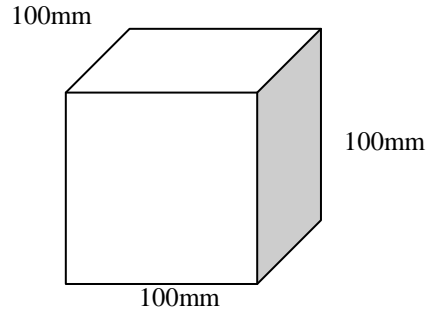


Figure 2: Variation of concrete compressive strength with percentages of cement replacement at different curing age

3.1.5 Cost Analysis

The typical cost analysis was conducted for the optimum blend replacement that met the value of the target strength which is 10% replacement of GSA compared with the control which is 0% GSA. The various materials needed for casting 1m³ of concrete for both the natural concrete and 10% replaced concrete are shown by the following calculations.



Size of cube used: 100 × 100 × 100
Volume of cube: $V = 0.1 \times 0.1 \times 0.1 = 0.001 \text{ m}^3$

Mix ratio: 1:2:4 (cement:sand:gravel)

$\frac{\text{Water}}{\text{Cement}}$ ratio ($\frac{w}{c}$): 0.55

Number of cube cated per percentage = 12

For 100% Cement i.e 0% GSA

Weight of cube = 2530g

Weight of cement = $\frac{1}{7} \times 2530 = 361\text{g}$

Weight of sand = $\frac{2}{7} \times 2530 = 723\text{g}$

Weight of gravel = $\frac{4}{7} \times 2530 = 144\text{g}$

Weight of GSA = 0

Since we are interested in cement and its replacement with GSA

Total weight of cement needed = 361 × 12 = 4332g = 4.332kg

Total weight of cement replaced by 10% GSA = $\frac{10}{100} \times 4332 = 433.2\text{g}$

Total weight of cement + 10% GSA = 4332 - 433.2 = 3898.8g = 3.8988kg

Cost of 1 bag of 50kg cement = ₦2700

Cost of producing 12 cube using cement without replacement = $\frac{4.332}{50} \times 2700 = 233.9 = ₦234$

Cost of producing 12 cube using cement with 10% GSA replacement = $\frac{3.898}{50} \times 2700 = 210.5 = ₦211$

Cost saving in cost of cement = 234 - 211 = ₦23

Percentage saving in cost of cement = $\frac{23}{234} \times 100 = 9.8 \approx 10\%$

IV. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The following conclusion can be drawn:

1. The experimental results showed that GSA is a good pozzolanic material which reacts with calcium hydroxide forming calcium silicate hydrate and the pozzolanic activity of GSA increases with increase of time (curing age).
2. Workability of concrete decreased with increase in cement replacement with the GSA blend. An acceptable limit for workability is at 15% replacement especially when a mechanical vibrator is to be employed.
3. The target grade of 25N/mm² was achieved at replacement of not more than 10% (34.22N/mm² at 0% GSA replacement, 32.01N/mm² at 5% GSA replacement and 31.78N/mm² at 10% replacement). For replacement above 10%, the grade obtained fell well short of target (23.23N/mm² at 15%, 19.78N/mm² at 20%, 16.67N/mm² at 25% and 13.11N/mm² at 30%).
4. The use of cement with 10% GSA replacement will reduce the cost of cement in concrete to 10% of the total cost.

4.2 Recommendations

1. It is recommended to use a maximum replacement of GSA in concrete production of 10%
2. It is recommended that the concrete curing should be extended beyond 28 days to ascertain the long term strength development of GSA modified concrete.
3. GSA calcinations temperature should be varied to establish optimal temperature for pozzolanic activity of GSA.

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