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SUITABILITY OF GROUNDNUT SHELL ASH AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL IN CONCRETE PARKING LOTS PLACED ON THE GROUND

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Abstract: Concrete parking lots range in size from small, such as at corner convenience stores, to medium, such as at multi-unit housing projects, to large, such as those for shopping centers and office or commercial developments. Most parking areas include driveways, some of which need to accommodate relatively heavy loads. This study evaluates the application of groundnut shell ash as partial replacement of cement in reinforced and unreinforced concrete parking lots placed on the ground. Hydraulic cement was replaced at 0%, 10%, 20%, 30% and 40% with groundnut shell ash in concrete parking lots. The properties of fresh and hardened concrete parking lots at 0%, 10%, 20%, 30% and 40% groundnut shell ash replacement of cement were evaluated. The results indicate that groundnut shell ash is similar to class C fly ash and can be used as partial replacement of cement. The compressive strengths of the various mixes were evaluated at 3rd, 7th, 14th, 28th, 56th and 91st day age. The study therefore concluded that groundnut shell ash is a good supplementary cementitious material and can be incorporated up-to 20% in the construction of concrete parking lots.
Keywords: Compressive strength, Parking lots, Concrete, Groundnut shell ash, Hydraulic cement

1. INTRODUCTION

Concrete parking lots have many similarities to other types of concrete pavement. On the other hand, parking lots differ from other pavements in that most of the area is intended for storage of vehicles and other goods rather than for movement of vehicles. The design of concrete parking lots should follow generally accepted procedures for concrete pavements as outlined in this guide. Load-bearing capacity, drainage, crack control, life-cycle cost, constructability, and maintainability are other characteristics that are important in the design and construction of concrete pavements, including parking lots (WSDOT M46-01. 2016, ACI 330R, 2008, ACI 330.1M-14, 2015 and ACI 360R-10, 2010).

Typically, concrete parking lots do not serve the same broad spectrum of traffic loading, from light vehicles to heavy trucks, as highways and arterial streets. Facilities designed to accommodate both light vehicles and heavier delivery trucks may employ traffic controls to separate and channel the heavier trucks away from areas designed for automobiles and light trucks. Facilities designed for heavier vehicles are likely those facilities where relatively accurate predictions of vehicle sizes and numbers are possible. Facilities intended to serve only light vehicles may have concrete parking lot slabs with thicknesses influenced by the practical limitations of the material and environmental effects rather than by the pavement stress created by vehicle loads.

Durability-related distress is often the most critical maintenance concern for lightly loaded concrete parking lot pavements, which are subject to the effects of fuels and lubricants leaked from vehicles as well as environmental influences. Vehicles in parking areas usually travel at low speeds, diminishing the importance of smoothness tolerances. Because parking lots must also accommodate pedestrians, designs and geometrics should reflect pedestrian safety considerations including crosswalks, a slip-resistant surface texture, and nighttime illumination (ACI 232.1R-12, 2012, ACI 330R, 2008, ACI 330.1M-14, 2015 and ACI 360R-10, 2010).

Supplementary cementitious material (SCM) are inorganic material such as fly ash, silica fume, metakaolin, or slag cement that reacts pozzolanically or hydraulically. Pozzolans are made up of siliceous or siliceous and aluminous materials that, in finely divided form, will react with calcium hydroxide to form cementitious materials. The term “pozzolan” evolved from the name given to a deposit of volcanic material located near Pozzuoli, Italy. This deposit, originally referred to as pozzolana, consisted of pumice ash, or tuff, comprised of trachyte found near Naples and Segni, Italy. Trachyte is a volcanic rock comprised primarily of feldspar crystals in a matrix of siliceous glass.

Pozzolana was formed from an explosive volcanic eruption in 79 AD at Mount Vesuvius, which engulfed Herculaneum, Pompeii, and other towns along the bay of Naples. The term “natural pozzolan” encompasses a broad range of materials. A few of these materials are pozzolanic in their natural state. However, most of the materials considered natural pozzolans require some type of processing to render the material pozzolanic. Some may require only drying and grinding/classifying, while others may require heat treatment and grinding to adequately activate the pozzolanic nature of the material. Groundnut shell ash falls in this category (WSDOT M46-01. 2016, ACI 330R, 2008, ACI 232.1R-12, 2012, ACI 330.1M-14, 2015 and ACI 360R-10, 2010). Pozzolanic materials have long demonstrated their effectiveness in producing high performance concrete. Artificial pozzolanas such as rice husk ash have gained acceptance as supplementary cementing materials in many parts of the world (Adole *etel,* 2011). In recent times, many waste materials like fly ash periwinkle shell ash, and ashes produced from various agricultural wastes such as palm oil waste, rice husk ash, corncob ash, millet husk ash, groundnut husk ash have been tried as pozzolanas or secondary cementitious materials. These supplementary cementing materials play an important role when added to Portland cement because they usually alter the pore structure of concrete to reduce its permeability, thus increasing its resistance to water penetration and water related deterioration such as reinforcement corrosion, sulphate and acid attack (Prasad, Jain, and Ahuja, 2006 and Rahmani, and Ramzanioanpour, 2008).

(a)   (b)

Figure 1a and b: Concrete parking lots on the ground and Slabs-on-ground

In a study Olutoge et al (2013) studied the characteristics strength and durability of groundnut shell ash blended cement concrete in sulphate environments. They concluded that groundnut shell ash blended cement concrete haven good resistance to magnesium sulphate, sodium sulphate and calcium sulphate media and would perform better in soils containing these media ($MgSO_4$, Na2 SO_4, and $CaSO_4$.). 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 any sulphate environment. According to Alabadan, Njoku and Yusuf (2006), groundnut Shell ash contains some of the oxides found in pozzolanas and Portland cement. They recommended that groundnut shell ash up to 30% replacement of ordinary Portland cement in concrete would be acceptable.

Buari et al (2013) studied the characteristics strength of groundnut shell ash and ordinary portland cement blended concrete in Nigeria and concluded that groundnut shell ash is a good pozzolanic material which reacts with calcium hydroxide forming calcium silicate hydrate and that pozzoolanic activity of groundnut shell ash increases with increase in time.

This research is based on the current knowledge and practices for the design, construction and maintenance of concrete parking lots placed on the ground. The aim of this research is to evaluate the suitability of groundnut shell ash as supplementary cementitious material in construction and maintenance of concrete parking lots placed on the ground.

2. MATERIALS

— Cement and groundnut shell ash

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. The cement used in this study conforms to the provisions of ASTM C150/C150M (2015) and WSDOT M41-10 (2016). The groundnut shell ash used has properties similar to class C fly ash as specified in ASTM C618 (2015), WSDOT M41-10 (2016), and WSDOT M46-01. (2016).

— Aggregate properties

The fine aggregate and coarse aggregate used in this study conform to the specifications of ASTM C33/C33M (2014), USDOT-FHWA FP 14 (2014), WSDOT M41-10 (2016), and WSDOT M46-01. (2016).

3. METHODS

— Mix design and slump test

Concrete mix was designed at a mix ratio of 1: 2: 3 and in accordance with the specifications of USDOT-FHWA FP 14 (2014) WSDOT M41-10 (2016) and WSDOT M46-01. (2016). All concrete mixtures were designed by keeping the water cement ratio constant.

According to USDOT-FHWA FP 14 (2014), WSDOT M41-10 (2016) and WSDOT M46-01. (2016)the slump test is a measure of the consistency of the concrete and a change in the slump test indicates that something in the manufacturing of the concrete has changed. In this study, slump test was conducted on the fresh concrete in accordance with the procedures provided in WSDOT M41-10 (2016), WSDOT M46-01. (2016) and USDOT-FHWA FP 14 (2014).

— Compressive strength test and split tensile test

Compressive strength test and the split tensile test were performed on the hardened concrete in accordance with the procedure specified in USDOT-FHWA FP-14 (2014), WSDOT M41-10 (2016), and WSDOT M46-01. (2016).

— Water absorption and voids in hardened concrete

The density, percentage absorption, and percentage voids in hardened concrete for different percentage replacement of cement with groundnut shell ash was determined in accordance with the procedure specified in ASTM C642 (2013) at the 28^{th}, and 91^{st} day of curing. The specimens used were 100mm diameter and 50mm thick cylindrical concrete of volume $393cm^3$ and oven dry mass of 943g. Each portion of the specimens were free from observable cracks, fissures, or shattered edges. Each specimen was oven dried at a temperature of 100 to 110°C for 30 hours. After removing each specimen from the oven, it was allowed to cool in dry air (preferably in a desiccator) to a temperature of 20 to 25°C and the mass was determine and denoted as A. The experiment continued in line with the procedure specified in ASTM C642 (2013) and equations 1-7 are used to calculate water absorption, voids and densities of hardened concrete.

$$\text{Absorption after immersion (\%)} = \left[\frac{(B-A)}{A}\right] X\ 100 \quad (1)$$

$$\text{Absorption after immersion and boiling (\%)} = \left[\frac{(C-A)}{A}\right] X\ 100 \quad (2)$$

$$\text{Bulk density, dry (g/cm}^3) = g_1 = \left[\frac{A}{C-D}\right] X\ \rho \quad (3)$$

$$\text{Bulk density after immersion (g/cm}^3) = \left[\frac{B}{C-D}\right] X\ \rho \quad (4)$$

$$\text{Bulk density after immersion and boiling (g/cm}^3) = \left[\frac{C}{C-D}\right] X\ \rho \quad (5)$$

$$\text{Apparent density (g/cm}^3) = g_2 = \left[\frac{A}{A-D}\right] X\ \rho \quad (6)$$

$$\text{Volume of permeable pore space or voids, (\%)} = \left[\frac{g2-g1}{g2}\right] X\ 100 \text{ or } \left[\frac{(C-A)}{(C-D)}\right] X\ 100 \quad (7)$$

where,

≡ Volume of concrete sample (cm^3) = V
≡ Mass of oven dry sample in air (g) = A
≡ Mass of surface–dry sample in air after immersion (g) = B
≡ Mass of surface-dry sample in air after immersion and boiling (g) = C
≡ Apparent mass of sample in water after immersion and boiling (g) = D
≡ Density of water (g/cm^3) = ρ = 1

4. RESULTS AND DISCUSSION

— Properties of groundnut shell ash and aggregates used

Table 1 shows the chemical analysis of the groundnut shell ash used in this study. The results are similar to the properties of class C fly ash specified in ASTM C618-15 (2015). Tables 2, and 3 show the Sieve analysis results of the fine and coarse aggregate. Table 4 shows the physical properties of fine and coarse aggregates natural coarse aggregate used. The results satisfy the specifications inWSDOT M41-10 (2016), WSDOT M46-01. (2016), ACI 211.1-91 (2009), andACI 304R-00 (2000).For an aggregate to perform satisfactory in pavement, it must be sufficiently hard to resist the crushing, impact and abrasive effect of traffic over long period of time. The soft aggregates will be quickly ground to dust, whilst the hard aggregates are quite resistant to these effects and as such they are more durable.

Table 1: Chemical composition of groundnut shell ash.

Chemical Oxides	CaO	Fe_2O_3	MgO	SiO_2	Al_2O_3	K_2O	Na_2O	SO_3	LOI
Percentage composition (%)	8.69	1.80	6.74	16.21	5.93	15.73	9.02	6.21	4.43

Table 2: Sieve Analysis of Fine Aggregates

S/N	Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
1.	10	0	-	-	100
2.	4.75	17.70	1.77	1.77	98.23
3.	2.36	58.80	5.88	7.65	92.35
4.	1.18	129.50	12.95	20.26	79.74
5.	0.60	148.50	14.85	35.45	64.55
6.	0.30	324.5	32.45	67.90	32.10
7.	0.15	308.0	30.80	98.70	1.3
8.	0.075	13.0	1.3	99.70	0.3
Total		1000g	100%	231.73	

Table 3: Gradation of Natural Coarse Aggregate

S/N	Sieve size (mm)	Weight Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
1.	20	0	-	-	100
2.	12.5	298	29.8	29.8	70.2
3.	10	583	58.3	88.1	11.9
4.	4.75	85	8.5	96.6	3.4
Total		966	96.6	214.5	

Table 4: Physical properties of fine and coarse aggregates

Properties	Coarse Aggregates	Fine Aggregate	WSDOT M46-07.25 Specifications
Specific Gravity	2.7	2.65	2.5 – 3.0
Water Absorption (%)	1.1	1.28	0.0 – 8.0
Aggregate crushing value (%)	21.95	-	20 - 30
Aggregate impact value (%)	20.81	-	
Los Angeles abrasion value (%)	29.40	-	27 - 49
Fineness modulus	2.15	2.32	-

ASTM D5874-02 (2007) specification requires that aggregates to be used in concrete pavement must have an aggregate crushing that is less than 30%. The WSDOT M41-10 (2016), ASTM C131/131M (2006) specification require that aggregates to be used in concrete pavements must have a Los Angeles wear loss that is less than 35%. Based on the aggregate crushing value (ACV), aggregate impact value (AIV) and Los Angeles abrasion loss results, the coarse aggregate used in this study meets, relevant code requirements.

— Mix proportioning and slump values

A labelling system was developed to denote the different concrete mixes evaluated in this study. The mix proportioning shown in Table 5 shows 400Kg/m^3 of cementitious material which satisfied the minimum cementitious material content of 300Kg/m^3 to 360 Kg/mm^3 for standard and high performance concrete in accordance with the specifications of USDOT-FHWA F-14 (2014), WSDOT M41 -10 (2016), TXDOT (2014), WSDOT M46-01. (2016), ACI 211.1-91 (2009),ACI 304R-00 (2000), and ASTM C94/C94M -17 (2017). The fine aggregate to total aggregate ratio is 0.4 which satisfies the 0.35 to 0.45 specifications of USDOT-FHWA F-14 (2014), WSDOT M41 -10 (2016), TXDOT (2014), WSDOT M46-01. (2016), ACI 211.1-91 (2009), ACI 304R-00 (2000), and ASTM C94/C94M -17 (2017).

Table 5: Concrete Mix Design at 1:2:3 mix ratio

Specimen mark	Water/Cementitious material Ratio	Percentage replacement of cement with groundnut shell ash (%)	Cement (Kg/M^3)	Groundnut shell ash (Kg/M^3)	Fine Aggregate (Kg/M^3)	Coarse Aggregate (Kg/M^3)
A0	0.45	0	400	0	800	1200
A10	0.45	10	360	40	800	1200
A20	0.45	20	420	80	800	1200
A30	0.45	30	380	120	800	1200
A40	0.45	40	340	160	800	1200

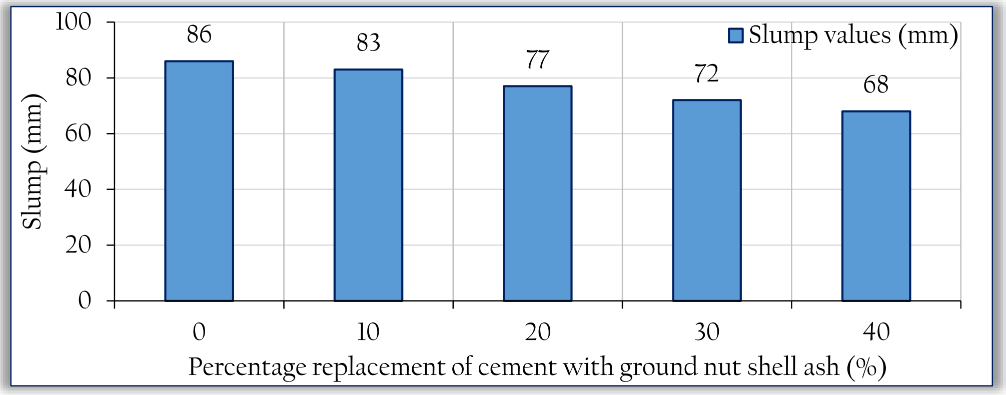

Figure 2: The Relationship between the Measured Slump and the Percentage Replacement of cement with ground nut shell ash

The measured slump values for each of the different fresh concrete mixes were presented in Table 6. Figure 2 shows the Relationship between the Measured Slump and the Percentage replacement of cement with groundnut shell ash. The slump values were within the range of 63 mm to 86 mm.

— Compressive strength values and split tensile strength values

The average compressive strength values of the various mixtures of percentage replacement of cement with groundnut shell ash at an age of 3rd, 7th, 14th, 28th, 56th and 91st day are given in Table 7. Figures 3 and 4 show the relationship between the compressive strength (N/mm^2) and Curing age (days) for different percentage replacement of cement with groundnut shell ash.

Table 7: Average Compressive Strength Test Results (f_{ck}).

Specimen mark	Percentage replacement of cement with groundnut shell ash (%)	Density Kg/m^3	3rd day N/mm^2	7th day N/mm^2	14th day N/mm^2	28th day N/mm^2	56th N/mm^2	91st day N/mm^2
A0	0	2433	14.10	21.20	29.58	38.91	47.88	58.23
A10	10	2433	12.60	16.60	26.00	35.82	46.61	58.23
A20	20	2435	10.08	14.50	22.30	33.08	44.92	55.43
A30	30	2434	8.80	11.80	20.60	28.37	39.86	51.12
A40	40	2392	6.01	9.40	17.90	25.68	33.48	45.09

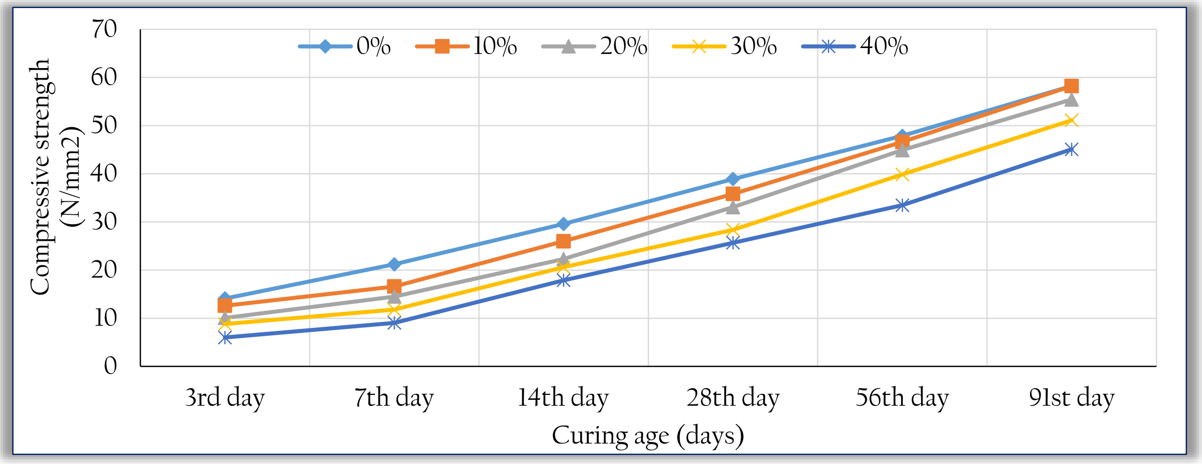

Figure 3: Relationship between the compressive strength (N/mm^2) and Curing age (days) for different percentage replacement of cement with groundnut shell ash

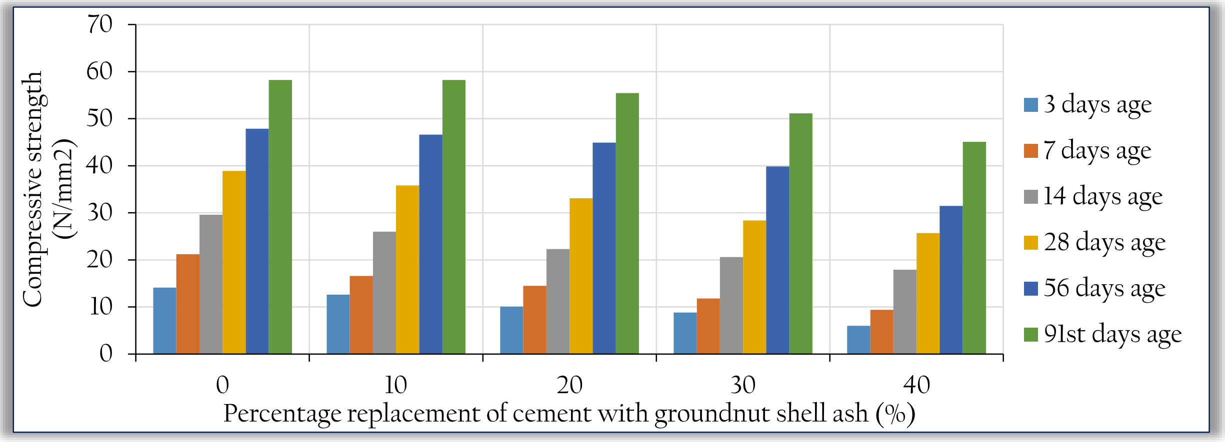

Figure 4: Relationship between the compressive strength (N/mm^2) and the percentage replacement of cement with groundnut shell ash

From Table 7, and Figures 3, and 4, it can be seen that all the concrete mixtures show increase in strength with increase in the curing age and a decrease in compressive strength with increase in the percentage replacement of cement with groundnut shell ash. Concrete specimens containing groundnut shell ash show lower early strength and high later strength. This is due to the reduction of pore spaces (voids) by the groundnut ash shell which leads to increase in strength and durability. From the test results presented in Table 7, and in Figures 3, and 4, it can be observed the compressive strength of concrete mixtures containing 0% to 30% replacement of replacement of cement with groundnut shell ash satisfied the ACI 330R (2008),ACI 330.1M-14 (2015),ACI 360R-10 (2010),ACI 211.1-91 (2009),ASTM C94/C94M -17 (2017),ASTM C94/C94M -17 (2017), TXDOT (2014), WSDOT M41-10 (2016), WSDOT M46-01. (2016) and USDOT-FHWA FP-14 (2014) 28 days minimum compressive strength specification of 28N/mm^2 to 31N/mm^2 for standard concrete parking lots and 0% to 20% replacement of replacement of cement with groundnut shell ash satisfied the minimum compressive strength of 31N/mm^2 to 41N/mm^{2}for high performance concrete pavement/parking lots. It is evident from the results presented that the compressive strength of all the mixtures continued to increase with the increase in age. However, maximum strength at all ages occurs with 0% replacement of cement with groundnut shell ash. The results presented indicate that groundnut shell ash can be used to replace up to 20% cement in concrete parking lots production and construction.

Table 8: Average Split Tensile Test Results

Cube test mark	Percentage replacement of NCA with RCA (%)	7 Day split tensile strength (N/mm^2)	14 Day split tensile strength (N/mm^2)	28 Day split tensile strength (N/mm^2)
A0	0	2.57	3.06	3.22
A10	10	2.54	2.98	3.14
A20	20	2.42	2.85	3.00
A30	30	2.35	2.76	2.91
A40	40	2.30	2.71	2.86

The split tensile strength of concrete mixtures was evaluated at the age of 7th, 14th, and 28th day age. From Table 8, it can be seen that there is increase in split tensile strength values with the increase in age. The maximum split tensile strength for all the mixtures under study occurs at 0% of cement.

— Water absorption and Volume of permeable voids in hardened concrete

The specimen use for the Water absorption and Volume of permeable pore space (voids) in hardened concrete at 28th and 91st day age satisfied the specifications of ASTM C642 (2013). From Tables 9 and 10 and Figure 5 it can be observed that water absorption and volume of permeable pore space (voids) decrease with increase in percentage replacement of cement with groundnut shell ash except with 40% replacement where an increase was observed. The results indicate that the concrete made with up to 30% replacement of cement with groundnut shell ash has reliable durability qualities and will perform favorable if used in construction and maintenance of concrete parking lots placed on the ground.

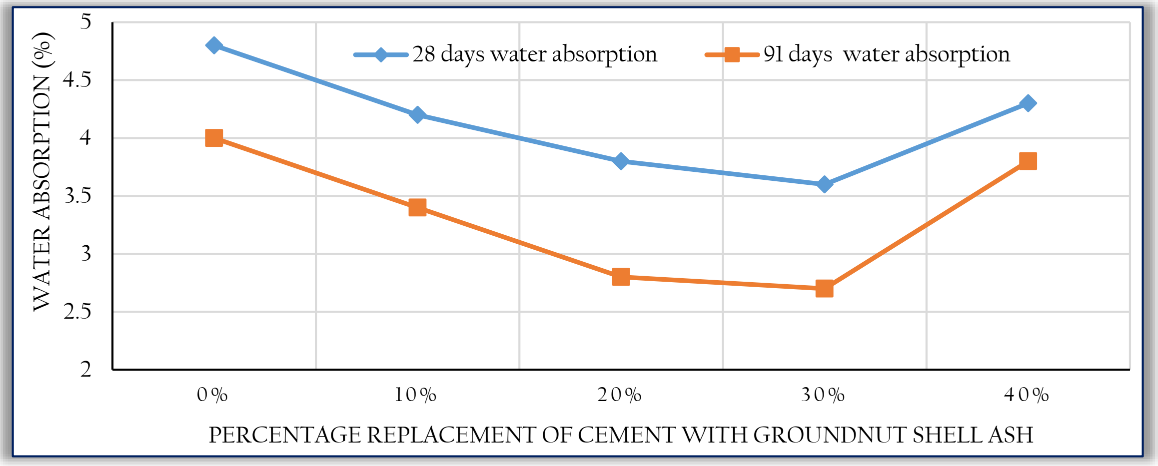

Figure 5:Water absorption after immersion in hardened concrete at 28th and 91st days (%)

Table 9: Water absorption and Volume of permeable pore space (voids) in hardened concrete at 28th day age.

S/N	Description and units	Percentage replacement of cement with groundnut shell ash				
		0%	10%	20%	30%	40%
1.	Volume of sample (cm^3)	393	393	393	393	393
2.	Mass of oven dry sample in air (g)	956	956	957	957	940
3.	Mass of surface–dry sample in air after immersion (g)	1002	996	993	991	980
4.	Mass of surface-dry sample in air after immersion and boiling (g)	1016	1008	1003	1000	996
5.	Apparent mass of sample in water after immersion and boiling (g)	623	615	610	607	603
6.	Absorption after immersion (%)	4.8	4.2	3.8	3.6	4.3
7.	Absorption after immersion and boiling (%)	6.3	5.4	4.8	4.5	5.2
8.	Density of water (g/cm^3)	-	-	-	-	-
9.	Bulk density, dry (g/cm^3)	2.43	2.43	2.44	2.43	2.39
10.	Bulk density after immersion (g/cm^3)	2.55	2.53	2.53	2.52	2.50
11.	Bulk density after immersion and boiling (g/cm^3)	2.59	2.57	2.55	2.55	2.53
12.	Apparent density (g/cm^3)	2.87	2.80	2.76	2.73	2.79
13.	Volume of permeable pore space or voids, (%)	15.33	13.21	11.60	10.99	14.33

Table 10: Water absorption and Volume of permeable pore space (voids) in hardened concrete at 91st day age.

S/N	Description and units	Percentage replacement of cement with groundnut shell ash				
		0%	10%	20%	30%	40%
1.	Volume of sample (cm^3)	393	393	393	393	393
2.	Mass of oven dry sample in air (g)	956	956	957	957	940
3.	Mass of surface–dry sample in air after immersion (g)	994	988	984	983	976
4.	Mass of surface-dry sample in air after immersion and boiling (g)	1007	1000	996	991	985
5.	Apparent mass of sample in water after immersion and boiling (g)	614	607	603	598	592
6.	Absorption after immersion (%)	4.0	3.4	2.8	2.7	3.8
7.	Absorption after immersion and boiling (%)	5.3	4.6	4.1	3.6	4.78
8.	Density of water (g/cm^3)	-	-	-	-	-
9.	Bulk density, dry (g/cm^3)	2.43	2.43	2.44	2.43	2.39
10.	Bulk density after immersion (g/cm^3)	2.53	2.51	2.50	2.50	2.48
11.	Bulk density after immersion and boiling (g/cm^3)	2.56	2.55	2.53	2.52	2.51
12.	Apparent density (g/cm^3)	2.80	2.74	2.70	2.61	2.70
13.	Volume of permeable pore space or voids, (%)	13.21	11.31	9.63	6.90	11.48

5. CONCLUSIONS

Based on the results and performance of the application of recycled concrete aggregate and groundnut shell ash in production and construction of concrete parking lots placed on ground. The following conclusions were drawn:

- At 1:2:3 mix ratio, the compressive strengths of new concrete parking lot are in the order of 38.91N/mm^2 to 25.68 N/mm^2 at the 28day age for 0% to 40% replacement of cement with groundnut shell ash.
- Concrete used to construct parking lot pavements should be batched, mixed, and delivered in accordance with ASTM C94. Components of the mixture should follow the requirements contained in other appropriate and relevant ASTM specifications.
- Proportioning concrete by methods utilized in ACI 211.1 and ACI 304R will help to ensure that the concrete used in parking lot paving will provide the required strength, long-term durability, economy, and workability envisioned by the owner, designer, and contractor.
- The use of groundnut shell ash in construction and maintenance of concrete parking lots on the ground should be encouraged. This study recommends up to 20% replacement of cement with groundnut shell ash in concrete parking lots on the ground at 1:2:3 mix ratio.
- Groundnut shell ash addresses the problem of disposal cost of groundnut shell, environmental pollution, sustainability of the cement industry and construction cost.

References

[1] ACI 330R (2008). Guide for the design and construction of concrete parking lots. American concrete institute. http://www.concrete.org/330R
[2] ACI 330.1M-14 (2015). Specification for Unreinforced Concrete Parking Lots and Site Paving. American concrete institute. http://www.concrete.org/330.1m-14
[3] ACI 360R-10 (2010). Guide to design of slabs-on-ground. American concrete institute. http://www.concrete.org/360R-10
[4] ACI 211.1-91 (2009). Standard practice for selecting proportions for normal, heavy weight and mass concrete. American concrete institute. http://www.concrete.org/211.1-91
[5] ACI 304R-00 (2000). Guide for measuring, mixing, transportation and placing concrete. American concrete institute. http://www.concrete.org/304R-00
[6] ACI.232.IR-12 (2012). Report on the use of raw or processed natural pozzolans in concrete. American concrete institute, USA. http://www.concrete.org/232.ir-12
[7] Adole, M. A., Dzasu, W. E., Umar, A., and Oraegbune, O.M, (2011). Effects of Groundnut Husk Ash-blended Cement on Chemical Resistance of Concrete, ATBU Journal of Environmental Technology, 4, (1).
[8] Alabadan, B. A, Njoku, I. C. F and Yusuf, M. O. (2006). "The Potentials of Groundnut Shell Ash as Concrete Admixture". Agricultural Engineering International: the CIGR Ejournal. Manuscript BC 05 012, Vol. VIII.
[9] ASTM C94/C94M -17 (2017). Standard specification for ready mixed concrete, ASTM international, West Conshohocken, PA, USA. http://www.astm.org/C94
[10] ASTM C150/C150M, (2015). Standard specification for Portland cement, ASTM International, West Conshohocken, PA, www.astm.org.
[11] ASTM C33/C33M-16e1 (2016). Standard specification for concrete aggregates. ASTM international, West Conshohocken PA, USA. http://www.astm.org/C33
[12] ASTM C642 (2013). Standard Test Method for Density, Absorption, and Voids in Hardened Concrete. ASTM international, West Conshohocken, PA, www.astm.org/C642-13.

[13] ASTM C168-15 (2015). Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. ASTM international, West Conshohocken, PA, USA. http://www.astm.org/C618-15

[14] ASTM D5874-02, (2007),"Standard Test Method for Determination of The Impact Value (IV) of a Soil", ASTM International, West Conshohocken, PA, www.astm.org.

[15] ASTM C131/C131M-14, (2006), Standard Test Method for Resistance to Degradation of Small size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine, ASTM International, West Conshohocken, PA, www.astm.org.

[16] ASTM C618 (2015). Standard specifications for coal fly ash and raw or calcined natural pozzolan for use in concrete, ASTM International, West Conshohocken PA, USA. http://www.astm.org/C618

[17] ASTM C642 (2013). Standard Test Method for Density, Absorption, and Voids in Hardened Concrete. ASTM international, West Conshohocken, PA, www.astm.org/C642-13.

[18] Buari T.A, Ademola S.A., and Ayegbokiki S.T., (2013). Characteristics strength of groundnut shell ash and ordinary Portland cement blended concrete in Nigeria. IOSR Journal of Engineering, Vol. 3 (7), Pp. 01-07.

[19] Olutoge F.A., Buatri T.A., and Adeleke T.A., (2013). Characteristics strength and durability of groundnut shell ash blended cement concrete in sulphate environments. International Journal of Engineering Research, Vol. 4 (7).

[20] Prasad, J., Jain, D.K. and Ahuja, A.K. (2006). Factors Influencing the Sulphate Resistance of Cement Concrete and Mortar. Asian Journal of Civil Engineering (Building and Housing), 7 (3), 259-268.

[21] Rahmani, H. and Ramzanioanpour, A.A. (2008). Effect of Silica Fume and Natural Pozzolanas on sulfuric Acid Resistance of Dense Concretes. Asian Journal of Civil Engineering (Building and Housing), 9 (3), 303-319.

[22] TXDOT (2014). Standard specifications for construction and maintenance of highways, streets and bridges, Texas Department of Transportation, State of Texas, USA. https://www.dot.state.tx.us/specifications

[23] USDOT-FHWA FP-14 (2014). Standard specification for construction of roads and bridges on federal highway projects. United states department of transportation, Federal highway administration. http://www.fhwa.dot.gov/fp-14

[24] WSDOT M41-10 (2016). Standard Specification for Road, Bridge, and Municipal Construction. Construction Administration Office, Engineering and Regional Operations Division, Washington State Department of Transport, State of Washington, USA. https://www.wsdot.wa.gov/M41-10

[25] WSDOT M46-01. (2016). Materials manual, Materials laboratory, Engineering and Regional Operations Division, Washington State Department of Transport, State of Washington, USA. https://www.wsdot.wa.gov/M46-10

[26] Xiao J, Falkner H., (2007). "Bond behaviour between recycled aggregate concrete and steel re-bars". Construction and Building Materials Vol. 21(2) Pp. 395–401.

[27] Yanagibashi, K., Morohashi, N., and Sakurada., T. (2007). "Bond Splitting Strength of High quality Recycled Coarse Aggregate Concrete Beams, Journal of Asian Architecture and Building engineering", Vol.6 (2) Pp. 331-337.

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