Mechanical Properties of an Impervious Concrete Using Palm Kernel Shell (PKS) as a Substitute for Coarse Aggregate.

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Abstract
The research work was carried out to maintain the societal need for proper disposal of waste. Palm kernel shell (PKS) is found as a waste product. The process of disposing and recycling has been a problem which has led to economic and environmental issues. This research is limited to the impact of aggregate on the engineering properties of pervious concrete in the mix ratio 1:5 with a W/C ratio of 0.31, this can be without replacement or the partial replacement of the coarse aggregate(granite) with PKS to see the possible percentage that it can be used and recommended, for this purpose the following test were carried out; sieve analysis, specific gravity, compressive test, permeability test and water absorption test. After the procurement of the materials, the batching was done by weight. In this study following the percentages of aggregate were used for partial replacement 10%, 20% 30% 40% and 50% for PKS in the partial replacement. From the result from of the compressive strength was at its peak when the granite was at the partial replacement of 70% granite, 30% palm kernel shell for 7 days, 14 days and 28 days with the corresponding values of 5.325MPa, 6.189MPa and 7.364MPa respectively.

Keywords: Palm Kernel Shell, Concrete, Agricultural waste, Aggregate

Introduction

In the natural water cycle, storm water naturally falls to the ground, where it is absorbed by the soil, where it is filtered, stored, evaporated, and then redistributed back into the continuously flowing cycle. Due to the massive impermeable pavements that have sealed the earth's natural filter, this cycle is currently in a decreased state (Cahill 2000). Human development and building methods have significantly changed concrete that has interconnected pores that permit water to flow through it; such concrete is referred to as pervious concrete. This concrete type has now been adopted for usage in pavement and building due to its eco-friendly factors. Cement, coarse aggregate (size should be 9.5 mm to 12.5 mm), and water make up pervious concrete; little to no fine aggregates are used. The strength can be increased by adding a little bit of sand. The combination has a void content of 15 to 25 percent and a water-to-cement ratio of 0.28 to 0.40. Usually, pervious concrete is laid at a thickness that is equal to or slightly greater than regular concrete. For pedestrian applications, pervious concrete typically has a thickness between 100mm - 200mm or more for heavy vehicular applications, such as bus stops and high-traffic roadways. Pervious concrete is frequently used in parking lots and walkways and has uses in sustainable construction.

They are special and effective for environmental challenges because of the geography, circumstances, and purposes for which they are used. They recharge water, which enhances its quality, reducing runoff from storms. Pervious concrete has been adopted in our surroundings for improvement and elongation of road life span. It is produced at low cost and is considered one of the most attractive, efficient, and sustainable for urban drainage system control.

The problem of uncontrolled accumulated water during rainy seasons which causes flood, erosion, runoffs etc. causes damage to lives, properties and disrupt human activities. Drainages are constructed at the edges of road to collect the water and channel the water including the excess and discharge the into larger water bodies likes dams, Ocean etc. The main purpose of the proper drainage system is to minimize or avoid the accumulation of water in pavements, sidewalks, garages etc. The demand of aggregate in construction of engineering structures has caused the increase in the cost and time of construction. To reduce the cost, availability of alternatives or replacement to coarse aggregate. The issue of coarse aggregate demand in pervious concrete in large quantities may be substituted with other material (palm kernel shell) that satisfies the engineering requirements. This reduces the stress on production of coarse aggregate (granite) and emphasis on the source reduction and recycling of agricultural waste (palm kernel shell).

Depending on the availability of material, cost and most importantly the engineering properties determine the construction of pervious concrete. Pervious concrete has interconnected pores that allows water to flow directly or channeled back into drainage or Groundwater. When constructed and placed in the essential place for Control it reduces the damages on paved roads. It is also a type of concrete that is also used for aesthetic purpose and still serve its purpose. To control excess water from drainage system different research methods have been adopted including pervious concrete. The problem on paved road damages may have been reduced by pervious concrete. This can allow property owners and government to extend, develop and establish in larger areas at lower cost for easy construction. The issue of coarse aggregate demand in pervious concrete in large quantities may be substituted with other material (palm kernel shell) that satisfies the important engineering requirements. This reduces the stress on production of coarse aggregate (granite) and emphasis on the source reduction and recycling of agricultural waste (palm kernel shell (PKS))

The typical concrete pavement does not filter rainwater underground since it has low water and air permeability. Due to its greater potential for absorption and more rapid penetration of rainwater into the earth, pervious concrete can remove storm water more quickly than conventional concrete (Schafer and Wang, 2006). Skid resistance is significantly increased by reducing the amount of water on the pavement surface. Many researchers (Sandanayake, *et. al*., 2020; Adewuyi, and Adegoke, 2008; Ogunfayo, *et. al*., 2015; Adeala and Soyemi, 2021) have made advances in the study of using local and waste materials in concrete production, which has garnered attention for its practical advantages in waste reuse and sustainable development.

Shetty (2006) and Ravindrarajah and Yukari (2008) investigated the use of pervious concrete, ecofriendly concrete for a sustainable construction. Their articles detail report on the experimental examination is not the engineering and physical characteristic of pervious concrete. Using different amount of low calcium fly ash as a substitute cement. Different characteristics of pervious concrete including porosity, unit weight, compressive strength, and weight loss during drying, shrinkage and water loss have all been investigated. Kukami, *et. al*., (2013) discovered that 66% to 78% of concrete is made of aggregate. Most used aggregate mainly gravels and fine aggregate which is sand are mostly and used for control while naturally occurring aggregate such as PKS, coconut shell will be used and studied as replacement of aggregate in mixing of concrete.

Various non-biodegradable materials have been researched into the production of light weight concrete and majorly for effective recycling of the wastes (Ghernouti *et al*., 2009; Chen, *et al*., 2015; Amalu *et al*., 2016; Sreenath & Harish-Shankar, 2017; and Soyemi, *et. al*., 2023). Conclusively, they all opined that replacing aggregates with waste materials can produce concrete of appreciable strength to be used for non-structural components of the building (structure). Additional benefits include the capacity to generate lightweight materials and decrease construction expenses.

The material's porosity, however, results in a relatively low strength. The material's compressive strength is only 20–30 MPa. Such resources Low strength prevents use as pavement. Only public squares, sidewalks, parking lots, and park walkways may be constructed with pervious concrete. By modifying the concrete and using certain aggregates, fine mineral admixtures, organic intensifiers, and other materials. The Pervious Concrete can be improved by the mix proportion, strength, and abrasion resistance considerably. Hardened qualities of pervious concrete include flexural strength, split tensile strength and compressive strength. Cubes measuring 150mm x 150mm x 150mm and beams measuring 500mm x 100mm x 100mm are made to explore the result of the compressive strength and the flexural strength, respectively. According to the test result concrete that is permeable and toughened, according to the test result gravel with smaller size 9.375 has the greater advantage.it has the compressive strength of (12.71N/mm2) and flexural strength of (1.91N/mm2) with 1:6 ratio mix proportion (Yang, and Jiang, 2003; Obla, 2010; and Yahia, and Kabagire, 2014).

The research is to study the mechanical properties of pervious concrete by replacing coarse aggregates with PKS. To achieve this, the following tests are carried out: sieve analysis and particle distribution for both granite and PKS, and determination of the properties (compressive, permeability and absorption rate) of pervious concrete using partial replacement of granite with palm kernel shell. This led to the determination of the optimum percentage of replacement of palm kernel shell as coarse aggregate without compromising the strength for which purpose it will serve.

Materials and Methodology

The tests and findings of the experiments conducted on the material used in this research work are described in this section. Majorly, the components are regular Portland cement, fine aggregate, coarse aggregate, and crushed PKS.

A sieve analysis test was carried out on the sand, coarse aggregate, and crushed PKS. This test was done for the coarse aggregate and fine aggregate by weighing 1kg of each aggregate when it has fully dried. The sieves were then manually aligned in descending order, that is, the larger size at the top and the sizes was reducing downward. The sieves were then secured tightly on each other. The measured aggregate was then poured into the topmost sieve; it was then shake manually horizontally for 10 to 15 minutes.

The coarse aggregate has a nominal size of 12.5 mm and is a normal weight aggregate. The bulk density, particle size distribution, porosity/water absorption, specific gravity, and other tests are carried out on coarse aggregate. All of these tests were carried out in line with BS 812, Part 101, from 1984, 1990, BS 812, Part 110, and 1990. There is need for the consideration of specific gravity of aggregate when dealing with light weight and heavyweight concrete. The specific gravity ranges between 2.5 and 3.0 and for palm kernel shell varies between 1.17-1.37.

The PKS was obtained (Plate 1) and then it was washed to remove all the fibre that surrounded the shell (Plate 2) which could influence the test results. To obtain the sufficient removal of the fibre it was sun-dried for three weeks and then it was crushed to an equivalent size of 12.5 mm and same tests carried out on coarse aggregate were also carried out on the PKS and then compared, this was done to ascertain that the replacement of the coarse aggregate can satisfy the engineering need as the granite.

Plate 1: Freshly obtained PKS with fiber.

Plate 2: Crushed and dried PKS without fiber.

Portable and clean water was used to mix the aggregate efficiently and thoroughly without segregation. The amount of water was controlled as it controls some concrete properties like workability, compressive strength etc.

The control mixes were done to get a result that can serve as reference for the other mixes. The controlled was produced with the mix ratio of 1:5 and w/c ratio of 0.31. This means one part of cement and five parts of coarse aggregate. it's this part of coarse aggregate that serves as 100%, while the part of the cement remained constant throughout the whole mix designed, the part of the coarse aggregate was then shared proportionally between the coarse aggregate and the fine aggregate which then produce the controlled mix of 100% granite, 90% granite 10% palm + kernel shell,100% of palm kernel shell and 90% palm kernel 10% sand.

Table 1: Materials proportion for the mix ratio

Mix ratio	cement	Granite(G)	Palm kernel shell (PKS)	Sand(S)	W/C ratio	Percentage of aggregate
1:5	1.25kg	6.13kg	0	0	0.31	100G
1:5	1.25kg		4kg	0	0.31	100PKS
1:5	1.25kg	5.52kg		0.61kg	0.31	90G 10S
1:5	1.25kg		3.6kg	0.4kg	0.31	90PKS 10S

The mix design for ratio 1:5 and w/c ratio of 0.31 was used based on the aggregate properties and design for pavements with natural stone or concrete pavers. The cement content and w/c ration was kept constant throughout the mix but the ranging proportion of the granite were based on the increase in the PKS i.e. 10%, 20%, 30%, 40% and 50%.

Table 2: Material Proportion for The Partial Replacement

Mix	cement	Granite(G)	Palm kernel shell (PKS)	W/C ratio	Percentage

ratio					
1:5	1.25kg	5.21kg	0.61kg	0.31	90G 10PKS
1:5	1.25kg	4.9kg	1.23kg	0.31	80G 20PKS
1:5	1.25kg	4.29kg	1.84kg	0.31	70G 30PKS
1:5	1.25kg	3.68kg	2.45kg	0.31	60G 40PKS
1:5	1.25kg	3.07	3.07kg	0.31	50G 50PKS

The ratio for mix of the aggregate of the pervious concrete was done in volume as per the size of the cubes and the sizes needed for the test to be carried out. Since, the weight of the palm kernel shell can't be compared to that of the granite. The percentage was removed from the 100% granite and the remaining weighed palm kernel shell was added to complete the required volume to fill the required mould.

The permeability of pervious concrete is necessary as it is specifically designed with pores for the passage of water. The test is necessary to know the amount of water amount of water and air percolating through the concrete matrix. Concrete permeability has an influence on durability, as it controls the rate water passing through concrete. This water percolating through pervious concrete may contain hazardous chemicals or harmful substances which may significantly have an effect on the strength of the matrix or cause cracking. The water penetration test was done by allowing 500ml water to flow in and out gently through the cubes only from one side with a surface area of 0.0225mm and height of 0.15mm over a constant period. This procedure was done in turn for each cube respectively.

Water absorption test is used to determine the rate at which a hardened concrete can absorb water with time. This is achieved by immersing fully the hardened concrete in water or concrete basin for a certain amount of time it can be checked at different intervals to know the rate in water ingested by a concrete cube with time.

The compressive strength was tested and obtained using the universal testing machine (UTM). The cubes mould of standard dimension 0.15m x 0.15m x 0.15m were demoulded, cured in curing tank and hardened concrete for 7, 14 and 28 days before crushing. The result gotten from crushing the cubes were recorded.

Results and Discussion

The specific gravity test was conducted when the aggregate was fully dried before adding water. The result obtained is presented in Table 3. The British standard BS 1330 Part 2 1995 explained the test procedure. It also explained that the result of specific gravity for fine aggregate should range between 2.5 to 3.0.

Table 3: Specific Gravity of the Aggregates

	GRANITE	PALM KERNEL SHELL
EMPTY PYCNOMETER(M1)	0.510KG	0.510KG
DRY SAMPLE(M2)	1.218KG	0.825KG
SAMPPLE + WATER (M3)	1.991KG	1.607KG
PYNOMETER +WATER(M4)	1.530KG	1.524KG
SPECIFIC GRAVITY	2.87	1.36

The result show that the specific gravity of granite is 2.87 which still falls between the range of BS 1130: PART 2: 1995 which is normal for crushed aggregates while PKS has a specific gravity of 1.36 which is lower than the specific gravity for aggregate as stated in accordance with BS 1130: PART 2: 1995 but it is within the range lightweight coarse aggregate which is explained to vary between 1.17 and 1.37.

The aggregate size distribution is to determine the size of the aggregates in sample of the aggregate respectively in accordance with BS 812: part 103, 1989. This is mostly done in graduation, which will contain standard graduation sieves in orderly arraigned way for a good aggregate. The impact of particle size can't be ignored as the distribution of well graded materials will have their impact on the workability of the concrete.

Table 4: Palm kernel shell distribution

Sieve size	Weight of retained	Percentage of retained weight	Cumulative percentage of retained weight	percentage passing
19 mm	0g	0	0	100
13.2 mm	48g	4.8	4.8	95.2
6.7 mm	869g	86.3	91.7	8.3
4.75 mm	58g	5.8	97.5	2.5
Pan	25g	2.5	100	0
Total	1000g		294	

Table 5: Granite distribution

Sieve size	Weight of retained	Percentage of retained weight	Cumulative percentage of retained weight	percentage passing
19 mm	0g	0	0	100
13.2 mm	11g	1.1	1.1	98.9
6.7 mm	784g	78.4	79.5	20.5
4.75 mm	167g	16.7	96.5	0.962
Pan	38g	3.8	100	0
Total	1000g		276.9	

Results from Tables 4 and 5 show some similarity in the distribution patterns.

The water absorption rate was done on the 28 days cubes after it has been fully cured and dried. The cube was wholly immersed into a curing tank over a certain period. The cubes were measured before and after the curing. Table 6 shows the water absorbed by each cube.

Table 6: Absorption percentage of control mixes

S/N	Percentage of aggregate	Dry weight	Wet weight	Absorbed water	Percentage of absorption
`1	100G	6.645	6.805	0.16	3.90
`2	100PKS	3.280	3.560	0.28	5.49

In table 6, the water absorption rates for 100% granite has the lowest absorption rate and the 100% palm kernel shell has absorption greater than the latter since palm kernel shell absorbs more water compared to granite.

Table 7: Water absorption rate of pervious concrete with partial replacement of granite with palm kernel shell

S/N	Percentage of aggregate	Dry weight	Wet weight	Absorbed water	Percentage of absorption
1	90G 10PKS	5.600	5.765	0.165	2.95
2	80G 20PKS	5.750	5.890	0.14	2.43
3	70G 30PKS	4.490	4.615	0.125	2.78
4	60G 40PKS	4.745	4.930	0.185	3.899
5	50G 50PKS	4.785	4.785	0.145	3.125

Table 7 shows that the higher the replacement of granite with PKS, the more the water absorbed. This confirms the perviousness of the concrete made with PKS.

When the mix ratio 1:5 has been established and the possible replacement ratio of the palm kernel shell, then an experiment was conducted on the strength of the cubes using the percentage 100G, 90G 10S, 100PKS, 90PKS 10S as the control mix. Then they were replaced in proportion as shown in Table and Table respectively.

Table 6: Compressive strength of the control

Mix proportion	Aggregate size	Control	Compressive strength (MPa)		
1:5	12.5mm aggregate size was used for both granite and palm kernel shell		7 days	14 days	28 days
		100G	4.753	6.276	7.844
		90G 10PKS	0.292	10.520	13.612
		100PKS	0.503	1.518	1.966

In analysis of the compressive strength from Table 6, the control mixes strength was increasing as the number of curing days was increasing. Since pervious concrete is known to gradually attain its maximum strength there is a possibility that it can attain more strength as the number of curing days is increasing.

The compressive strength of the pervious concrete produced from the control mixes from graph above including the partial replacement with palm kernel shell and sand (fine aggregate). The control mix and the replacement has been cured for 7 days, 14 days and 28 days. The peak of strength for the control in all mix is the 90% granite and 10% PKS. The strength of granite may be good, but it was improved with the addition of palm kernel shell. The strength of the mixture of palm kernel shall be low, after the addition of sand to the palm kernel shell it caused an increase in the strength and load bearing capacity.

Table 7 Compressive strength of pervious concrete partial replacement of granite with palm kernel shell

Mix proportion	Aggregate size	Replacements	Compressive Strength (MPa)		
	12.5mm aggregate size was used for both granite and palm kernel shell		7 days	14 days	28 days
		90G 10PKS	3.530	4.012	4.895
		80G 20PKS	3.825	4.305	5.427
		70G 30PKS	5.325	6.189	7.364
		60G 40PKS	4.062	4.533	4.977
		50G 50PKS	2.501	3.862	4.402

In the table above, the mix of palm kernel shell and granite shows that, in each of the column of different days there was an increase in strength of the pervious concrete with the 28 days being the highest strength but the rows of different mixes indicate that as the increase in strength got to the maximum strength of 70% Granite and 30% PKS there was decrease in strength as the percentage of the partial replacement increased.

Conclusion

The experiment, analysis, and discussion on the impact of aggregate on pervious concrete has been presented in this paper. It was then deduced from the study that palm kernel shell has a potential as a partial replacement in pervious concrete with no fine aggregate. The compressive strength was at its peak when the granite was at the partial replacement of 70% granite, 30% palm kernel shell for 7 days, 14 days and 28 days with the corresponding values of 5.325MPa, 6.189MPa and 7.364MPa respectively.

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