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Palm Kernel Shell as Coarse Aggregate Replacement in Pedestrian Interlocking Brick

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Abstract— This paper is based on the importance of recycling agricultural waste to be used as a constituent material to be used in hard landscaping. Pedestrian pavement or interlock is one of the important components in hard landscaping, due to some factors, it is termed as capital intensive material. Some of the contributing factors include coarse aggregate and cement which play a major role in that aspect. The choice of cost reduction lead to selection of material with the similar property with that of coarse aggregate for easy replacement. palm kernel shell is an agricultural waste which for several years has not been properly utilized in the construction industry. Some of the properties of palm kernel shell are determined in the laboratory, this include the compressive strength, the moisture resistivity of the material as well. slump test was carried out in order to determine the fresh property of the concrete. The results show that the average compressive strength of conventional aggregate for the three samples (A, B and C) at 7 days is 14.7N/mm2, while that of 14 days is 16.5N/mm2 and that of 28 days is 13.6N/mm2. Also, the average compressive strength of palm kernel shell for the three samples (A, B and C) at 7 days is 9.8N/mm2, 14 days is 10.3 N/mm2 as well as 28 days is 9.6 N/mm2. The result for moisture resistance test for palm kernel shell sample (A) is 14.8%, and that of (B) is 14.8%. Conventional aggregate sample (A) is 1.7% while that of sample (B) is 1.7%. The study concluded that palm kernel shell is a viable alternative to conventional coarse aggregate in production for pedestrian interlocks.

Keywords: Palm kernel shell, pedestrian pavement, coarse aggregate compressive strength.

INTRODUCTION

Aggregate is one of the basic and most important composition of concrete which help in deciding the strength when mixed with cement irrespective of its size. This help in deciding the compressive strength in concrete. As an important material which is recognized with high demand there is a possibility of scarcity of such material in the market.

One of the factors which requires proper attention is the source of aggregate which is usually gotten from hard igneous rock either mountains or Also rocks. This rock is quarried and broken down to smaller pieces in order to achieve the required sizes. The main problem surrounding this method is the environmental degradation of the beautiful surface of the earth which may never be the same again.

In order to avert such treat to the earth surface, there is need to look into replacement material which possesses similar or close to similar properties with the rocks.

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Hard landscaping is composed of basically concrete, stone and cement. Materials like walk way slab, concrete tile and interlocking bricks are recognized under this category. In order to achieve a solid concrete with its basic properties of compressive strength, there is need to focus on the coarse aggregate.

Engineers are challenged with the increasing concern of resource depletion and pollution worldwide, this posed a challenged to seek and develop an alternate renewable resource (Teo et al., 2016). These include Recycled material, by-products and waste materials in construction. Construction industries from most developing countries recently pay attention to usage of such material. This method can help increase advantage of both cost reduction and waste utilization within in the country. Allot of these by-products and agricultural waste are used as aggregate alternative for the production of concrete in construction waste.

The use of agricultural waste materials as replacement for coarse aggregates in pedestrian interlock has been investigated by various researchers. Some of the previous studies focused on utilizing palm kernel shells as replacements for coarse aggregate in pedestrian interlock.

As one of the importance of hard landscaping, it is not only to beatify the environment but to also protect it from erosion as well as prevent hosting of rodent and other little animals. Pedestrian interlock is one of the most advantageous hard landscaping material as it give room for maintenance without any damage done to it. Allot of hard landscaping required destruction to its surfaces in order to maintain either plumbing or electrical services laid below it.

As part of interlocking brick for landscaping, designs are made in different patterns and shapes as well as colors to please the eye.

CONCRETE AND CONCRETE COMPOSITION

As a composition of Concrete sand, cement, aggregate are the basic material needed to form then water serves as a catalyst in specified ratio, which hardens with time. The aggregate in this context refers to weathered rocks of sizes above 5mm2 (White, 2011).

Handoo in (2010) identifies concrete as a composite material consisting of a binding medium within which the particles are embedded While White (2011), describes it as a combination of aggregates and a paste composed of a Portland cement and water. These aggregates refer to sand and gravels or crushed rock.

According to Edward and Joseph (2016), Concrete is a rocklike material produced by mixing coarse and fine aggregates, Portland cement, water while giving it time to harden. The basic material for production of concrete are mostly within sight worldwide and concrete can be made into buildings ranging from hand held tools like shovel to computerized methods down to more sophisticated 3D method of building production .

Construction projects both civil and building recognizes concrete to be used globally due to the following reasons, Its close to perfect water resistivity, structural concrete member can be molded into a variety of shapes and forms in varying sizes with cost effectiveness and available material. (Mehta and Monteiro, 2016).

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Alengaram, et al., (2010) identify concrete as the name given to a mixture of rock particles in smaller size known as sand and larger ones described as gravels bound together using cement. This mixture is basically maneuvered to take the shape of its mold when cured at a suitable temperature and humidity to form a solid mass.

AGGREGATES IN CONCRETE

Aggregates is a collective term for the mineral material such as sand, gravel or crushed rock. Also aggregate are categorized into two basic types this include coarse and fine aggregate the fine aggregate known as sand is categorized under paste phase while the coarse aggregate is categorized under coarse phase (Handoo, 2010). Coarse aggregate is basically that material which contribute to the rigidity of the concrete, this makes up 70% - 80% of the volume of concrete. This means coarse aggregate plays a vital role in determining the physical properties of concrete.

This mineral material can be classified into three basic groups , it includes natural and artificial and recycled which are all used for concreting (Gambir, 2015).

As an important material which help determine the physical properties of concrete but on the other hand it is face with challenges of cost, transportation and environmental degradation during mining.

AGRICULTURAL WASTE AS AGGREGATE

The increasing concern of global pollution and massive material exhaustion has challenged allot of construction experts to research on new sustainable alternatives to replacing existing ones (Teo et al., 2016). In this context, Waste materials and by-products are the basic areas of focus. Third world countries are challenge to take advantage of such materials both agricultural and industrial waste to be utilized in the construction industries.

This will have help with multiple advantages of both cost of material and also a means of disposal of wastes in appropriately way.

According to research conducted by Adeboje and Yusuf (2017), it was observed that 10% replacement of coarse aggregate with coconut shell produced a compressive strength of 15.82 N/mm^2. This strength value reduced to 9.72 N/mm^2 when the replacement ratio was increased to 40%. They concluded that 10% replacement of coarse aggregate with coconut shell was recommended for concrete use to maintain the required compressive strength.

Another study conducted by Olutoge et al., (2018) evaluated the suitability of palm kernel shells (PKS) as a replacement for coarse aggregate in light weight concrete, the results showed that at 5% replacement of coarse aggregate with PKS, a compressive strength of 17 N/mm^2 was obtained. This was a significant increase from the value of 13 N/mm^2 obtained from the control sample without PKS. Therefore, they concluded that PKS is a good substitute for coarse aggregate in concrete.

Furthermore, a study by Olabanji et al., (2019) investigated the performance of interlocking concrete blocks containing coconut shell as a replacement for coarse aggregate. The results obtained showed that at 20% replacement, the compressive strength of the blocks was 15.7 N/mm^2 which met the structural requirements for

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pedestrian interlock. They recommended the use of coconut shells as a replacement for coarse aggregate in interlocking concrete blocks.

The use of coconut and palm kernel shells has been shown to be a viable replacement for coarse aggregate in pedestrian interlock. Adeboje and Yusuf (2017), Olutoge et al., (2018), and Olabanji et al., (2019) all suggested possible percentages of replacement that can be used to maintain the required compressive strength for interlocking blocks.

Toress et al., (2019) and Tay (2020) also reported that waste materials generated from industrial and agricultural activities can be recycled into new building materials, because they possess the ability of carbon dioxide (CO2) reduction when emitted and used little energy consumption to produce. In their natural, they can be directly used as aggregate or when processed.

Payam et al., (2010) made an observation on environmentally sustainable structures, especially in third world countries, the possibility of using industrial and agricultural wastes from different categories of industries as construction materials will be of high benefit and has a direct economic advantage.

As explained by Mehta (2011), the content of ordinary concrete basically includes 12% of cement while aggregate is 80% by mass. This means that globally in production, gravel, sand, and crushed stone are being consume at the rate of 10 to 11 billion tons annually.

Gambhir (2015) also highlighted that mining process and transport operations involving large quantities of aggregates consume so much energy, this dirrectly affects the ecology of the forest and river beds. The huge amount of energy consumption in aggregate production plays a role in global deposited of carbon dioxide into the atmosphere and subsequently the greenhouse effect.

As such, the need to alternate materials to normal aggregate in concrete is of paramount importance. Hence agricultural and industrial wastes which when inappropriately disposed can harm both humans and environment can be properly utilized by converting them from the original state to be used in various proportions with cement, thus reduce the cost in concrete works (Elinwa, 2013).

Delsye et al., (2016) reported that exploit of agricultural waste from its sources leads to sustainability in building construction industry, this will help in preservation of natural resources and also helps improve balance in ecological.

Gambir (2015) Classified waste materials into three categories.

- Organic wastes (agro wastes)
- Inorganic wastes (urban waste)
- Industrial wastes.

Another study by Ariyo et al., (2016) explored the use of PKS as a partial replacement for coarse aggregates in interlocking concrete blocks. The study revealed that up to 50% replacement with palm kernel shell showed no significant reduction in compressive strength, flexural strength, or abrasion resistance of the interlocking blocks.

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The study concluded that palm kernel shell could be used as a viable partial replacement for coarse aggregates in interlocking blocks (Ariyo et al., 2016).

Furthermore, a study by Chinda and Ezeokonkwo (2018).

PALM KERNEL AS AGGREGATE

Palm kernel shell is one of the most recognized agricultural waste which is being used in concrete, this shell is derived from oil palm tree (elaeis guineensis) which belong to the family of palms. It is an economically plant and predominantly found within West Africa and spread wide through the tropical regions. Basri et al., (2019) described the strong nature of palm kernel shell with its inability to deteriorate easily once embedded in concrete and therefore it does not deteriorate or leach to produce toxic substances within the composition.

Peter (2018), also investigated the performance of palm kernel shell as coarse aggregate in asphalt concrete, he observed that palm kernel shell can be used to replace coarse aggregate up to 30% before drastic reduction in strength becomes noticeable. He therefore recommended that roads with heavy vehicular movement should have not less than 10% of PKS and 100% replacement is can be used for lighter trafficked pavement in local settings.

A research carried out by Olutoge (2010) discussed the ability of sawdust and palm kernel shells to replacing of both fine and coarse aggregates in reinforced concrete slab production. His conclusion described 25% of sawdust and palm kernel substitution could reduce up to 7.45%. in cost of concrete production. His research pointed the possibility of partially replacement of fine aggregate and coarse granite with sawdust and palm kernel shell in the production of lightweight concrete respectively.

This give light to a research by Falade et al., (2010) which investigate the behaviors of lightweight concrete using periwinkle shells at elevated temperature; compressive strength of concrete as well as density and bond characteristics of the concrete matrix are the parameter measured. Outcome of the research displayed a decrease in compressive strength of concrete with increase in water/cement ratio and temperature but increases as the curing age is increased with cement content while the density decreased with increase in temperature. This affirmed that a concrete containing periwinkle shells is only suitable for light weigh structures that will be subjected to less than 300°C (Falade et al., 2010).

Ndoke, in (2016) found out that one of the basic agricultural waste that has a satisfactory rating in concrete production is palm kernel shell (PKS). In the decades, palm kernel shell (PKS) has been utilized by researchers as LWA to substitute conventional NWA in construction activities around Africa and Southeast Asia

Production of the Palm Kernel Shells

Annually, large amount of palm kernel shell is produced as waste material after palm oil production in palm oil industries (Ramli, 2013).

Ramli (2013) outlined that over four million hectres of palm trees is anticipated by the year 2020 in Malaysia. This means a direct increase in both palm oil production as well as its associated wastes such as PKS. Usually, the PKS is gotten from breaking palm nut in to pieces, it has a lightweight feature and also had in appearance and comes

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variety of shapes and sizes. The inability to utilize Palm kernel shells leads to environmental pollution especially in the southern parts of Nigeria.

A research in Ghana at Institute of Industrial Research on raw material resource assessment for activated carbon production, with attention on agricultural wastes like coconut shells, PKS and sawdust. Locations where this material were produced in large scale include the Volta Region, the Central Region, the Western Region, as well as the Eastern Region and the Ashanti Region were the focused destinations.

The study identified that production of coconut oil, palm oil and palm kernel oil are the basic contributing factors to generation of the raw materials which is coconut shells and palm kernel shells. Small scale traditional producers of such product are widely spread across the country whilst the larger industries are involved mainly in palm oil the production.

Due to the need for kernels and its oil by locals, access to PKS is made easier to come by in large quantities as majority of the industries break the shells to produce the kernels oil. The kernels could be further processed in some of the factories and others tried to sell them. The shell is usually dumped as unwanted material, this termed it as a waste.

Other shells like Coconut shell wastes, are spread over open space in the country and clearing them will require serious effort as compared to PKS. At the end, both wastes produced by traditional or local factories are used as fuel for cooking of other activities which required heat generation by burning.

In the established industries only little or less than 6% of the kernel shells discovered are sometimes mused fibre for heat generate for the boilers. The remaining are disposed as waste within the surrounding (Acquah, et al., 2019).

Physical Properties of Palm Kernel Shells

Abdullah (2013) described Palm Kernel Shells (PKS) as a material which possesses hard property as coarse aggregates, As explained by Okpala (2020), PKS has a varying specific gravity of between 1.17 and 1.37, while 4mm is found to be the maximum thickness of the shell. The material is also characterised with smooth and concave surface and not excluding convex surfaces which may likely affect the bonding with cement.

The PKS Shells basically becomes industrial wastes produced during processing of palm oil. The appearance of the waste is between black or dark grey.

The shells comes in variety of shapes and sizes different from one another, The shells surface are fairly smooth for both concave and convex faces. The thickness varies and depends on the species of palm tree from which the palm nut is obtained, It ranges from 0.15 - 8 mm (Basri et al., 2019, Okpala, 2020).

The water absorption capacity of the shell in 24h is within the range of 21 - 33%. This implies that PKS have relatively higher water absorption rate when compared to ordinary aggregates which has absorption rate of less than 2% (Neville, 2018).

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Study by Okpala, (2020) explained the causes of it high water absorption as a result of the porosity of the shell which is 37%. Mannan et al., (2016) outlined the improvement in porosity quality of PKS by using a method of pre-treatment, 20% of poly vinyl alcohol as a PVA solution is usually applied to it before usage. This method helps to decreased the absorption rate of PKS from 23.3 to 4.2%.

Due to the high porosity of PKS as compared to conventional aggregates, densities of compacted or loose bulk densities range from about 590 - 740 kg/m3 while its specific gravity ranges from 1.14 - 1.62.

The ranges of densities show that PKS are approximately 60% lighter in weight than conventional aggregates. Density of the shell are within the range of most lightweight aggregates (Okpala, 2020; Okafor, 2018). The hard nature of the shell gives it an advantage against deterioration.

Basri et al., (2019) outline the Los Angeles abrasion rate of the PKS and crushed stone was reported as 4.8 and 24%, This explains its good resistance to wear which is lower than that of conventional coarse aggregates.

Also, the aggregate impact value and aggregate crushing value of palm kernel shells aggregates were much lower as compared to conventional crushed stone aggregates. Okpalan (2020) reported the indirect compressive strength test of PKS aggregate as 12.10MPa with a standard deviation of 2MPa.

METHODOLOGY

The methods used in this paper include laboratory test to determine the compressive strength of the interlocking brick using the palm kernel shell as coarse aggregate and that of the traditional granite aggregate. Using an electrically controlled compressive strength maching testing machine. Analysis was done using the formula below to determine compressive strength of the concrete.

$$f_c = \frac{P}{A}$$

where:
(P) is the maximum load applied (in Newtons, N)
(A) is the cross-sectional area of the block (in square millimeters, mm^2).

As part of physical properties, the water absorption of PKS was determined in the laboratory using a pycnometer, a thermometer to determine the temperature and a heat source to extract moisture out of the material. after the lab test, The percentage water absorption for each sample was then calculated using the formula below.

$$\frac{\text{Mass of water absorbed}}{\text{Initial mass of substance (PKS)}} \times \frac{100}{1}$$

RESULT

COMPRESSION TEST ON CONCRETE CUBES
(Tested in accordance with BS1881:116)

The table below shows the compressive strength test for both normal aggregate and the palm kernel shell aggregate tested for Seven days, Eighteen days and Twenty-Eight days respectively.

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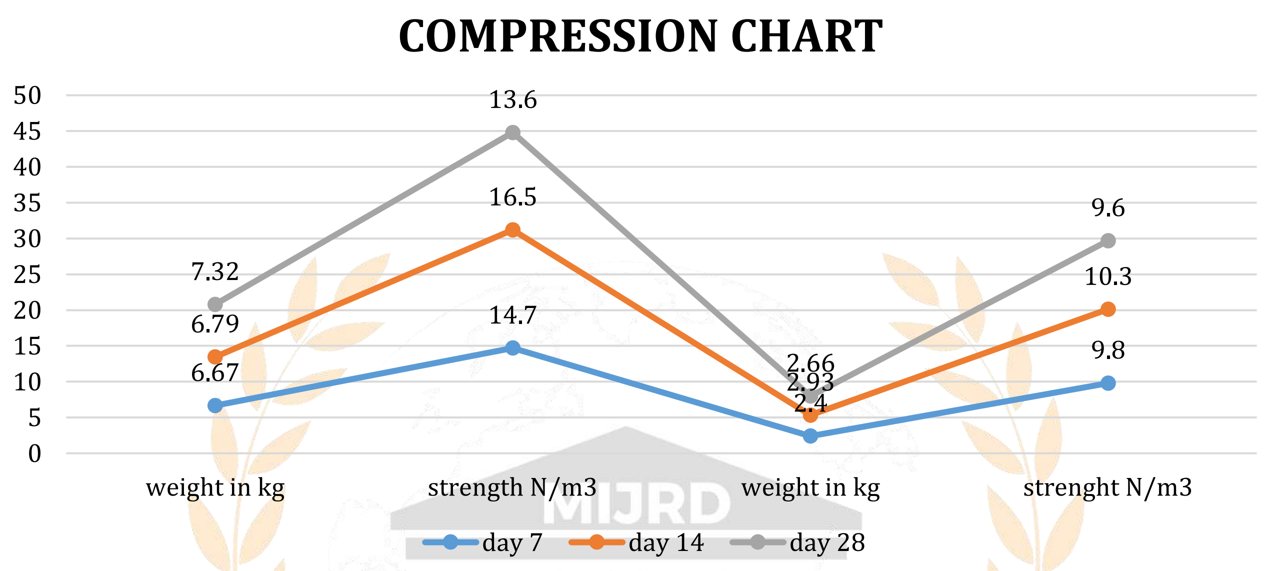
Compressive strength test comparison (Normal aggregate and pks)

Parameter	**Normal Concrete**		**Palm kernel shell Concrete**	
	Weight in kg	Strength N/m3	Weight in kg	Strength N/m3
Day 7	6.67	14.7	2.40	9.80
Day 14	6.79	16.5	2.93	10.3
Day 28	7.32	13.6	2.66	9.60



The weight of the normal concrete cubes increased from 6.67 kg at 7 days to 7.32 kg at 28 days. In contrast, the weight of the PKS concrete cubes was significantly lower, ranging from 2.40 kg at 7 days to 2.66 kg at 28 days.

This indicates that the Palm kernel shell concrete has a much lower density compared to the normal concrete. The normal concrete exhibited higher compressive strengths compared to the Palm kernel shell concrete at all ages.

At 7 days, the normal concrete had a strength of 14.7 N/mm², while the Palm kernel shell concrete had a strength of only 9.80 N/mm². The normal concrete continued to gain strength, reaching 16.5 N/mm² at 14 days and 13.6 N/mm² at 28 days. The Palm kernel shell concrete showed a slight increase in strength from 9.80 N/mm² at 7 days to 10.3 N/mm² at 14 days, but then decreased to 9.60 N/mm² at 28 days.

MOISTURE RESISTANCE TEST

Material/Particle size	**Initial mass**	**New mass (g)**	**Mass of water absorbed**	**Water absorbed (%)**
PKS Sample (A)	1.35	1.3	0.2	14.8
PKS Sample (B)	1.35	1.25	0.2	14.8
Conventional agg. (A)	2.90	2.95	0.05	1.7
Conventional agg. (B)	2.90	2.90	0.05	1.7

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From the result obtained, it can clearly be seen that water absorption percentage of PKS is 14.8 percent while that of normal aggregate is 1.7 percent which is less than the expected 3 percent.

CONCLUSSION

This study has investigated the feasibility of using palm kernel shell as a replacement for conventional coarse aggregate in the production of interlocking concrete blocks. Various tests were conducted to assess the suitability of these materials as a substitute for coarse aggregate in concrete production. The results showed that the palm kernel shell possesses desirable properties, making it a viable alternative to conventional aggregates in terms of compressive strength and moisture resistivity.

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