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Mechanical and Durability Properties of Palm Kernel Shell Ash Concrete

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***Abstract*—Concrete is the most commonly used material for construction purpose in the world. The expensive cost of concrete constituents such as cement, fine aggregate and coarse aggregate has made the need to search for alternative construction materials. Palm Kernel Shell Ash is an agricultural waste product which is burnt to form ash. This work examines the possibility of using Palm Kernel Shell Ash as partial replacement of cement. In this study PKSA was partially replaced as 0%, 6%, 12% and 18% in place of cement in concrete for M30 mix and compared with conventional concrete. The results show that high strength is attained at 6% replacement of PKSA with cement. Further the durability test shows that PKSA concrete is better resistance to acid, alkaline and water absorption.**

***Index Terms*—Compressive Strength, Durability, Flexural Strength, Palm Kernel Shell Ash, Split Tensile Strength, Workability**

I. INTRODUCTION

Concrete is the most widely used material on earth after water. Many aspects of our daily life depend directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available (Saravanan et al. 2015). There has been so much demand on construction materials in many countries around the world. Concurrently with the rapid expansion of construction, housing and other building, at the same time the rising cost of production with very serious shortage on construction material that will play a critical role in our long term future. The discovery of the alternative of conventional building materials that is cheaper and accessible became highly critical issue.

Due to the limited utilization of waste materials, the rate at which they disposed as landfill materials is expected to increase consequently leading to potential future environmental problem. Accumulation, burning and landfill of solid waste disposal could be expensive and undesirable. Reuse these materials in workable areas such as in the construction industry which is considered as very active area over the entire world is a current practice (Fernandez, 2007).

Palm Kernel Shell Ash (PKSA) has the potential to be used as a partial replacement for cement leading to reduction in the cost of construction and the convenient means of waste disposal, resource preservation and other environmental gains. The applications of agricultural wastes as aggregate or cement replacement material in concrete have engineering potential and economic advantage especially in low cost non-load bearing light weight concrete.

Quadri (2012) investigated the strength properties of Palm Kernel Shell Ash Concrete. The use of PKSA as a partial replacement for cement in concrete is discussed. The volume percentage of PKSA to Portland cement in the order 0:100, 10:90 and 30:70 and mix ratio of 1:2:4 were cast and tested. The compressive strength tests showed that 10% of the PKSA in replacement for cement was 22.8N/mm^2 at 28 days. This research showed that the lower volume of replacement will enhance the reduction of cement usage in concrete, thereby reducing the production cost.

Oluwadamilola (2016) examined the Compressive Strength of concrete containing Palm Kernel Shell Ash. PKSA was used as a partial replacement for ordinary Portland cement using mix 1:2:4. The results showed that at 28 days test cubes containing 5%, 10%, 15%, 20%, 25% and 30% PKSA content achieved compressive strength of 26.1MPa, 22.53MPa, 19.43MPa, 20.43MPa, 16.97MPa and 16.5MPa compared to conventional concrete. The results showed that the use of PKSA increased the water required to achieve the workable concrete mix.

Azunna (2019) studied the compressive strength of concrete with Palm Kernel Shell as a partial replacement for coarse aggregate. Biological local materials are dumped as waste in our environment, causing pollution and congestion as substitute materials. Therefore, this research work was carried out. The result of water absorption and compressive strengths showed that the water absorption capacity of Palm Kernel Shell is normal compared to plain concrete and the replacement of 10% and 25% gave 4.78N/mm^2 and 4.44N/mm^2 compressive strengths respectively.

II. MATERIALS USED

A. Cement

The Ordinary Portland Cement was used in this experiment to prepare the control specimens.

B. Fine Aggregates

Fine Aggregates commonly known as river sand free from debris were brought from nearby having 2.54 of specific gravity and size 4.75mm was used.

C. Coarse Aggregates

Coarse Aggregates known as crushed aggregates were also brought from nearby having 2.71 of specific gravity and nominal maximum size of 20mm were used.

D. Palm Kernel Shell Ash

The PKSA used for this experiment was obtained from village. The material was gathered and spread out dry for 24 hours before burning in an open air environment. Then the ash was taken to the laboratory and sieved using sieve number 0.425mm.

E. Water

Potable water accessible within the campus laboratory was utilized for the mixing and curing of concrete specimens.

III. EXPERIMENTAL INVESTIGATION

A. Mix Proportion

The concrete mix design was proposed by using IS 12269-2009. The grade of concrete used was M-30 with water to cement ratio of 0.4.

B. Workability

The workability of concrete is tested by using slump cone test and compaction factor test in order to produce homogeneous and workable mix.

C. Test on Hardened Concrete

The concrete cubes were cast and cured under normal conditions. Then the concrete cubes were tested at 7days, 14days and 28days for determining compressive strength. Further the split tensile strength of concrete cylinders and flexural strength of concrete beams were determined at the age of 14days and 28days.

D. Acid Attack Test

The cube specimens were cast to determine the acid attack of control concrete and concrete with PKSA. After 28days of curing in water, specimens were immersed in 5% sulphuric acid solution. Before the cubes were immersed in acid solution, the weight of specimens was noted. Then after 28days, the cubes were taken out and weighed again to determine the loss of weight due to acid attack.

E. Sulphate Attack Test

The cube specimens were cast to determine the sulphate attack of control concrete and concrete with PKSA. After 28days of curing in water, specimens were immersed in 5% sodium sulphate solution. Before the cubes were immersed in alkaline solution, the weight of specimens was noted. Then after 28days of immersing in alkaline solution, the cubes were taken out and weighed again to determine the loss of weight due to sulphate attack.

F. Water Absorption Test

The concrete cubes were cast and tested after 28 days continuous curing period for water absorption test. Then the cube specimens were dried for 24 hours at normal temperature. The average dry weight of concrete specimens after removing from moulds was measured and the average weight of cube specimens after submerging in water for curing was measured. Then the percentage of water absorption was measured for each concrete specimen.

IV. RESULTS AND DISCUSSIONS

A. Workability of concrete mixes

1) Slump Cone Test

The results of the slump cone test performed on the concrete are shown in Table 1.

Table 1 Slump Cone Test Results

SI. No	*% Replacement of PKSA*	*Slump Value (mm)*
1	*0%*	*115*
2	*6%*	*92*
3	*12%*	*80*
4	*18%*	*75*

The height of slump was reducing as the percentage replacement with PKSA was increasing as shown in Fig. 1. The workability of fresh PKSA concrete measured by the slump test reduced as the PKSA content increased. This was due to the fact that PKSA absorbed more water when compared to cement and thus decreasing the workability of concrete mix.

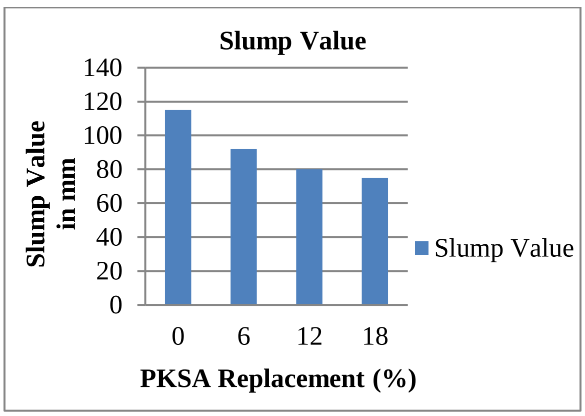

Fig. 1 Slump Cone Test Results

2) Compaction Factor Test

The results of the compaction factor test performed on the concrete are shown in Table 2.

Table 2 Compaction Factor Test Results

SI. No	*% Replacement of PKSA*	*Compaction Factor*
1	*0%*	*0.92*
2	*6%*	*0.90*
3	*12%*	*0.87*
4	*18%*	*0.84*

The compaction factor values reduced as the PKSA content increased as shown in Fig. 2. These results indicated that concrete became less workable as the PKSA percentage increased and the more water is required to make mixes more workable. The high demand for water as the PKSA content increased due to high amount of silica in the mixture.

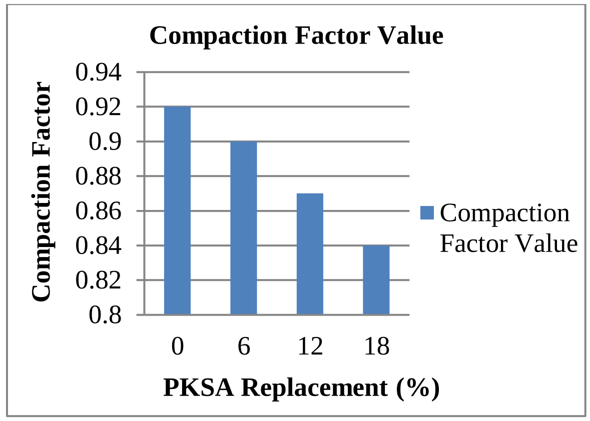

Fig. 2 Compaction Factor Test Results

B. Compressive Strength Test

The compressive strength of concrete is done with the help of compression testing machine and the results are shown in Table 3.

Table 3 Compressive Strength Test Results

% Replacement of PKSA	*7 Days (N/mm^2)*	*14 Days (N/mm^2)*	*28 days (N/mm^2)*
0%	*23.49*	*28.40*	*36.52*
6%	*25.09*	*29.53*	*38.46*
12%	*22.15*	*26.24*	*35.10*
18%	*20.22*	*24.35*	*33.14*

The compressive strength varied with the increase of percentage replacement of Ordinary Portland Cement with Palm Kernel Shell Ash as shown in Fig. 3. From the above values of compressive strength of concrete cubes casted with different % replacement of OPC with PKSA, we could observe that the strength was more for 6% replacement of PKSA. At the same time, the strength was getting reduced for 12% replacement and beyond it.

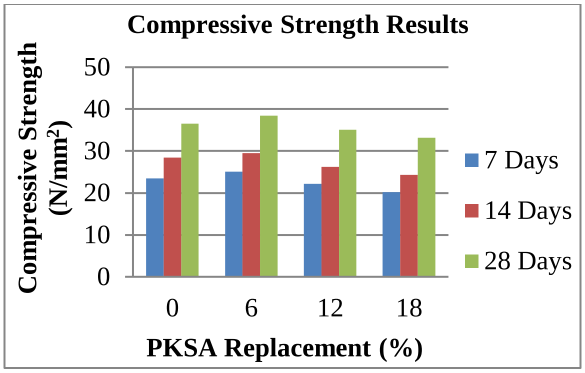

Fig. 3 Compressive Strength Test Results

C. Split Tensile Strength Test

The split tensile strength of concrete is done with the help of compression testing machine and the results are shown in Table 4.

Table 4 Split Tensile Strength Test Results

% Replacement of PKSA	*14 Days (N/mm^2)*	*28 days (N/mm^2)*
0%	*3.10*	*3.25*
6%	*3.27*	*3.49*
12%	*2.52*	*2.76*
18%	*2.49*	*2.64*

The split tensile strength of concrete cylinders at 6% replacement was more when compared to that of the control mix at 0% replacement as shown in Fig. 4. Beyond 6%, the split tensile strength decreased with the increase in the percentage replacement of Ordinary Portland Cement with Palm Kernel Shell Ash. There was an increase in the strength from 0% to 6%. Again in the case of 12% and 18%, the strength decreased. So the optimum percentage of replacement is 6%.

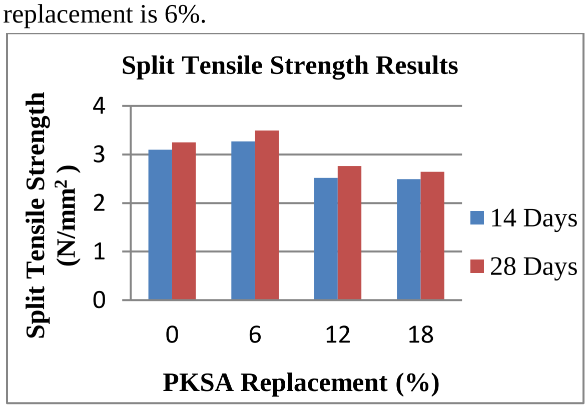

Fig. 4 Split Tensile Strength Results

D. Flexural Strength Test

The flexural strength of concrete is done with the help of flexural testing machine and the results are shown in Table 5.

Table 5 Flexural Strength Test Results

% Replacement of PKSA	*14 Days (N/mm^2)*	*28 days (N/mm^2)*
0%	*2.74*	*2.92*
6%	*2.85*	*3.01*
12%	*2.40*	*2.56*
18%	*2.17*	*2.33*

The flexural strength test was carried at 14days and 28 days as shown in Fig. 5. An increase in flexural strength was observed at 6% replacement of cement by palm kernel shell ash and thereafter decreasing. Flexural strength for concrete mix with 12% and 18% palm kernel shell ash content was found to be less than that of conventional concrete. Flexural strength decreased with increasing palm kernel shell ash content.

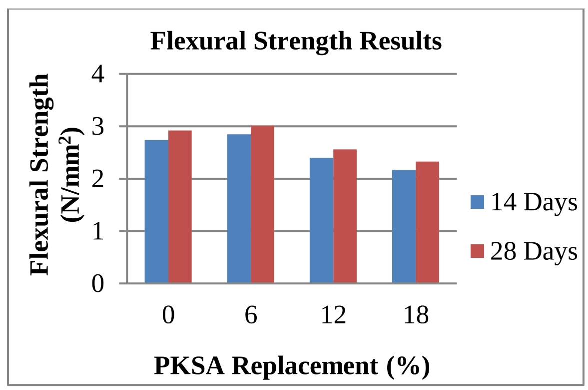

Fig. 5 Flexural Strength Results

E. Durability Test

1) Water Absorption Test

Water absorption test was carried out for all mixtures and the percentage water absorption was measured. The percentage water absorption increased with increase in palm kernel shell ash content. The highest value of water absorption was found for concrete mix with 18% palm kernel shell ash content. The percentage water absorption for all mixtures is shown in Table 6.

Table 6 Water Absorption Test Results

% Replacement of PKSA	*Wet Weight (kg)*	*Dry Weight (kg)*	*% Water Absorption*
0%	*2.790*	*2.762*	*1.01%*
6%	*2.692*	*2.657*	*1.32%*
12%	*2.618*	*2.575*	*1.67%*
18%	*2.554*	*2.506*	*1.91%*

2) Acid Attack Test

The weight is reduced with increase in the percentage replacement of PKSA as shown in Table 7. Therefore, the acid attack is more severe in conventional concrete than optimum mix.

Table 7 Acid Attack Test Results

PKSA Content (%)	*Average Weight*		*Loss (kg)*	*% Loss*
	Before Acid Attack	*After Acid Attack*		
0%	*2.910*	*2.864*	*0.046*	*1.58%*
6%	*2.873*	*2.831*	*0.042*	*1.46%*
12%	*2.786*	*2.750*	*0.036*	*1.29%*
18%	*2.764*	*2.743*	*0.021*	*0.76%*

3) Sulphate Attack Test

Sulphate attack test was conducted for all mixtures and the percentage loss was calculated as shown in Table 8. The weight is reduced with increase in the percentage replacement of PKSA. Therefore, sulphate attack is more for conventional concrete compare to optimum concrete.

Table 8 Sulphate Attack Test Results

PKSA Content (%)	*Average Weight*		*Loss (kg)*	*% Loss*
	Before Sulphate Attack	*After Sulphate Attack*		
0%	*2.934*	*2.895*	*0.039*	*1.33%*
6%	*2.905*	*2.870*	*0.035*	*1.20%*
12%	*2.813*	*2.784*	*0.029*	*1.03%*
18%	*2.792*	*2.775*	*0.017*	*0.61%*

V. CONCLUSION

Based on the scope of work carried out in this investigation, the following conclusions are drawn:

- Workability of concrete mix decreases with increase in palm kernel shell ash content.
- At 6% replacement of palm kernel shell ash the increase in compressive strength of PKSA concrete mixes compared with control mix of concrete thereafter decreasing compressive strength.
- Split tensile strength and flexural strength decreases with increase in PKSA content and is more than conventional concrete at 6% replacement of PKSA.
- Test conducted on water absorption shows that the optimum mix with PKSA absorbs more amount of water when compare to conventional mix. This may be attributed to the passage of water admitting through pores by the palm kernel shell ash.
- Acid attack and Sulphate attack test shows that optimum mix has better resistance to acid and sulphate attack when compare to conventional concrete.

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