INFLUENCE OF NUT OIL EXTRACTS ON PROPERTIES OF CEMENT PASTE AND MORTAR

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Abstract

The natural environment is endowed with resources that are useful in the everyday life of a man. In line with the need to explore and make good use of the resources made available by nature and the adaptation of sustainable construction practice which has to do with the use of materials that are environmentally friendly, this research is directed towards accessing the effect of tree nut oil (coconut and palm kernel oil) as admixtures on the properties of cement paste and mortar. Specific properties accessed includes the consistency of cement paste, the setting times of cement paste, compressive and flexural strength of cement mortar, as well as water absorption test. A mix ratio of 1:3 was employed with a water cement ratio of 0.45. the mortar specimens were prepared with varying dosage of the admixtures being (0%, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%). Also, tests were carried out after curing in water for 3, 7, 14, and 28 days. The result of the test carried out on the specimens indicated that coconut and palm kernel oils can be effectively used as admixture in the preparation of cement mortar. The introduction of these oils into cement paste was observed to increase the consistency of the paste above the consistency of the control specimen, hence delayed initial setting time and final setting time of cement paste.

On the properties of cement mortar, the oils were seen to significantly improve on the compressive and flexural strength of cement mortar. Water absorption was significantly reduced. Conclusively, coconut and palm kernel oil can be considered a bio-admixture having water repellent abilities.1.5% replacement of cement with the admixtures performed significantly on all properties and thus be considered the optimum dosage of the admixtures in mortar production.

Key words: coconut oil, palm kernel oil, bio-admixture, set retarder, setting time, compressive, flexural strength

INTRODUCTION

The current socio-economic condition prevailing in our society nowadays demands sustainable construction practices. Sustainability has to do with the uses of green or recycled products; Sustainable growth in the construction industry can be achieved only if the materials that are created and used and the structures that are designed and built are eco-friendly, cost-effective, ductile and give durable service performance over their specified design life (CIRIA, 1997).

The traditional cement mortar is composed of cement, sand and water. Beside these constituents; it may also contain admixtures aiming at improving the mortar strength and durability. The idea of improving mortars properties by using various admixtures is not new but known already by the first civilization (Vitruvius, 1999). Mortars used in ancient times were sometimes of poor quality therefore masons made use of various additives to achieve desired properties.

The production and placement of mortar with an adequate strength and durability can be influenced by a number of factors, such as the prevailing weather condition, the distance between the production and the placement area, as well as the characteristics of the mortar materials; for instance, very high or low weather temperature affects the strength performance of placed mortar, and this can result in mortars that are weak in strength, and also porous. Porous in the sense that, the pores in the body of the mortar are not made tight enough to restrict the inflow of water into the interiors of the placed mortar, high level of water absorption in placed concrete or mortar can be detrimental to its strength and durability, due to the fact that water has been considered the carrier of most aggressive chemicals going into placed mortar. Mortars, as well as other concrete elements should be made stiff enough to repel moisture which can carry along aggressive chemicals. It is therefore on this note that admixtures (water repellent admixtures) should be introduced into the fresh mortar so as to take care of some certain properties of the produced mortar like its ability to repel water to the greatest possible magnitude.

Researches have revealed the suitability of many materials as admixtures in construction, some which are industrial based products while some are locally sourced, and most of these locally sourced admixtures have biological origin and are classified as bio-admixtures. Bio-admixtures are those admixtures that have bio origin, mostly obtained from plants. Plants has always been recognized as a source of naturally occurring compounds, with some having rather complex molecular structures and also having varying physical properties (Magufuli, 2009). Some of the locally sourced admixtures include the vegetable Oils from Sunflower, Olives, Soya Beans, Peanuts, Linseeds, Corn and Rapeseeds (Justnes, 2003). There have been found to be good water repellent admixtures in mortar. Other examples of bio admixtures are extracts from cypress tree (Woldemariam et al, 2014), water hyacinth (Sathya et al., 2014), pine tree bark (Chege et al, 2014), and blue gum plant (Woldemariam et al, 2015), plantain pseudo-stem pitch fluid (PPPF)(Umoh and Nnana, 2014) .

In view of sustainable development and to encourage the inclusion of local products in construction, this study seeks to examine the effect of vegetable oil extracts (coconut and palm kernel oil) on the properties of cement paste and mortar, in order to ascertain the suitability of these vegetable oils, in mortar production and also to encourage sustainable construction practices.

LITERATURE REVIEW

Tree nut oils can be extracted or processed by pressing, roasting, solvent extruding, supercritical fluid extraction (SFE) etc. Each processing approach has influence on the oil oxidative stability, oils obtained by supercritical fluid extraction (SFE) tend to increase thermal oxidative instability than pressing and solvent extruding, whereas roasting breaks oil-bearing cells and decrease oil's viscosity (Gong & Pegg,2015; Shahidi & John, 2013; Kamal-Eldin & Moreau, 2009).

Admixture is defined as material other than water, aggregates, hydraulic cement, and fiber reinforcement that is used as an ingredient of concrete or mortar and is added to the batch immediately before or during mixing (ASTM C125). Agricultural waste such as palm kernel shell ash, groundnut shell ash, rick husk ash, corn cob, Lignocellulosic wastes has been used as admixture to improve the properties of cement paste or concrete (Fadele & Ata,2016; Ettu et al, 2013; Karade, 2010; Kolawole & Mbachu,1998) and encouraging results have been reported.

BS EN 934-2 defines a set retarding admixture as an admixture which extends the time commencement of transition of the mix from the plastic to the rigid state. Umoh and Nnana (2014) assessed the suitability of plantain pseudo-stem pitch fluid (PPPF) as bio-admixture and was observed to retard the setting time of cement paste and mortar significantly, thus a potential set retarding admixture.

EXPERIMENTAL DESIGN

Materials

The cement used was Portland limestone cement (CEM II/ B-L 32.5R) produced in conformity with the Nigerian Industrial Standard (NIS 444-1: 2003). The fine aggregate used satisfied the requirement of BS 882:1992. Water for the mixing and curing purposes was fetched from the tap of the building material laboratory, University of Uyo.

The coconut fruits were first separated from the nuts, washed and ground. The coconut oil (CO) was obtained from the fruits by pressing out the water from the ground fiber and then roasting the extract to get oil. While the palm kernels (PK) were also separate from shells and the oil extracted by roasting.

SPECIMEN PREPARATION AND PRODUCTION

Cement paste

Cement pastes were prepared with cement and water as control sample. Thereafter, varying proportions of coconut oil or palm kernel nut oil in percentages of 0.5%, 1%, 1.5%, 2%, 2.5% and 3% by weight of cement in each case, and standard consistency and setting times of the pastes were determined.

Mortar Mix Proportion

Mix ratio of 1:3 (i.e. one part of cement to three parts of sand) and a 0.45 water cement ratio were considered the basis for the preparation of specimens. Materials were proportioned using batching by weight. The first mix being the reference mix was carried out without the introduction of admixtures i.e. mix with (0% coconut oil, 0% palm kernel oil). The admixtures were subsequently added in quantities of 0.5%, 1%, 1.5%, 2%, 2.5% and 3 % replacement by weight of cement. The proportion of materials is presented on Table 1.

Table 1: Mix Proportion

Mix ratio	Dosage of extracts (%)	Weight of cement (kg)	Weight of sand (kg)	Weight of admixture (kg)	Weight of Water (kg)
1:3	0	2	6	0	0.9
1:3	0.5	1.99	6	0.01	0.896
1:3	1	1.98	6	0.02	0.891
1:3	1.5	1.97	6	0.03	0.887
1:3	2	1.96	6	0.04	0.882
1:3	2.5	1.95	6	0.05	0.878
1.3	3	1.94	6	0.06	0.873

Mortar Production

Mortar mix of cement and fine aggregate in the ratio of 1:3 with water- cement ratio of 0.45 was adopted as control. Coconut oil (CO) or palm kernel (PK) oil of 0%, 1%, 1.5%, 2%, and 2.5% were used as water replacement by weight in the mix in each case. Each of the admixtures was added to the mixing water and thoroughly mixed. The fresh mortar was placed in a cube mould (50mm x 50mm x 50mm) and prism mould (160mm x 40mm x 40mm) half-filled, at the first instance, and tamped with 25 strokes and the remaining half filled and compacted with the same strokes. The mortar specimens were left undisturbed for 24 hours in the laboratory after which they were de-moulded and cured in a curing tank prior to testing.

TESTING OF SAMPLE AND SPECIMENS

Consistency and setting times of cement paste

The consistency and setting times of cement paste was measured by the Vicat apparatus as per the requirement of BS EN 196-3 and as shown in Figure 1.

Figure 1: Determination of Setting Time using Vicat apparatus

Compressive strength test

The compressive strength was carried out to ascertain the strength of the mortar cubes after a particular treatment. Test was carried out on the specimens at the curing ages of 3, 7, 14 and 28 days to ascertain the strength gain by the specimen at those ages of curing. The test was carried out using a compressive testing machine available at the building department lab. University of Uyo as shown in Figure 2.

Figure 2: Compressive Strength Testing Machine

Flexural strength of mortar

The flexural strength of a hardened mortar prism specimen (160mm x 40mm x 40mm) was determined by the three-point loading according to BS EN 1015 - 11 (1999). The test was conducted after 3, 7 14, and 28 days of curing the prism specimens. The testing machine had two (2) supporting rollers and a third loading roller. The prism specimens were placed on the supporting rollers and the third roller was kept above it (and mid- way between the supporting rollers) (Figure 3). Load was then applied to the test specimens and the flexural strength was calculated as follows: $\mathbf{F} = \frac{1.5wl}{bd^2}$, Where F is the flexural strength in N/mm^2; w is the load applied on the specimen; b and d are the internal dimensions of the prism mould; L is the distance between the supporting rollers.

Figure 3: Mortar prism during flexural strength test

Water Absorption test

This was conducted as per the specifications in ASTM C1403-15. Mortar specimen of size 160mm x 40 mm x 40mm was used for this test, at the curing ages of 28 days. The specimens being taken out of the curing tank after 28 days was allowed to get dried. Measurement was taken immediately the specimens was taken out of water, continuous measurement was carried out on the specimens until there was no change in weight after some days, that measurement was considered (W_1), there after it was immense in water for twenty-four hours, before taken out to take the final measurement (W_2). The rate of water absorption was determined using ($W_2 – W_1$) expressed in percentage.

RESULTS AND DISCUSSIONS

Physical and Chemical Properties of coconut oil

The results of the chemical analysis (fatty acid profile) carried out on coconut oil as presented on Table 2 indicated that the predominant fatty acid in coconut oil and Palm Kernel Oil is Lauric which is responsible for most of the characteristic of the oil. Lauric acid (or dodecanoic acid) is a saturated fatty acid with a 12-carbon atom chain. As a component of triglycerides, it comprises about half of the fatty acid content in coconut milk, coconut oil, laurel oil, and palm kernel oil (Beare-Rogers et al, 2001). Like many other fatty acids, lauric acid is inexpensive, has a long shelf-life, and is non-toxic and safe to handle. It is mainly used for the production of soaps and cosmetics.

For these purposes, lauric acid is neutralized with sodium hydroxide to give sodium laurate, which is a soap. Most commonly, sodium laurate is obtained by saponification of various oils, such as coconut oil (Anneken, et al, 2006).

The present of palmitic acid in coconut oil is a great boost as to its water repellant abilities. Palmitic acid is naturally present in coco butter, soya bean and sun flower. Meanwhile, these vegetables have already been proven to have water repellent abilities (Justnes et al, 2003).

Table 2: Chemical Analysis of Coconut Oil (PO) and Palm Kernel Oil (PK)

Free Fatty Acid	Constituent (Mg/100g)	
	Coconut Oil (PO)	Palm Kernel Oil (PK)
Caproic acid	0.40	1.28
Elaidic acid	7.30	1.04
Caprylic acid	6.60	3.72
Lauric acid	46.2	43.50
Myristic acid	16.4	1.50
Palmatic acid	8.20	0.30
Stearic acid	3.10	4.80
Oleic acid	7.50	4.00
Linolic acid	1.80	10.50
Linoleic acid	0.10	0.30
Heneicosylic	0.01	3.40
Arachidonic	1.00	1.90
Margaric acid	ND	1.1
Others	0.96	20.36

Consistency of Cement Paste

The consistency of the cement paste with varying dosage of coconut oil and palm kernel oil is presented in Table 3. The consistency of cement paste with 0% dosage falls within the standard consistency of cement paste of between 27 – 33 %. However, the introduction of the extracts increased the consistency of the paste, coconut oil (CO) recorded its highest consistency of 33.03% at 2% dosage replacement of cement, while palm kernel oil (PK) record the highest consistency of 35.67% at 2.5% replacement of cement. This increase is attributed to the high content of Lauric acids (46.2% and 43.5% for Coconut oil and palm kernel oil respectively) in the oils.

Table 3: Consistency of Cement Paste with different dosages of admixtures

Dosage of Extract (%)	Consistency (%)	
	Coconut Oil (CO)	Palm Kernel Nut Oil (PK)
0.0	33.00	33.00
0.5	32.56	33.23
1.0	32.00	32.70
1.5	32.24	34.61
2.0	33.03	35.00
2.5	32.93	35.67
3.0	32.71	35.45

Initial and Final Setting Time of Cement Paste

In Table 4, the initial setting time of cement paste as well as those incorporating the extracts met the standard minimum initial setting time of 45 minutes and maximum final setting time of 600 minutes (NIS 447: 2003). A delay in initial setting time and an increased final setting time was observed on introduction of coconut and palm kernel oil as admixture to the cement paste. The results confirmed that tress nut oil extracts can act as set retarding admixtures as specimen which is attributed to the Palmitic acid and Linoleic acid present in the extracts (see table.2) which supports Sathya et al, (2014).

Table 4: Result for the Initial and Final Setting Time of Cement Paste

Dosage of admixtures (%)	Coconut Oil		Palm Kernel Nut Oil	
	Initial setting time (hr : mm)	Final setting time (hr : mm)	Initial setting time (hr : mm)	Final setting time (hr : mm)
0.0	1.58	6.19	1.58	6.19
0.5	2:00	5:50	3:23	7:20
1.0	2:00	5:10	2:55	6:42
1.5	2:18	6:40	2:47	7:18
2.0	2:24	6:54	2:42	8:10
2.5	2:45	6:30	2:33	8:28
3.0	1:58	6:46	2:47	7:10

COMPRESSIVE STRENGTH OF CEMENT MORTAR

Table 5, presents the result of the compressive strength of mortar with varying dosage of coconut and palm kernel oils at different curing ages. The control specimens record a 15.8 N/mm^2 strength at 3days, at 0.5 % incorporation of the extracts, meanwhile other specimen treated with the coconut oils recorded a 7% increase in early strength development while palm kernel showed a 2.5% decrease in early strength, an optimum increase strength of 8.8% for coconut and 6.9% for palm kernel at 1.5% extract incorporation. After 7 days of curing, the control specimen recorded a value of 41.8% increase in strength, coconut and palm kernel oil recorded decrease in strength of 21.3 N/mm^2, 20.2 N/mm^2 and 19.6 N/mm^2, 19.1N/mm^2 on 0.5% and 1% extracts incorporation respectively. The highest strength development at 7day curing was recorded by 2% Palm kernel oil (22.9 N/mm^2). The optimum strength development at 14 days of curing was reported for 1.5 % extract incorporation, with an increase of 3.6% and 2.3% for Coconut oil and Palm kernel oil respectively.

at the 28 day of curing of mortar, 1.5% incorporation of coconut and palm kernel oil recorded a strength increase of 6.9% and 3.3% respectively, while decreasing gradually to 41% and 36% respectively at 3%.

Table 5: Mean Compressive Strength of Mortar

Extract	CO compressive strength (N/mm^2)				PK Compressive strength (N/mm^2)			
Percentage (%)	**3 days**	**7 days**	**14 days**	**28 days**	**3 days**	**7 days**	**14 days**	**28 days**
0	15.8	22.4	30.2	36.4	15.8	22.4	30.2	36.4
0.5	16.9	21.3	26.1	31.3	15.4	20.2	24.2	29.9
1.0	14.6	19.6	25.3	29.7	14.1	19.1	23.4	27.5
1.5	17.2	21.8	31.3	38.9	16.9	20.6	30.9	37.6
2.0	16.5	22.8	28.5	29.5	15.3	22.9	23.3	25.8
2.5	16.8	21.7	21.8	27.8	11.7	16.2	19.5	23.7
3.0	17.0	21.7	22.8	25.8	11.5	16.0	18.8	23.3

FLEXURAL STRENGTH OF CEMENT MORTAR

Table 6 Shows the flexural strength of mortar at different curing ages. The control specimens recorded the highest early flexural strength development of 2.69 N/mm^2 at 14 days curing age. There was a decrease in flexural strength with the control specimens on the 7 days of curing, but a remarkable flexural strength recorded with palm kernel oil having the highest strength of 2.13 N/mm^2 with 1.5% and decreases again to 1.75 N/mm^2 at 14days.

At 28 day of curing, the control specimen reported an increase strength of 2.43 N/mm^2 while 1.5% incorporation of Coconut and palm kernel oil recorded optimum flexural strengths of 1.98 N/mm^2 and 2.19 N/mm^2 respectively, these values of flexural strength were within the standards specified by ASTM C348-14.

Table 6: Mean Flexural Strength of Mortar

Extract	CO Flexural strength (N/mm^2)				PK Flexural strength (N/mm^2)			
Percentage (%)	**3 days**	**7 days**	**14days**	**28days**	**3 days**	**7 days**	**14 days**	**28 days**
0	2.24	1.86	2.69	2.43	2.24	1.86	2.69	2.43
0.5	1.37	1.46	1.51	1.57	0.98	1.16	1.46	1.02
1.0	0.98	1.42	1.11	1.24	1.55	1.43	1.46	1.58
1.5	1.81	1.81	1.89	1.98	1.69	2.13	1.75	2.19
2.0	1.38	1.93	1.93	1.49	1.81	1.88	2.10	1.58
2.5	1.29	1.43	1.65	1.37	1.46	1.38	1.69	1.46
3.0	1.37	1.37	1.52	1.55	1.32	1.44	1.69	1.30

WATER ABSORPTION OF CEMENT MORTAR

The result of the water absorption test carried out on the specimens are presented on Table 7. Water absorption expresses the ability of a material to allow or permit the inflow of water into its interiors; this can be due to the porosity of the materials. Highly porous material will allow the inflow of more water. The control specimen recorded the highest porosity level of 4.66%, there was a reduction in water absorption at all dosage of the extracts in the mix. the water absorption rate trend decreased with increase in the dosage of extract. At 3% incorporation of coconut and palm kernel oil 0.57% and 0.3% were recorded respectively. The inclusion of water repellent admixture in a mix reduces water absorption and the passage of water through the matrix by capillary action (Comex, 2006). The extracts in the mix principally acted by blocking or lining the capillaries or pores within the matrix. Alternatively, some materials produce a hydrophobic (water repelling) action at the surface of the material, making the ingress of water difficult. With the observed results, coconut and palm kernel oils can be considered a water repellent admixture conforming to ASTM C1403-15 stipulation.

Table 7: Water Absorption Results

Dosage of Admixture	Percentage Water absorption	
	Coconut Oil	Palm Kernel Oil
0	4.66	4.66
0.5	3.17	3.81
1	2.96	3.41
1.5	0.73	1.28
2	0.67	1.05
2.5	0.65	0.74
3	0.57	0.30

CONCLUDING REMARKS

Given the Numerous benefits of tree nut oil extracts as potential bio-admixtures in cement paste and mortar, the following remarks can be drawn:

1. Coconut and palm kernel oil can be used in mortar production as a bio-admixture given its influence on the properties of cement paste and mortar.
2. Coconut and palm kernel oil can increase the consistency of cement paste significantly.
3. Coconut and palm kernel oil extracts could be used as setting time retarder in Portland cement mortar.
4. Coconut and palm kernel oil extracts are rich in Lauric, Palmitic and Linoleic acids responsible for delay in setting time and consistency.

5. Coconut and palm kernel oil can significantly reduce the level of water absorption in cement mortar to the greatest possible magnitude.

6. The optimum dosage of 1.5% coconut and palm kernel oil could significantly improve compressive and flexural strength of Portland cement mortar.

5.3 RECOMMENDATIONS

Based on the findings made at the course of this research, the following recommendations have been proposed.

1. The cultivation of coconut and palm kernel oil should be greatly encouraged, as this on the long run will help conserve the environment also making available raw materials for the production of coconut and palm kernel oil.

2. The use of locally sourced materials in the construction practice should be greatly encouraged and researches in local materials funded by the government.

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