International Journal of Environmental Studies and Safety Research
ISSN: 2536-7277 (Print): 2536-7285 (Online)
Volume 6, Number 1, March 2021
http://www.casirmediapublishing.com

AN EXPLORATIVE STUDY ON THE SUITABILITY OF JUTE LEAF (*Corchorus spp.*) POWDER AS AN ADMIXTURE IN CONCRETE PRODUCTION

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ABSTRACT: The properties and performance of concrete are largely determined by the properties of the cement paste. Admixtures in concrete confer some beneficial effects such as acceleration, retardation, air entrainment, water reduction, plasticity etc., and these effects are due to their action on cement. Classical chemical additives to concrete are considered as one of important factors for improving the properties of concrete in structural designs. Today the construction industry is in need of finding effective materials for increasing the strength of concrete structures with low cost, and with less environmental damage. This research was aimed at addressing such issues by investigating the suitability of Jute leaf powder as an admixture in concrete production. At 7 days hydration period in water, the control had a compressive strength of 18.50N/mm2, it was observed that the introduction of jute leaf powder increases the compressive Strength of the concrete expect in the case of 0.2% where there is a decrease in strength compared to the control cubes throughout. At 28 days hydration period in water, the control had a compressive strength of 28.33N/mm^2, it was observed that at 0.2% admixture dosage, the concrete had the lowest compressive strength of 26.00N/mm^2. Other percentages are high but that of 0.4% concrete cubes is highest. This shows that the optimum value is 29.01 N/mm^2 at 0.4% of admixture. The Flexural Strength results revealed that the concrete with all different admixture dosage levels increases in strength as the admixture percent increases. At 28days, the concrete beams with 0% admixture developed strength of 3.92N/mm^2 while the 0.05%, 0.2% and 0.4% had a flexural strength of 3.98N/mm^2, 5N/mm^2, and 5N/mm^2 respectively. Therefore an increase in jute leaf powder increases the flexural strength of the concrete beams. The work shows that compressive strengths of 94.71%, 91.76% and 102.4% of the control (0%) can be achieved at the 28-days. The admixture ratio of (Jute/cement) was ranging between 0-0.4% by weight with mix proportion of (1:2:4) (cement:sand:gravel) by volume and same water to cement ratio (W/C) of 0.57. The experimental tests show that when modified concrete is compared with the normal concrete (without admixture), there is an increase in concrete compressive strength and flexural strength with increase in the ratio of jute leaf powder to certain percentage. Thus, the Jute leaf powder has shown promise as a low-cost concrete admixture in terms of increasing the setting time of concrete.

Keywords: Exploitative, Study, Suitability, Jute Leaf, Powder, Admixture, Concrete, Production

INTRODUCTION

Concrete is a composite material made up of cement, fine aggregate (sand), coarse aggregate (granite chippings or cursed rocks), water and admixtures or super plasticizers molded into different shapes and sizes (NIS, 87:2000). Cement is an essential but expensive constituent of concrete which has the property of setting and hardening under water by virtue of a chemical reaction (Neville, 1981). The properties of concrete depend on the qualities and quantities of its components (Okoli, Owoyale, and Yusuf, 2008). The importance of cement as well as its cost implications can't be over emphasized. Materials scientists, chemists, engineers, and manufacturers' technical representatives have helped the concrete industry to improve our ability to control work times, workability, strength, and durability of Portland cement concrete by adding some supplementary substances named admixtures (Mihai and Rosca, 2008). Over the years it has been found that certain locally available materials have played very important roles in modifying the properties of cement. These materials are called admixtures. According to Israel's ready mix industries (2017), Admixtures are chemicals in the form of powder or liquid which are added to the concrete during the mixing process, at the plant or inside the transit mixer, prior to casting, in order to improve certain properties of the concrete or to add properties which are not present in regular concrete. Amin (2014) opined that the making of concrete is an art as well as a science.

Basically, concrete admixtures are divided into two groups: plasticizers and superplasticizers, the main difference between them being the extent of the admixture's ability to reduce the quantity of water required, whilst maintaining or even improving the concrete's workability. In general, the difference between the two types can be defined as follows: the plasticizer can reduce up to10% of water required in the mix whilst maintaining the concrete's workability, while the superplasticizer can reduce 20% and more of the water quantity (Readymix industries, 2017). Therefore any material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties can be called an admixture. There is an apparent need to utilize locally sourced building materials for the construction of buildings since the cost of the conventional building materials appears to be on the increase (Job, Matawal, and Achuenu, 2009). Therefore the need to go into research as well as the workability of local materials in order to create an avenue for average income earners to own comfortable shelter has been the motivating factor.

Corchorus olitorius, commonly known as jute leaf, Nalta jute, tossa jute, Jew's mallow, West African sorrel and bush okra, is a species classified under the subfamily Grewioideae of shrub in the family Malvaceae native to tropical and subtropical regions throughout the world (Stewart, 2011). The genus Corchorus was first described by Linnaeus in his great work Species Plantarum (in 1753). It is derived from the Ancient Greek word κόρχορος or κόρκορος (korkhoros or korkoros) which referred to a wild plant of uncertain identity, possibly jute or wild asparagus (David, 2008). Jute leaf is the primary source of jute fiber. The leaves and young fruits are used as a vegetable, the dried leaves are used for tea and as a soup thickener, and the seeds are edible. Different common names are used in different contexts, with jute applying to the fiber produced from the plant, and mallow-leaves for the leaves used as a vegetable. The plants are tall, usually annual herbs, reaching a height of 2–4 m, unbranched or with only a few side branches. The leaves are alternate, simple, lanceolate, 5–15 cm long, with an acuminate tip and a finely serrated or lobed margin. The flowers are small (2–3 cm diameter) and yellow, with five petals; the fruit is a many-seeded capsule. Each 100g of the leaves contained 43-58 calories, 4.5-5.6g protein, 0.3g fat, 7.6-12.4g carbohydrate, 80.4-84.1g H_2O, 1.7-2.0g fiber, 2.4g ash, 266-366mg Ca, 97-122mg P, 7.2-7.7mg Fe, 12mg Na, 444mg K, 6,410-7,850µg beta-carotene equivalent, 0.13-0.15mg thiamine, 0.26- 0.53mg riboflavin, 1.1-1.2mg niacin, and 53-80mg ascorbic acid.

Leaves contain oxydase and chlorogenic acid.The folic acid content was substantially higher than other folacin-rich vegetable (Al-Snafi, A.E., 2016). It is unclear whether Corchorus olitorius originated in Africa or in Asia. Some authorities consider that it comes from the Indo-Burmese area or from India, along with several other related species. Others point out that there is a greater genetic variation in Africa and a larger number of wild species in the genus Corchorus. Wherever it originated, it has been under cultivation for a very long time in both continents and probably grows, wild or as a crop, in every country in tropical Africa. Due to the need to explore all necessary means to control setting and early hardening, workability, or to provide additional cementing properties, the idea of the use of Jute leaf as an admixture in concrete was born. Jute leaf has been used mainly as a source of food with great health benefits for a very long time across the world, it is also readily available and its growth is sustainable. Therefore while wastes generated by means of agriculture have created disposal and management problems which pose serious challenges to efforts made towards environmental conservation, their use contributes to resource conservation, environmental protection and the promotion of concrete properties. This makes a significant contribution to the conservation of natural resources and maintains ecological balance. In this study, Jute leaf powder was used as an admixture in concrete. The incorporation of jute leaf as an admixture in concrete may result to changes in the water-cement ratio, workability, density, strength properties, setting time, and cement type (Ikpong, 1992). Survey by the raw material research and development council of Nigeria on available local building materials reveals that certain local building materials deserves serious consideration as substitute for imported one's. In many developing countries like Nigeria, proper utilization of agricultural waste have not been given due attention. Therefore the use of jute leaf powder as an admixture in concrete will provide an economic use of agriculture and consequently produce higher strength properties in the concrete.

MATERIALS AND METHODS

This study assessed the viability, workability, compressive strength and flexural strength of concrete made when powder extracted from Jute leaf is used as an admixture in concrete production.

Materials

The materials used for this project work include cement, fine aggregate (sand) coarse aggregate (gravel), powder extracted from Jute leaf and water.

Cement

Cement is a binder, a substance which sets and hardens independently and can bind materials together (Neville, 2011). The cement type used for this project is Dangote Ordinary Portland cement (OPC), grade 42.5, manufactured by Dangote Cement factory, which conforms to Type 1 cement as specified by BS 12 (1978).

Fine Aggregate

The river sand passing through 4.75 mm sieve and retained on 600 μm sieve, conforming to Zone II as per IS 383-1970 was used as fine aggregate in the present study. The sand is free from clay, silt and organic impurities. The aggregate was tested for its physical requirements such as Gradation, Fineness modulus, and Specific Gravity and Bulk modulus in accordance with BS 882 part2 (1973).BS 882: part 1(1970).

Coarse Aggregate

Throughout the investigations, a crushed coarse aggregate of 20 mm procured from the local crushing plant in Jos was used. The aggregate was tested for its physical requirements such as Gradation, Fineness modulus, Specific Gravity and Bulk density

Water

Fresh portable water with pH value less than 6 free from organic matter and oil was used in mixing the concrete. Water in required quantity was weighed by a weighing balance and added to the concrete.

Jute Leaf Powder

The material was obtained randomly from a vendor. The leaves were cleaned and sun dried for two weeks. The dried leaves were then pounded into powder in open air.

Methods

The tests carried out includes sieve analysis, density, chemical analysis/composition test of Jute leaf powder, workability/slump test, consistency test, setting time and strength properties of the concrete to ascertain the suitability of the constituent materials. A mix ratio of 1:2:4 by weight was used. The mixing was done manually. The slump and compacting factor test were carried out to maintain workability at the desired level. Cement and jute leaf powder were combined in different percentages except for the concrete containing only OPC which was adopted as the control mix. Concrete specimens were cast in 100mm×100mm×100mm steel moulds and tested for compressive strength after 7, 14, and 28 days of curing in water. The concrete cubes were crushed to determine the optimum compressive and flexural strength respectively.

PRESENTATION AND DISCUSSION OF RESULTS

Table 1: Chemical Composition of the Dry Oils of Jute Leaf

S.no	NAME	R	AREA	M+
1.	Compounds of cyclohexadiene	23.14	0.52	220.18
2.	t-Butylphenol	24.3	15.01	206.23
3.	Heptadecyl alcohol	26.28	2.67	256.46
4.	Eicosene	30.64	5.31	280.2
5.	Methyl nonyl ketone	31.62	1.09	198.34
6.	Heptadecylic or Margaric acid	33.28	1.44	270.27
7.	Palmitic acid	34.62	28.52	255.31
8.	Isoheptadecane alcohol	36.74	1.73	256.46
9.	Alkyl decane alcohol	37.10	0.96	200.31
10.	Palmitic alcohol	38.38	1.58	266.40
11.	Stearic acid	39.14	3.85	312.20
12.	Pentadecane	39.28	0.81	212.06
13.	1-eicosene	40.74	0.77	280.20
14.	Tetratetracontane	41.28	5.89	619.20
15.	Heptadecanoic acid	43.00	1.06	270.10
16.	Hexatriacontane	43.10	3.87	506.97
17.	Stearyl aldehyde	43.64	1.03	268.49
18.	Methyl undecenoate	44.36	1.44	256.46
19.	Tetratetracontane	44.82	7.77	619.20
20.	octadecyl propane alcohol	46.92	1.12	328.57
21.	Tetratetracontane	47.92	7.36	619.2
22.	Tritetracontane	50.76	6.17	605.15

*source: Hanan et al (2017).

The leaves and stem of the jute leaf were separated from each other, air-dried and then coarsely powdered to give powdered leaves. Column chromatography was performed with silica gel 60 (70-230 mesh). Thin layer chromatography was performed with plastic backed plates coated with silica gel F254 and the plates were visualized by spraying with vanillin/H_2SO_4 solution followed by warming. Isolated dry oils extracted were then analysed by Gas Chromatography (GC) (Hanan, Musarat and Syed, 2017)

Consistency of cement and jute leaf powder.

Table 2: Consistency of Cement/Jute Leaf Powder

S/n	% Admixture	Amount of cement / admixture (g)	Amount of water (liters)	Water/cement ratio (%)	Depth of penetration (mm)	Remarks
1.	OPC + 0%	400	0.130	32.5%	0.57	Very good
2.	OPC + 0.05%	400	0.130	32.5%	0.60	Very good
3.	OPC + 0.4%	400	0.130	32.5%	0.50	Very good

This test was done on cement and the jute leaf powder in accordance to EN 196-1 (2016) the result is shown in table above

Setting Time of Cement/Jute Leaf Powder.

Table 3: Initial Setting Time of Cement/Jute Leaf Powder

S/n	% Admixture	Amount of cement / admixture (g)	Time	Depth of penetration (mm)
1.	OPC + 0%	400	2hrs 58mins	5.00
2.	OPC + 0.05%	400	2hrs 50mins	5.00
3.	OPC + 0.4%	400	2hrs 38mins	5.00

Table 4: Final Setting Time of Cement/Jute Leaf Powder

S/n	% admixture	Amount of cement / admixture (g)	Time	Depth of penetration (mm)
1.	OPC + 0%	400	4hrs 30mins	20.50
2.	OPC + 0.05%	400	4hrs 35mins	21.00
3.	OPC + 0.4%	400	5hrs	23.00

The initial and final setting time test was done on cement and the jute leaf powder in accordance to EN 196-3 (2016). The results show that the addition of jute leaf powder prolonged the setting time of cement. The results are shown in the tables above.

Workability of Concrete with jute leaf powder

Table 5: Workability of Concrete with jute leaf powder

Admixture %	W/C	Slump (mm)	Compacting factor
0	0.57	11	0.83
0.05	0.57	14	0.90
0.20	0.57	15	0.88
0.40	0.57	12	0.92

The result of the fresh concrete test of workability in table 13 shows the water-cement ratio, slump and compacting factor values for concrete with different dosage of admixtures. A free water cement ratio of 0.57 is adopted. The slump for OPC concrete was 11mm.The slump value increased to 14mm at 0.05% replacement. The least slump value was at 11mm which later increase as jute leaf powder was added to the concrete mix. Thus, the concrete made with jute leaf powder has a high level of workability. The compacting factor values are within the range of between 0.8 to 0.9.So the concrete are highly workable as described in ASTM C143-C143M. Therefore the addition of jute leaf powder increased the concretes workability. The workability of the concrete was determined using slump test and compaction factor test. Table 11 shows the water/cement ratio, slump values and compaction factor for jute leaf powder/OPC concrete. A free water/cement ratio of 0.57 was used for all the mixes.

Mechanical Properties of Concrete
Density of Concrete Cubes

Table 6: Density of concrete cubes (using water-cement ratio of 0.57)

Age (Days)	w/c Ratio	Density of Cubes (g/m³) Admixture (%)			
		0	0.05	0.2	0.4
7	0.57	2458	2501	2613	2547
14	0.57	2504	2553	2547	2603
28	0.57	2721	2607	2646	2560

Table 6 and 7 give the result of the density of concrete cubes and beams which indicates a strong relationship existing between the density and the addition of jute leaf powder in the mix. The higher the amount of jute leaf powder in the mix, the higher the density of the concrete produced. This could be as a result of the high specific gravity of the admixture at 1.47 which occupied a proportion of the volume with significant weight increase. It was also observed that the density was also affected by the hydration period for all the mixes. The density increases progressively with increase in hydration period. This could be attributed to the cement and some spaces being originally filled with water. This consequently reduces available pore spaces filled with consequent increases in density. Neville (2011) gives a range of densities of normal weight concrete as being between 2400 kg/m3 and 2800 kg/m3. The densities obtained in this research ranges between 2458kg/m3 and 2721kg/m3, thus enabling the concrete so made to be classified as normal weight concrete.

Table 7: Density of Beams at 28 days

	Density (g/m³)			
Admixture (%)	0	0.05	0.2	0.4
Water Cement Ratio	0.57	0.57	0.57	0.57
28 days	2473	2501	2553	2693

Table 7 shows the densities of the beam specimen. The result of the densities indicates that the control cubes and the concrete cubes produced with jute leaf powder experienced an increase in density as the hydration period increases.

The Compressive Strength Test

Table 8: Compression strength result for concrete (OPC)

S/n	Age of concrete (days)	Cube weight (kg)	Density (kg/m^3)	Failure load (KN)	Compressive strength (N/mm^2)
1.	7	2.46	2458	185.0	18.50
2.	14	2.50	2504	211.7	21.17
3.	28	2.72	2721	283.3	28.33

Table 9: Compression Strength Result for 0.05 Percent Addition of Jute Leaf Powder.

S/n	Age of concrete (days)	Cube weight (kg)	Density (kg/m^3)	Failure load (KN)	Compressive strength (N/mm^2)
1.	7	2.50	2501	203.0	20.30
2.	14	2.55	2553	263.3	26.33
3.	28	2.61	2607	268.3	26.83

Table 10: Compression Strength Result for 0.2 Percent Addition of jute leaf powder.

S/n	Age of concrete (days)	Cube weight (kg)	Density (kg/m^3)	Failure load (KN)	Compressive strength (N/mm^2)
1.	7	2.61	2613	163.0	16.30
2.	14	2.55	2547	191.7	19.17
3.	28	2.65	2646	260.0	26.00

Table 11: Compression strength result for 0.4 percent addition of jute leaf powder.

S/n	Age of concrete (days)	Cube weight (kg)	Density (kg/m³)	Failure load (KN)	Compressive strength (N/mm²)
1.	7	2.55	2547	215.0	21.50
2.	14	2.60	2603	226.7	22.67
3.	28	2.56	2560	290.1	29.01

Tables 8, 9, 10, and 11 show the compressive strength of concrete produced with different dosage of jute leaf powder cured in water for hydration period of 7, 14, and 28 days. The tables also show that the rate of increase of compressive strength over time was linear. The average strength of 3 cubes crushed was taken for each curing age respectively.

a. **Compressive strength of the control specimen (OPC concrete):**

The result in table 8 indicates that the strength of the concrete increase with increase in curing age. The maximum strength attained at 28days is 28.33N/mm²

b. **Admixture at 0.05%**

The compressive strength of Portland cement concrete with an admixture of 0.05% cured in water (H_2O) and crushed at hydration period of 7, 14, and 28 days is shown in table 19. At 28 days the compressive strength of the concrete is 26.83N/mm². This is slightly lower than the compressive strength for the control mix.

c. **Admixture at 0.2%:**

Table 10 indicates the strength of 16.30N/mm², 19.17N/mm², and 26.00N/mm² achieved at 7, 14 and 28days respectively giving the lowest values when compared to other admixtures. This concrete indicates a slight decrease in strength than the preceding replacement.

d. **Admixture at 0.4%:**

The compressive strength of Portland cement concrete with an admixture of 0.4% cured in water and crushed at hydration period of 7, 14, and 28 days shows a slight increase in all the curing ages crushed. A compressive strength value of 29.01N/mm² was achieved in 28days. The result shows an increase in strength as the percentage of admixture was increased.

Table 11 shows that the optimum value of jute leaf powder in concrete is at 0.4%. It is also clear that increase in strength of concrete containing admixtures is not linear with increase in percentage since its compressive strength values are higher than that of 0.2% which is lower than that of 0.05%. Hence the optimum value is 29.01N/mm² at 0.4% admixtures.

The flexural strength test

Table 12: flexural strength result for 28 days.

S/n	Age of concrete (days)	Cube weight (kg)	Density (kg/m³)	Failure load (KN)	Flexural strength (N/mm²)
1.	28	12.17	2473	23.5	3.92
2.	28	12.90	2501	24.5	3.98
3.	28	12.56	2553	30.0	5.00
4	28	12.19	2693	30.0	5.00

Table 12 shows the flexural strength of concrete produced with different dosage of jute leaf powder cured in water for hydration period of 28 days. The table also shows that the rate of increase of flexural strength with increase in admixture was linear.

Admixture activity index (AAI) of concrete containing jute leaf powder

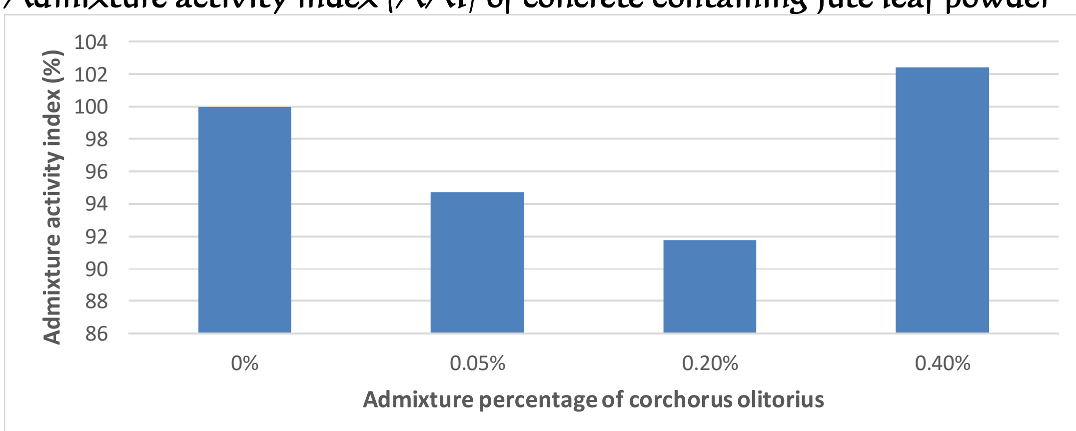

Figure 1: Admixture activity index of OPC concrete containing jute leaf powder

The admixture activity index of OPC concrete containing jute leaf powder at various additions are; 0.05% is 94.71%, 0.2% addition is 91.76%, and 0.4% resulted to 103.60% The AAI relationship is shown in figure 1 above. The result in figure 2 shows the admixture activity index of the OPC at 0.05% to 0.4%. The average admixture index for the various replacements was found to be 95.11%. This satisfied the ASTM C 595 (2018) 75% minimum requirement for admixtures to be used as a constituent of Portland cement in concrete production.

Water absorption test

Table 13: Water Absorption Test Results for 14days

Admixture %	W_2 (g)	W_1 (g)	% Water absorption
0	2576.83	2474.39	4.14
0.05	2514.08	2394.81	4.98
0.20	2624.55	2505.71	4.79
0.40	2517.20	2390.29	5.31

Table 14: Water Absorption Test Results for 28days

Admixture %	W_2 (g)	W_1 (g)	% Water absorption
0	2672.83	2534.39	5.46
0.05	2581.92	2450.81	5.35
0.20	2684.55	2545.71	5.45
0.40	2629.03	2496.29	5.32

The water absorption of the specimens that contained the Jute leaf powder absorbed more water than the plain concrete at 14 days. However, the rate of absorption was less than that of the plain concrete at 28 days as shown in table 13 and 14 above.

CONCLUSION

From the result of the different tests conducted, this study concludes that jute leaf powder is a potential material for use as an admixture in concrete production. Jute leaf powder has shown the properties of a retarder by prolonging the setting time of cement paste.

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