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Effects of a Locally Sourced Water Reducing/Retarding Admixture on Concrete

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ORIGINAL ARTICLE

ABSTRACT: The results of experiments to determine the effects of a water reducing/retarding admixture locally sourced from orange tree leaves on concrete are presented in this paper. The admixture was added to the concrete mix in percentages of 1, 2, 5, 10 and 15 by weight of cement. The results showed that the workability of the mix improved while the water cement ratio reduced gradually as the admixture content was increased from 1% to 15%. Cube crushing tests performed showed that the 28th day compressive strengths of the concrete increased considerably as the admixture content increased from 1% to2% up to 5% beyond that of the control. Thereafter, the compressive strengths dropped at 10% and 15% admixture contents. The percentage increase in compressive strengths of the concrete with 1%, 2% and 5% admixture contents were 6.58%, 14.07% and 23.53% respectively above that of the control.

Keywords: water reducing, retarding, admixture, workability, crushing tests, compressive strengths

INTRODUCTION

Admixtures are materials other than the standard combination of Portland cement, water and aggregates which are added to concrete to improve or modify its properties. Some of these properties are workability, strength, rate of setting, frost resistance, impermeability and colour. They are generally added to the batch of concrete at the same time as the other ingredients or later during the mixing operation. There are different types namely air-entraining, water-reducing or plasticizers, water repelling agent, bonding admixture, super plasticizers, accelerators, corrosion inhibitors, retarders and permeability reducers.

Retarding admixtures have been known to slow down the hydration of cement and lengthen the setting time of concrete. They are beneficially used in hot weather conditions in order to overcome the accelerating effects of higher temperatures and large masses of concrete on the setting time. Conversely, water reducing admixtures decrease the water requirements of the concrete mix for a given slump or modify the corresponding setting time (Rixom and Mailvaganam, 1999). This may result in a reduction in the water/cement ratio for a given slump and cement content or an increased slump for the same water/cement ratio and cement content.

This study assesses the effects of a locally sourced water reducing/retarding admixture on concrete. The underlying objectives are to develop a cost effective admixture from the leaves of orange trees, determine the properties of the admixture and compare its effects with those of concrete with no admixtures. The study will provide a suitable, easily accessible alternative for conventional water reducing/retarding admixtures which are usually expensive.

Background Literature

Admixtures have long been recognized as important components of concrete used to improve its performance. Early civilization witnessed the use several different materials as admixtures; the Romans used milk and lard, Europeans made use of eggs, the Chinese used polished glutinous rice paste and boiled bananas and the Persians used cactus juice and latex from rubber plants. Hence, an admixture can be defined as a material other than water, aggregates, hydraulic cement and fiber reinforcement used as an ingredient in a cement based mixture to modify its properties (ACI, 1993).

Chemical admixtures are used to enhance the properties of concrete or mortar in the plastic and hardened state (ACI, 1998). These properties may be modified to increase compressive and flexural strengths at all ages, decrease permeability and improve durability, inhibit corrosion, reduce shrinkage, accelerate or retard initial set, improve slump and workability, increase cement efficiency and the economy of the mixture. The addition of an admixture or combination of admixtures may be the only feasible means of achieving the aforementioned objectives.

On addition, the admixtures interact with the hydrating cement based system thereby modifying one or more of the concrete properties. Admixtures are an important component of concrete along with the usual constituents namely cement, water, aggregates and where applicable reinforcing steel (EFCA, 2005). There are several types of admixtures namely retarding, water-reducing, air-entraining, plasticizers, accelerating, hydration-control, corrosion inhibitors, shrinkage reducers, alkali-silica reactivity inhibitors and coloring admixtures. Other miscellaneous admixtures are also

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available for grouting, improving workability, improving bonding, damp-proofing, reducing permeability, gas-forming, anti-washout, foaming and pumping.

Retarding admixtures currently make up about 1.5% of all admixtures sold in Europe and are typically based on solutions of phosphates, phosphonates, sucrose, gluconate and polysaccharides. Retarding admixtures (retarders) are known to delay hydration of cement without affecting the long-term mechanical properties. They are used in concrete to offset the effect of high temperatures which decrease setting times, or to avoid complications when unavoidable delays between mixing and placing occur (EFCA, 2006).

Consequently, set retarders are considered the second most commonly used admixtures in the highway industry, especially in the construction of bridge decks (Mindess et al, 2003). The use of set retarders in concrete pavement construction enables farther hauling (thus eliminating the cost of relocating central mixing plants), allows more time for plastic grooving of concrete pavements, allows more time for hand finishing around the headers at the start and end of the production day and helps to eliminate cold joints in two-course paving and in the event of equipment breakdown (USDT, 1990).

Set retardation occurs in two stages as follows: the admixture forms a film around the cement compounds by absorption, thereby preventing or slowing the reaction with water. The thickness of this film however, dictates by how much the rate of hydration is retarded. After a while, this film breaks down and normal hydration proceeds (ACPA, 1991). In addition to their role in controlling setting time, retarders (like any other admixtures) influence the properties of fresh and hardened concrete. Air entrainment of concrete is affected as fewer air-entraining agents need to be used because some retarders readily exhibit this property. Also, slump loss might increase even when abnormal setting behavior does not occur while the 1-day strength of the concrete has been observed to reduce. However, experiments showed that the ultimate strength and the rates of dry shrinkage and creep improved (Ai and Young, 1997).

METHODOLOGY AND MATERIALS

Materials Used for Assessment

The materials used for this study are the leaves of orange trees (from which the admixture was prepared), constituents of the concrete mix namely the coarse aggregate (granite), fine aggregate (sharp sand), and cement (Ordinary Portland cement), water, chemicals and reagents. The granite used was well graded, free from unwanted particles and of 18mm sizes while the sharp sand consisted of 5mm sized particles on average.

Most of the chemicals and reagents used in this study were obtained from chemistry laboratory of the Federal University of Technology, Akure (FUTA). These included de-ionized water, concentrated ammonia solution, ammonium chloride, concentrated HNO_3 and concentrated H_2SO_4. The water used for all the experiments was also obtained from a bore-hole located on FUTA campus. It was free from suspended particles like organic matter and silt which were capable of affecting the hydration process of cement.

Equipment Used

The equipment utilized in the study included 150mm × 150mm × 150mm molds (for molding the concrete cubes), weighing balance for weighing the concrete materials, electronic weighing balance for weighing the leaves, shovel for mixing the concrete, hand trowel for designing the concrete surface, tank for curing of the concrete cubes, slump cone with 300mm height used in carrying out the slump test, base plate, tamping rod, meter ruler for measuring the slump, concrete cylinder used for the compaction test, compression testing machine used to determine concrete compressive strength, scoop used for taking the samples, BS sieves, compacting factor apparatus, two floats for compaction test of the concrete, impact testing machine, cylindrical metal measure, rebound hammer used in compressive strength test of concrete and mechanical extensometer used in elasticity of concrete.

Tests and Test Procedure

The tests carried out include analytical test on the orange leaves, aggregate impact value (AIV) and aggregate crushing value (ACV) tests on the coarse (granite) aggregates, sieve analysis of the fine (sharp sand) aggregate, workability tests, crushing test on the concrete cubes.

Analytical Tests on the Orange leaves

The orange leaves were weighed by using an electronic weighing balance. The leaves were then sundried for about three weeks and reweighed so as to determine the percentage loss of water. The leaves were then ground into powder upon which the tests were carried out. These included chemical and mineral tests to determine the organic compounds and elements present in the leaves.

The powder, weighing 0.5g, was put into a crucible and thereafter, placed in the furnace for ashing (i.e. burning off all organic matter content of the powder). The ashing took three hours after which it was put inside dissectors to cool. The sample was then filtered with 0.1 molar solution of $HN0_3$ after which the filtrate was then ready for mineral/elemental tests.

Aggregate Impact Value (AIV)

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact (BS812: Part 112, 1990). The test involved putting the aggregate in the test cup which was fixed firmly in position on the base of the impact testing machine and subjected to a total of 15 blows each being delivered at an interval of not less than 1 second.

Thereafter, the aggregate was removed from the cup by holding it over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles are sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. The fine particles adhering to the inside of the cup and the underside of the hammer were transferred to the tray using a stiff bristly brush. The whole sample was then sieved through the

2.36mm BS test sieve unto the tray until no further significant amount passed through in 1 minute. The fractions passing were weighed and retained on the sieve to an accuracy of 0.1g. The whole procedure was repeated as a check using a second sample of the same mass as the first sample.

Aggregate Crushing Value (ACV)

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load (BS812: Part 110, 1990). The test involved positioning the test apparatus on the base plate and adding the test sample in thirds, each third being subjected to 25 strokes from the tamping rod distributed evenly over the surface of the layer and dropping from a height approximately 50mm above the surface of the aggregate. The aggregate surface was carefully levelled and the plunger inserted so that it rested horizontally on it, the apparatus was then placed with the test sample and plunger in position between the plates of the testing machine. This was then loaded at a uniform rate so that the required force of 400kN was reached in 10 min.

Thereafter, the load was then released and the crushed material was removed by holding the cylinder over a clean tray and hammering on the outside with a suitable rubber mallet until the sample particles were sufficiently disturbed to enable the mass of the sample to fall freely on to the tray. The fine particles were transferred to the base plate and the underside of the plunger to the tray by means of a stiff bristle brush. The whole of the sample on the tray was then sieved on the 2.36mm until no further significant amount passes in 1 min. The fraction passing the sieve was then weighed and the whole procedure was repeated using a second sample of the same mass as the first sample.

Workability Test on the Concrete

A total of 120 cubes were cast comprising of control cubes and cubes containing 1%, 2%, 5%, 10% and 15% orange leaf powder by weight of cement. A mix ratio of 1:2:4 (that is 22.09kg of cement, 44.18kg of sand and 88.36kg of granite) was used to produce the concrete which was batched by weight. After the mixing of the batched material, water was added and mixed thoroughly with shovel to achieve a homogenous mix and then the cubes were molded (figure 1) and cured in a curing tank for the durations as shown in Table 1.

Figure 1. Molding of Concrete Cubes

Table 1. Curing Durations for Concrete Cubes

S/N	Description	Days				Total Cubes
		7	14	21	28	
1	Control Cubes	5	5	5	5	20
2	Cubes with 0.242kg (1%) orange leaf powder by weight of cement	5	5	5	5	20
3	Cubes with 0.484kg (2%) orange leaf powder by weight of cement	5	5	5	5	20
4	Cubes with 1.21kg (5%) orange leaf powder by weight of cement	5	5	5	5	20
5	Cubes with 2.42kg (10%) orange leaf powder by weight of cement	5	5	5	5	20
6	Cubes with 3.63kg (15%) orange leaf powder by weight of cement	5	5	5	5	20
	Total number of cubes cast					120

- **Slump Test**

This involved filling a truncated cone (300mm in height with top and bottom diameter as 100mm and 200mm) with concrete in three equal layers. Each layer was tamped with 25 blows with a tamping rod. Immediately after the top layer had been tamped, the concrete was struck level with the tamping rod and the mold was then raised slowly and carefully in a vertical direction, thereby causing the concrete to sub-side. The slump was measured with a meter rule (in mm) as the difference in vertical heights between the original and final levels.

- **Compacting Factor Test**

In this test, the top hopper (in the two hopper apparatus shown in figure 2) was filled with concrete to overfilling without compacting. The opening at the bottom was released successively allowing the concrete into the hopper below and consequently into the bottom cylinder. The weight of the concrete in the cylinder, W_1 was determined after leveling the surface (figure 3). The same cylinder was then filled with another sample of concrete from the batch, compacted and weighed to get the maximum weight, W_2. The ratio of the observed weights W_1/W_2 gave the compacting factor.

Figure 2. Compacting equipment

Figure 3. Concrete filled cylinder on weighing balance

Compressive Strength Test

Crushing tests were performed on the concrete cubes to determine their compressive strengths. After curing for 7, 14, 21 and 28 days, all the cubes were weighed and crushed in the compressive strength machine. The load was applied to the cubes through hydraulic operation of the machine until failure occurred. The corresponding peak load and stresses at this point were recorded and used to determine the average compressive strengths.

ANALYSIS AND INTERPRETATION OF RESULTS

Particle Size Distribution (Sieve) Analysis

500g of sharp sand was used in this analysis and this was sieved through nine sieves with varying sizes. Table 2 shows the different sieve sizes used and the corresponding percentage retained on and passing through each of the sieves. It can be observed that the percentage retained in the pan was 12.68% which was less than 30% indicating the suitability of sharp sand for the tests.

Table 2. Particle Size Distribution Analysis

Sieve diameter	Wt of Sieve + sample (g)	Wt of sample (g)	Wt of retained (g)	% retained	% passing
2.36mm	356.20	338.60	17.60	4.03	95.97
1.70mm	354.90	346.40	8.50	1.95	94.02
1.15mm	380.80	369.70	11.10	2.54	91.48
600μm	364.20	348.00	16.20	3.71	87.77
500μm	417.50	377.40	40.10	9.19	78.58
425μm	376.80	352.50	24.30	5.57	73.01
212μm	555.50	340.70	214.80	49.20	23.81
150μm	304.20	237.70	66.50	15.23	8.58
75μm	345.50	316.90	28.60	6.55	12.68
Pan	398.20	389.30	63.4	12.68	0.00

Analysis of the Orange Leaves

Analysis for the moisture content of the wet orange leaves was determined to be 78.9%. Elemental analysis of the orange leaves in powder form showed the results as presented in table 3 while the analysis of the compounds in the leaves showed the results as presented in table 4.

Table 3. Elements present in the Orange Leaves

Element	Mass present	% by mass
Nitrogen (N)	29,600 g/kg	2.96
Phosphorus (Ph)	22,170 mg/kg	2.22
Potassium (K^+)	39,020 mg/kg	3.90
Calcium (Ca^{2+})	28,986 mg/kg	2.90
Magnesium (Mg^{2+})	19,055 mg/kg	1.92
Sodium (Na^+)	14,951 mg/kg	1.50
Copper (W^{2+})	32,250 mg/kg	3.23
Iron (Fe^{2+})	45,946 mg/kg	4.60
Zinc (Zn^+)	35.775 kg / mg	3.60
Lead (Pb^{2+})	25,486 kg/mg	2.55
Manganese (Mn^+)	23,550 kg/mg	2.40
Cobalt	31,125 kg/mg	3.12
Barium (Ba^{2+})	35,497 kg /mg	3.55

Table 4. Compounds present in the Orange Leaves

Compounds	Mass present (mg/kg)	% by mass composition
Pb^{4-}	21,454	2.15
$Co3^{2-}$	35,152	3.52
$So4^{2-}$	16,105	1.61
No^{3-}	25,695	2.57
Cl^-	4,498	0.45

The tests carried out on the powdered orange leaves showed the presence of salts of baric and phosphoric acid (see Table 3) usually found in conventional water reducing/retarding admixtures. Also, lignosulfates used in conventional admixture formulations which are predominantly calcium or sodium based were also found to be present (Al-Khaiat et al, 2004).

Aggregate Crushing Value (ACV) and Aggregate Impact Value (AIV) of Granite

Using a 4kg granite test sample, the average AIV obtained was 20.2 while the average ACV obtained was 29.4 which were well within the British Standard specified ranges for the AIV of between 17 to 21 (BS812: Part 112, 1990) and the ACV of between 27 to 30 (BS812: Part 110, 1990). These results justified the use of this granite.

Slump and Compacting factor test

Table 5 shows the slump values for the wet concrete (control and test samples) at ten minute intervals for a total duration of one hour. The same table shows the compacting factors (and the water-cement ratios) for the wet concrete with and without the powdered orange leaf. It can be observed from Table 5 that the slump values gradually reduce (horizontally across the table) as the admixture content is increased from 1% to 15%. A similar trend is shown by the compacting factor shown horizontally across the table.

Table 5. Slump and Compacting factor values

Time (min)	Slump values (mm)					
	Control	Admixture				
		1%	2%	5%	10%	15%
0	63.0	80.0	75.0	68.0	60.0	58.0
10	57.0	76.0	71.0	63.0	57.0	54.0
20	54.0	73.0	69.0	59.0	55.0	52.0
30	52.0	70.0	67.0	57.0	54.0	50.0
40	51.0	68.0	65.0	56.0	53.0	48.0
50	50.0	67.0	64.0	55.1	52.4	47.0
60	49.7	69.8	63.6	54.8	52.0	46.8
Compacting factor	0.960	0.965	0.951	0.948	0.936	0.924
Water-cement ratio	0.53	0.55	0.52	0.48	0.45	0.42

Figure 4 shows a graphical representation of the slump values for the wet concrete with different admixture contents. The slump values at 5% admixture content appears to be the most conservative approaching average values i.e. calculating average values for the initial slump at 1% and 15% admixture contents, (80+58)/2 gives 69 which is very close to the initial slump at 5% admixture content.

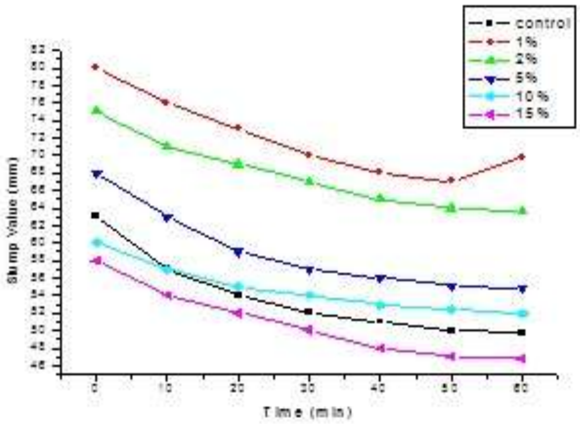

Figure 4. Graph of Slump values

Compressive Strengths

Five cubes were crushed under each category comprising the control and concrete with varying admixture content. Thereafter, the average compressive strengths after each duration was determined as shown in table 6. It can be observed that the average compressive strengths are highest at 5% admixture content.

Table 6. Compressive Strengths of the Concrete Cubes

Curing Duration	Average Compressive Strength (N/mm^2)					
	Control	Admixture				
		1%	2%	5%	10%	15%
7	12.48	13.94	14.01	15.92	13.88	12.98
14	15.04	16.00	16.29	17.78	14.54	14.12
21	18.72	18.18	18.94	20.28	16.78	15.76
28	22.18	23.64	25.30	27.40	18.64	18.12

Figure 5 shows the graph of the average compressive strengths plotted against the curing duration in which it is apparent that the values are highest at 5% admixture content followed closely by values at 2% admixture content.

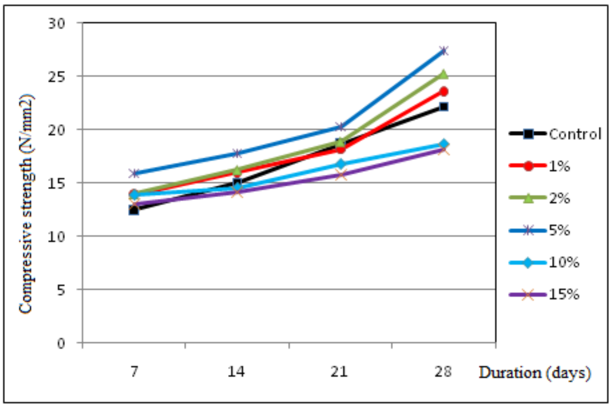

Figure 5. Graph of Compressive strengths plotted against the curing duration

CONCLUSION AND RECOMMENDATIONS

Conclusion

Based on the results of the analytical tests on the powdered orange leaves, it can be concluded that it can be used as water reducing/retarding admixture since it contains both calcium and sodium based compounds.

The slump test indicates that the slump reduces and the concrete becomes more workable as the admixture content is increased gradually from 1% to 2% to 5% to 10% up to 15%. The slump values at 5% admixture appear to be most conservative with corresponding compacting factor and water-cement ratio of 0.948 and 0.48 respectively. This water-cement ratio amounts to a reduction of about 1.105kg of both the water and cement used in preparing the concrete in comparison with the control sample. Hence, it is apparent that the powdered orange leaves can be used as a water reducing admixture.

The compressive strengths obtained from the cube crushing tests were highest at 5% admixture content. An average strength of 27.40N/mm^2 was attained after 28 days at 5% admixture content which is about 23.53% above that of the control. At 1% and 2% admixture contents, average strengths of 23.64 and 25.30 were recorded (after 28 days) which were 6.58% and 14.07% higher than that of the control respectively. The strength gain over the curing duration at 5% admixture content was more noticeable than with the control and other samples with the admixture added. In addition, it is apparent that the process of gaining the ultimate 28th day strength was delayed by addition of the powdered orange leaves. Hence, it seems that the powder can be effective as a retarding admixture.

Recommendations

The effect of intermediate admixture contents (that is between 2% and 5%, between 5% and 10% as well as between 10% and 15%) should be examined to ascertain whether there outcome would be significantly different from what has been obtained in this study or similar. The effect of high temperatures on the compressive strength performance of concrete with the admixture added should also be examined as this could affect the physical and chemical properties of the powdered orange leaves.

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