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Experimental Study of Self-Compacting Concrete Using Plantain Leaf Ash and Polycarboxylate Ether Solution as Superplasticizer

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Concrete is a binding material, made up of constituent of cement, fine aggregate, coarse aggregate and water. Self-Compacting Concrete is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The study also intended to quantify the amount of plantain leaf ash to be added to the concrete according to the value of concrete properties measured. For such purpose, the fresh concrete must possess intense fluidity and great cohesiveness. Plantain leaf ash is waste and is causing threat to environment in terms of odour and to reduce this problem of this material the project has been undertaken so that it can be used for construction purpose. The following points were attempted for the resdearch;

i. To replace cement by different percentage of Plantain leaf ash,
ii. To prepare concrete by replacing the cement by Plantain leaf ash,

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iii. To compare the fresh properties of self-compacting concrete containing varying amounts of plantain leaf ash with that containing commercially available superplasticizer,
iv. To study the compressive strength of normal conventional concrete and self-compacting concrete.

Keywords: Admixture, nonconventional concrete; plantain leaf ash; superplasticizer; Self-Compacting Concrete (SCC).

1. INTRODUCTION

Self-compacting concrete (SCC) is an inventive concrete that doesn't need vibration for setting and compaction. It can stream on its own weight, totally filling formwork and accomplishing full compaction, even within the sight of blocked support. The solidified cement is thick, homogeneous and has similar designing properties and strength as the ordinary customary vibrated concrete. Self-compacting concrete offers a speedy pace of concrete position, with quicker development times and simplicity of stream around clogged support [1-4].

The aim of this investigation of self-compacting concrete utilizing Plantain leaf ash as fractional substitution of customary Portland concrete is to get self-compacting concrete fulfilling EFNARC rules and make correlation of self-compacting cement to typically compacted concrete regarding functionality and compressive strength. Only, that this study is limited to self compacting concrete with partial replacement of cement with plantain leaf ash, it is believed that other cementicious materials like fly ash can be used to produce self compacting concrete with a different property than the above study.

For this study: Determining the impact of Plantain leaf ash as fractional substitution of cement on the properties of SCC in {FRESH STATE (filling ability and passing ability) and HARDENED STATE (compressive strength)}, Obtaining explicit exploratory information to see new and solidified properties of self-compacting concrete, Creating SCC utilizing Plantain leaf ash as fractional substitution of concrete in changing measurements fulfilling European guidelines and to concentrate on their way of behaving, Deciding if the properties are primarily adequate for its application as per important norm as a development material, Evaluating the ramifications of its utilization as a development material in the fabricated climate.

Also, For this study, concrete with varied percentages of plantain leaf ash at 5%, 10%, 15%, were used to replace ordinary Portland cement with the addition of super plasticizer with a water cement ratio of 0.55 to produce self-compacting concrete (SCC) in terms of filling ability and passing ability. It was compared with normally compacted concrete made up of Portland cement with water cement ratio 0.55 and mixture ratio of 1:2:4.

This research will poduce concrete of high and significant strenght and durability to be used in construction of all structures and also effectively utilize and it will minimize maintenance, labour cost and cost due to the vibrators required. Plantain leaf which is very popular across Nigeria and in most cases it is so excess that it pollutes the enviroment, so this project will aid the waste resuse of plaintain leaf to produce SCC that would be very good in the construction industry.

The Civil Engineering laboratory of Chukwuemeka Odumegwu Ojukwu University and their instruments was used for the following practical. The workability characteristics using slump flow test, V-funnel test, L-box test and compressive strength characteristics at 7, 14, 21- and 28-days using cubes of 150 mm X 150 mm X 150 mm was determined.

2. LITERATURE REVIEW

Proff. Shriram et al., [5]. *"*The fresh and hardened properties of self-compacting concrete using Fly ash as partial replacement of cement in different percentages in addition to filler has been determined by Shiram, [5]. The new properties not entirely set in stone by processing the Slump esteem, V-channel worth and L-box esteem and the solidified still up in the air by registering the Compressive strength, Flexural strength and Split tensile strength of the specimens. It is observed that the fresh properties of concrete show an acceptable value up to 30% replacement of fly ash and also the hardened properties of concrete are significantly improved when compared to the conventional mixture".

Arivalagan, S. [6]. Conducted "an experimental program aimed at producing and evaluating SCC made with high volumes of fly ash. Nine SCC combinations and one control concrete were examined in this review. The content of the cementitious materials was maintained constant (400 kg/m3), while the water / cementitious material ratios ranged from 0.35 to 0.45. The self-compacting mixtures had a cement replacement of 40, 50 and 60% by Class F fly ash. Tests were completed of solidified cements like compressive strength. Oneself compacting cements fostered 28-day compressive qualities going from 26 to 48 MPa. The outcomes show that a practical self- compacting cement could be effectively evolved by integrating high-volumes of Class F fly debris. The venture examined the creation of self-compacting concrete more reasonable for the development market by supplanting high volumes of Portland concrete by fly debris. The review zeroed in on correlation of new properties of SCC containing differing measures of fly debris with that containing monetarily accessible admixture. Test results demonstrated the attainability to foster minimal expense SCC utilizing Class F fly ash" [7,8].

Prajapati et al. (2013). Had studied about "the self-compacting concrete containing different percentages of fly- ash such as 10%, 20% and 30% as replacement of cement by its weight where the amounts of fine aggregate and coarse aggregate are kept steady. The new properties of the cements, for example, droop esteem, V-channel and L-enclose esteem which go used to decide the stream and ability to pass of the concrete were acquired from EFNARC Guidelines. He observed that the addition of fly ash in concrete results in decrease in super-plasticizer content for better workability. He reasoned that with expansion in fly-ash content in concrete outcomes in decline in strength of concrete at 28 days".

Beerlingegowd, B et al., [9]. Had studied about "the properties of self-compacting concrete which is obtained by partially replacing cement with limestone powder. He figured the new properties and solidified properties of the concrete. He likewise tracked down the solidness attributes of the concrete. In this study, he concluded that with 30% replacement of limestone powder in the concrete results in 20% increase in the workability and mechanical properties of the concrete. He also concluded that with 20% replacement of limestone powder results in increase in acid resistance and sulphate resistance of the concrete. He additionally saw that the chloride content in the sample is diminished with expansion top to bottom of the sample".

Farediwala, M. A. et al., [10]. Presented "experimental research on the workability and compressive strength of self-compacting concrete containing water binder ratios of 0.40 and 0.50. The concrete is treated with various measurement of super-plasticizer in light of carboxylic with fly-debris. To evaluate the passing ability of the self-compacting concrete, slump flow test, V-funnel test and L-box test had been conducted. He likewise reasoned that when the water concrete proportion was lower, the impact of fly-debris and dose of super-plasticizer ought to be higher to work on the compressive strength of the concrete. He saw that the compressive strength of concrete blend containing new measurement of super-plasticizer could be assessed from the functionality tests itself".

3. METHODOLOGY

This work involves the use of plantain leaf ash in producing self-compacting concrete. Test such as slump test, V- Funnel test, L-box test, cube compressive strength was carried out as workability test while sieve analysis was carried out as a preliminary test, since they contributed to the strength development of the concrete.

Plantain leaf ash varied at 5%, 10%, 15%, was used to replace ordinary Portland cement with the addition of super plasticizer (polycarboxylate ether solution) with a water cement ratio of 0.55 at a concrete mixture ratio of 1:2:4 to produce self-compacting concrete (SCC). While concrete with ordinary Portland cement with water cement ratio 0.55 at a concrete mixture ratio of 1:2:4 was used as the control. The desired compressive strength was determined at 7, 14, 21 and 28 days.

The main testing devices used in carrying out the test are: Set of Sieves**,** Compressive Strength Machine, Slump Test Machine, V-Funnel and L-box**.** Also, materials used in carrying out the experiments were cement, sand, coarse aggregate, water, plantain leaf ash (PLA) and chemical admixture (superplasticizer – Costamix 200R).

- **Mixture Design Analysis**

  $Vc + Vs + Vg + Vw + Va = 1\ m^3$

  $Sgc = 3.15$, $Sgs = 2.65$, $Sgg = 2.7$, $Sgw = 1$

Mixed ratio; 1:2:4 and W/C of 0.55 Ws = 2Wc, Wg = 4 Wc, Ww = 0.55Wc

Therefore, Vc + Vs + Vg + Vw + Va = 1 m^3 Wc = 315.8 kg (weight of cement for 1 m^3)

So therefore; Ws = 631.6 kg, Wg = 1263.2 kg, Ww= 173.69 kg

- For weight of cement for 150 mm X 150 mm X 150 mm, (0.003375 m^3) Since 1m^3 = 316.8 kg
  Then 0.003375 m^3= 1.066 kg
  For 8 cubes we have= 8 X 1.066= 8.5266 kg
- For weight of sand for 150 mm X 150 mm X 150 mm, (0.003375 m^3). Since 1 m^3 = 631.6 kg Then 0.003375 m^3 = 2.13165 kg
  For 8 cubes we have= 8 X 2.131.65= 17.053 kg
- For weight of granite for 150 mm X 150 mm X 150 mm, (0.003375 m^3). Since 1 m^3 = 1263.2 kg Then 0.003375 m^3= 4.2633 kg
  For 8 cubes we have= 8 X 4.2633= 34.1064 kg
- For weight of water for 150 mm X 150 mm X 150 mm, (0.003375 m^3). Since 1 m^3 = 173.69 kg Then 0.003375 m^3= 0.5862 kg

For 8 cubes it should be = 8 X 0.5862= 8.5266 kg Calculating for plantain leaf ash replacement;

For 5% replacement = Wc = 8.5266 = 0.42633 kg Cement to be used = 8.5266 – 0.42633 = 8.1 kg For 10% replacement = Wc = 8.5266 = 0.85266 kg

Cement to be used = 8.5266 – 0.85266 = 7.67394 kg For 15% replacement = Wc = 8.5266 = 1.27899 kg Cement to be used = 8.5266 – 1.27899 = 7.24761 kg Superplasticizer percentage = 8.5266 = 0.1279 kg

4. RESULTS AND DISCUSSION

In the first stage, four mixed samples shown in Table 1 were prepared to achieve the best possible mixtures which would fulfill the requirement of the technical specification for SCC. Based on work results, fresh properties of SCC for each trial mixture with different test methods (Slump flow, L- Box and V-funnel) were shown in Table 2. It is clear from Table 2 that, mixture 2 will satisfy the range of different tests (Slump flow, L-Box and V-funnel) given by specified by the technical specification for self-compacting concrete. While others do not satisfy the range of such tests. Therefore, mixture 2 is considered the best mixture of self-compacting concrete and can be used as a reference concrete (control) with varying percentages of SCC;

Table 1. Trials mixes for self-compacting concrete (SCC)

Materials	Mixture 1 control (0%)	Mixture 2 PLA 5 %	Mixture 3 PLA 10 %	Mixture 4 PLA 15 %
Cement (kg)	8.53	8.1	7.67	7.25
Plantain leaf ASH (kg)	NIL	0.43	0.85	1.28
Water	4.69	4.69	4.69	4.69
SAND (kg)	17.05	17.05	17.05	17.05
Coarse aggregate (kg)	34.12	34.12	34.12	34.12
Super plasticizer (kg)	0.1279	0.1279	0.1279	0.1279

Table 2. Results of trial mixes for SCC

Test Method	Mixture 1	Mixture 2	Mixture 3	Mixture 4
Slump test (mm)	-	75	25	30
V-funnel test (sec)	-	10	12	13
L-Box test H2/H1 (mm)	-	0.83	1.00	1.30
Remarks as per SLUMP EFNARC	Very low	Medium	Low	Low

4.1 Rheological Properties

» Slump Test

The result of slump flow were obtained by a slump flow test. The test results shown in Fig. 1 indicates that Slump flow decreased from the mixture 2 with the slump value at 75, to mixture 3 at 25 and mixture 4 at 30.

» L-Box Test and V- Funnel Test

“L-Box test was used to evaluate the passing ability of SCC. Unlike slump flow, the passing ability of concrete increased as the percentages of SCC increased. The typical acceptable range of blocking ratios for the good passing ability of according to technical specification for SCC are 0.8 to 1.0. Mixes (mixture 2 and mixture 3), L-Box test ratio (H2/H1) value in between 0.80 to 1.0 except (mixture 4), which mean, as these mixes (mixture 2 and mixture 3) are up to the requirement given by technical specification for SCC with a good filling and passing ability. While mixture 4 having L-Box test ratio (H2/H1) 1.30 is out of range given by technical specification for SCC”.

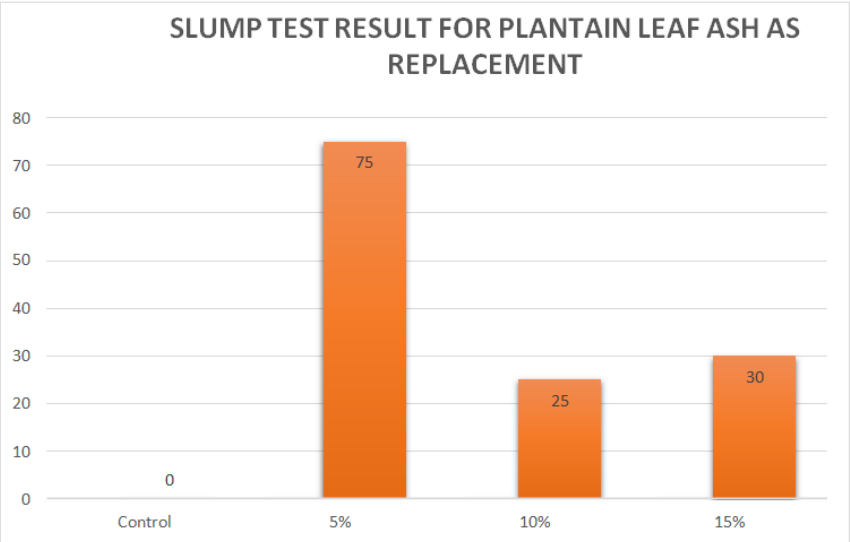

Fig. 1. Slump test results

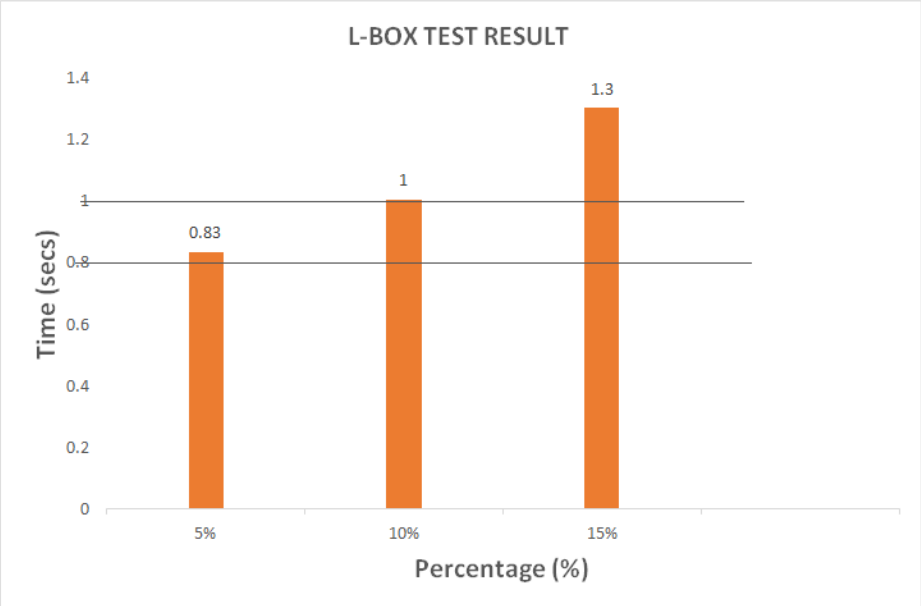

Fig. 2. L-Box test result of SCC with PLA

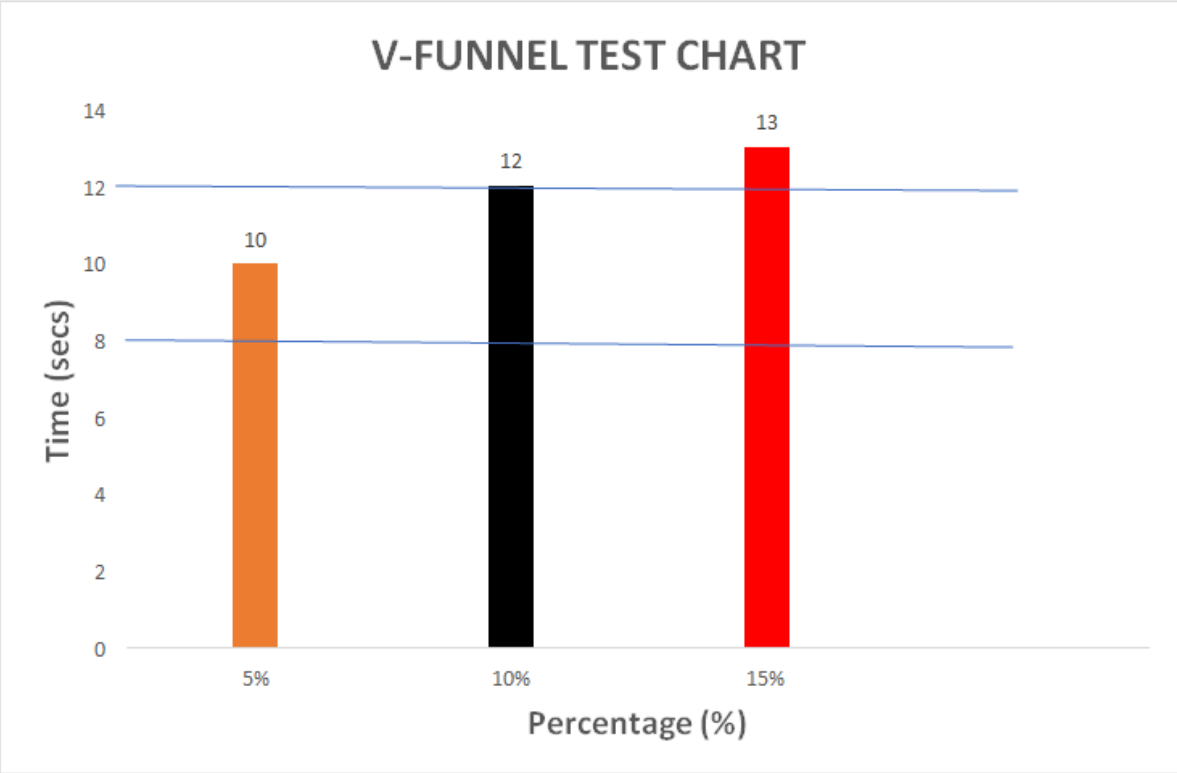

Fig. 3. V-funnel test result

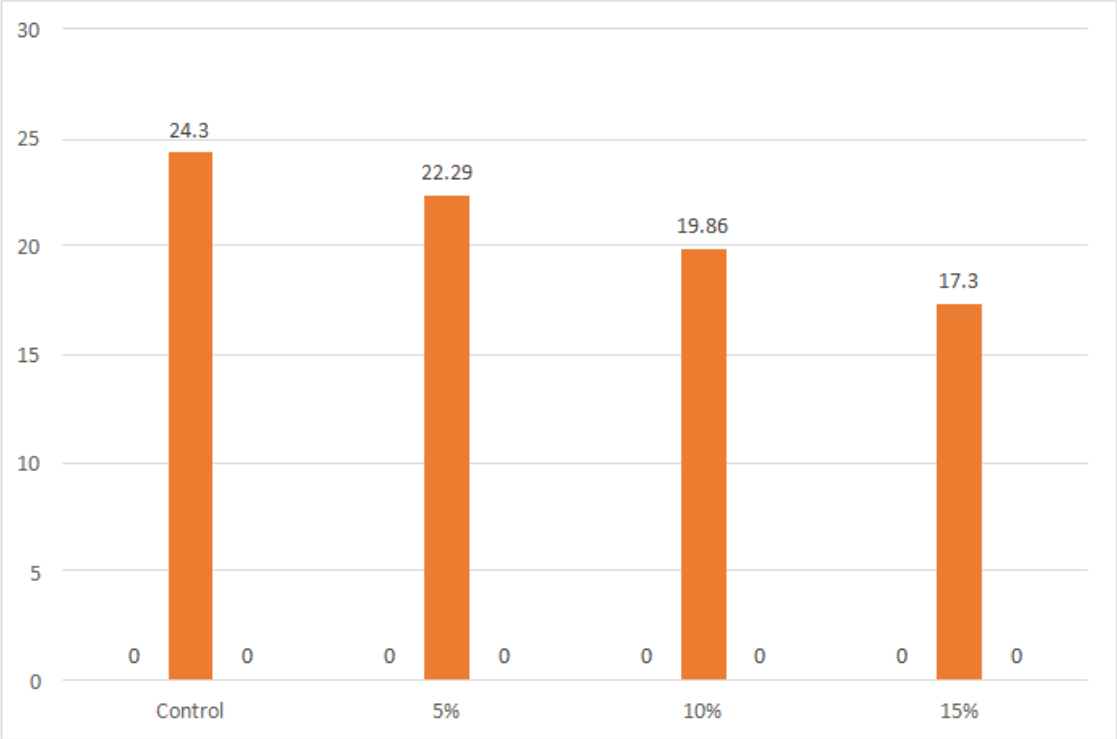

Fig. 4. 7-Days compressive strength test results

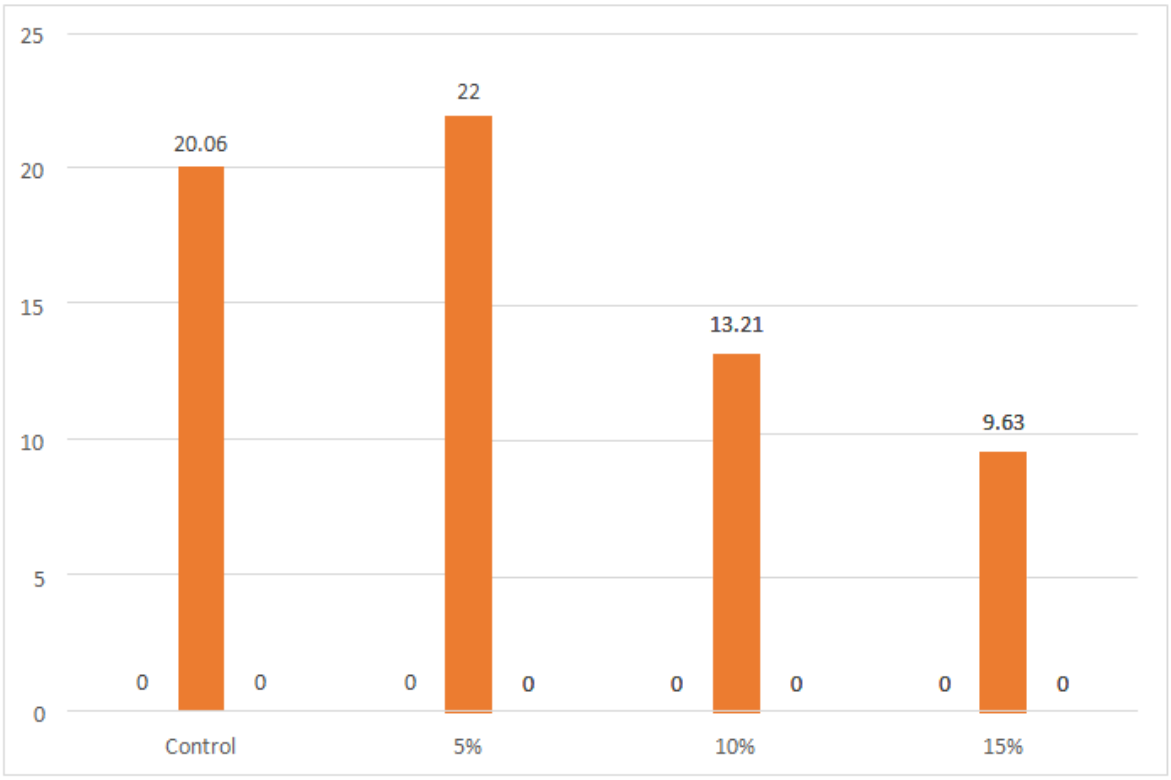

Fig. 5. 14-days compressive strength test results

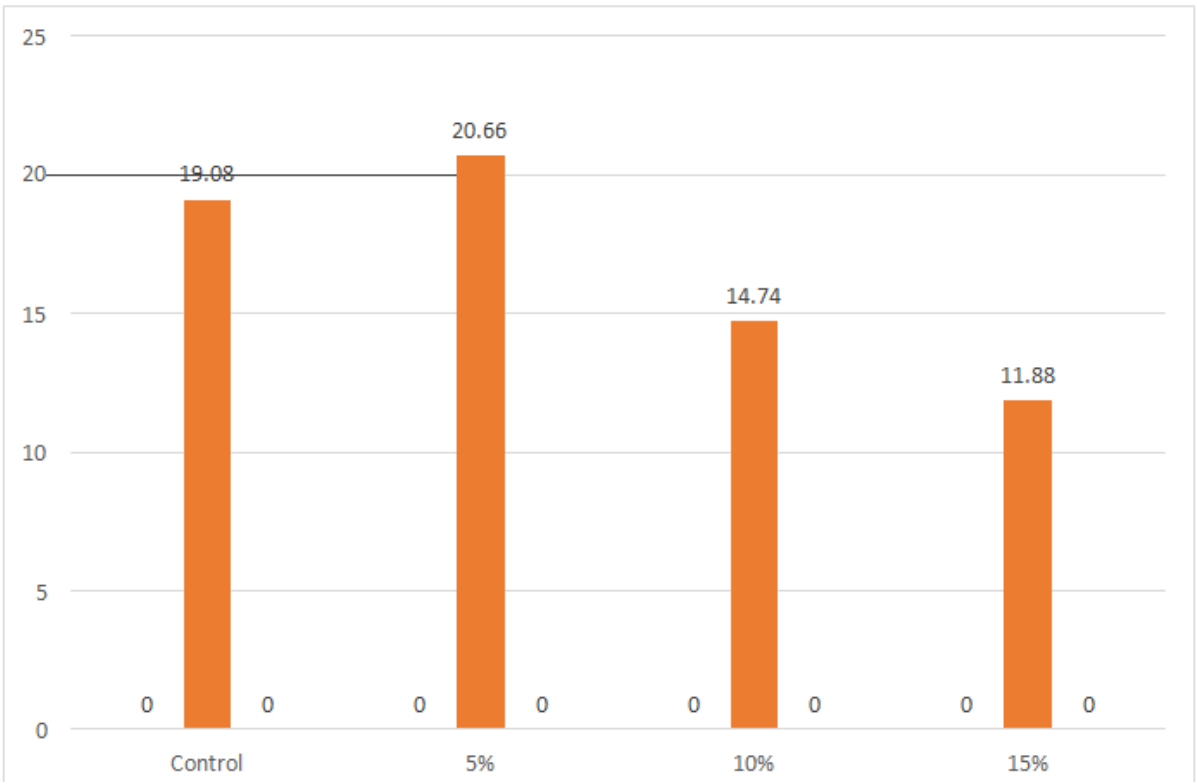

Fig. 6. 21-days compressive strength test results

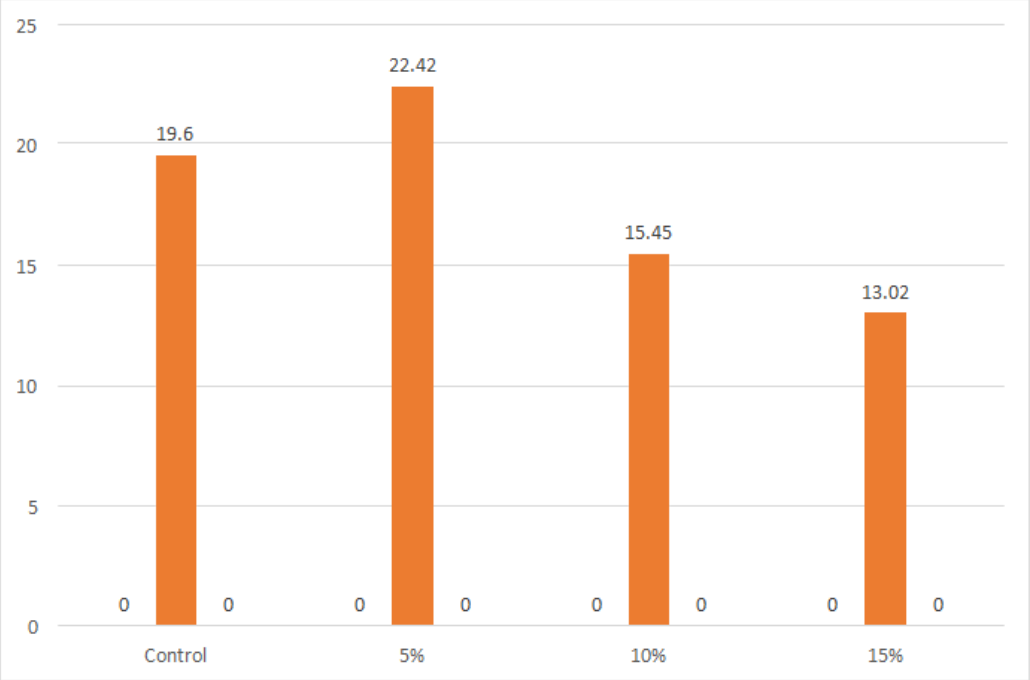

Fig. 7. 28-days compressive strength test results

Ahmad et al. [11] The V-Funnel test, was used to evaluate the Flowability of self-compacting concrete. V-Funnel Test Results tests are used to find the filling ability of SCC. It estimates the ease of flow of concrete. A shorter flow time indicates greater flowability. Similar to the slump flow test, the flowability of self-compacting concrete decreased as the percentage of PLA increased. Maximum flowability was obtained when the substitution was 5% while minimum flowability was obtained at 15% substitution of PLA. However, flow time is between 6 sec to 12 sec have acceptable range given by technical specification for SCC as shown in Fig. 2. However, at a higher dosage of 15% have flow time 13 sec which is out of the range given by technical specification for SCC.

» Compressive Strength

Compressive strength is the evaluation of the greatest compressive loading concrete can withstand. The compressive strength test is performed under the standard procedure of ASTM as ASTM C39/C39M for cubic specimens having standard dimensions as 150mm by 150mm by 150mm.

In the 7-Days compressive test results, there was a decrease in average strength of the cubes as the percentage of PLA was increased (i.e., from the control mixture to the 15% mixture of PLA). Similarly, after 14, 21 and 28 days curing there was decrease in average strength, but unlike the 7-Days curing, at 5% PLA, the 14 -28 Days curing cubes had a sharp increase in average strength then decreased from 10 - 15%.

5. CONCLUSION

In this experimental study, partial replacement of cement with plantain leaf ash and admixture (superplasticizer) was carried out and the conclusion from this study was summarized tests carried out so far.

Self-compacting concrete with the targeted fresh properties concrete was produced with up to 15% of cement replaced with plantain leaf ash.

i. From the result obtained, the replacement of cement with 5% plantain leaf ash shows a very good filling and passing ability with increase water/cement ratio.
ii. It was concluded that a higher dosage of the super plasticizer causes a retarding effect on the setting time of concrete, and there is the need for the reduction of super plasticizer dosage and also the reduction in the size of the coarse aggregate used. A nominal size of about 12.5 mm coarse aggregate could be used in the

subsequent study and the percentage of super plasticizer dosage should be reduced by weight could also prove effective.

iii. The honey comb developed was due to the size of the coarse aggregate and the non-compacting factor of the concrete.

iv. It was observed that Plantain leaf ash absorbs water and has an effect on water reduction in concrete mixture.

v. From the result obtained during the compressive strength test, a replacement of cement with 5% PLA shows a very good average strength no matter the amount of curing days.

vi. From the result obtained from both L-box and V-funnel test, replacement of cement with 5% and 10% falls in line with the acceptable range given by technical specification (EFNARC Requirements) for SCC.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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