COMPARATIVE EVALUATION OF *MUSA PARADISIACA* PSEUDO-STEM PITH FLUID AND SODIUM PHOSPHATE AS RETARDERS IN CEMENT MORTAR

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ABSTRACT

This study compares the retarding effect of plantain pseudo-stem pith fluid with that of sodium phosphate in mortar to ascertaining the efficacy of the former as an eco-friendly retarder for sustainable construction in developing countries. A cement paste of cement and water, and a mortar mix of 1: 3: 0.45 (cement: fine aggregate: water/cement ratio) by weight, respectively, were prepared as reference; and subsequently each of the retarders in the range of 0 to 1% by weight of water were added as replacement to the mixing water. Consistency and setting times of the paste were tested; and 50 mm cube mortar and 160 mm × 40 mm × 40 mm prism were cast and tested for compressive and flexural strength up to 28 days. The results revealed that the consistency ranged from 26.7% to 30.4% for both retarders, and the setting times were delayed more for the blended pastes than the reference. The highest compressive strengths of 26.93 N/mm^2 and 27.33 N/mm^2 were attained with sodium phosphate dosage of 0.625% and plantain pseudo-stem pith fluid of 0.865% dosage, respectively, at 28 days' hydration. The flexural strength of the sodium phosphate mortar specimens at 28 days attained higher values than that of the plantain pseudo-stem pith fluid and the reference. Statistical test on consistency, setting times and compressive strength of the retarders indicated no significant difference. It can be concluded that plantain pseudo-stem pith fluid of 0.825% as water replacement in a mortar mix is a good bioadmixture to commercial retarders.

KEYWORDS: *Compressive strength; flexural strength; mortar; plantain pseudo-stem pith; setting times; sodium phosphate*

1.0 INTRODUCTION

Plantain (*Musa spp*.) is a major starchy staple in sub-Saharan Africa for both the rural and urban populaces, providing more than 25% of the carbohydrates and 10% of the daily calorie intake for more than 70 million people on the region (Swennen, 1990). It occupies a strategic role in rapid food production, being a perennial crop with a short gestation period of about three months from the beginning of flowering until harvest (Ayoola, 2011). Its cultivation is attractive to farmers due to the low labor requirements for production compared with cassava, maize, rice and yam. Accordingly, Marriot and Lancaster (1993)

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stated that the cost of plantain production in terms of cost per hectare per ton and per unit of food energy is the lowest compared with other crops grown in the traditional agricultural system. It is reported that Nigeria is one of the largest producers of plantain in the world (FAO, 2013); it is ranked first in Africa and fifth in the world, and produced 2,722,000 metric tons in 2011 (FAO, 2012).

After the fully mature plantains have been harvested, the pseudo-stems are usually left to decay, thereby constituting environmental pollution. However, a few studies carried out to determine mineral constituents in the pseudo-stem pith juice have revealed that it contains carotene, mucilage, calcium, monoterpene alkaloids, glycosides, sugars, triterpenes, linoleic acid and iridoids (Bailey, Bailey & Hortatorium, 1976); similarly, the mineral elements detected by Akpabio, Udiong and Akpakpan (2012) in the pseudo-stem (that is, the leaf-fold) and the pith wastes are Na, K, Cr, Mg, Zn, Fe and Cu. In addition, plantain pseudo-stem waste contains a high level phytochemicals and a high amount of carbohydrate which can be exploited for the preparation of pulp for paper making and for production of cellulose derivatives and sugar (Akpabio et al., 2012). Umoh and Nnana (2014) identify Ca^+, Cl^-, NO_3^-, Na, SO_4^{2-}, and sugar as elements found in pseudo-stem pith fluid.

Sodium phosphate admixture with the chemical name sodium dihydrogen phosphate dihydrate ($NaH_2PO_4.2H_2O$) is a water-soluble white crystalline and odorless solid. Investigation by Collepardi (1995) has shown that sodium phosphate slows down the rate of early hydration of C_3S by extending the length of the dormant period (i.e. the second stage of hydration), and that most phosphates retard the setting of cement. Phosphates are commonly used as an ingredient in commercial set-retarding admixtures (Metha & Monteiro, 2006). Ramachandran and Lowery (1992) screened potential retarders for ordinary Portland cement and found that sodium phosphate ($NaH_2PO_4.2H_2O$) was one of the effective retarders, while sodium hexametaphosphate, $(NaPO_3)_6$, showed a moderate set retarding capacity. Gong and Yang (2000) showed that sodium phosphate effectively retards the hydration of alkali-activated red mud-slag cementitious materials.

Retarding admixtures are used to slow down the speed of the reaction between cement and water by affecting the growth of the hydration products and/or reducing the rate of water penetration to the cement particles. The use of a retarder will increase the setting time and may delay strength development of the concrete (EFCA, 2006). Retarders act as inhibitors to the chemical processes between cement and water, thereby prolonging the setting time (Okereke, 2003). It is believed that retarders modify crystal growth or morphology, becoming absorbed on the rapidly formed membrane of hydrated cement and slowing down the growth of calcium hydroxide nuclei, thus forming a more efficient barrier to further hydration than is the case without a retarder (Neville, 2006).

Retarders are normally added at a concentration between 0.1% and 1.0% (Satiyawira, Fathaddin & Setiawan, 2010) and are typically based on phosphates, phosphonates, gluconate, polysaccharides, and sucrose among others (EFCA, 2006). In this study, retarders for consideration are a bioadmixture derived from plantain pseudo-stem pith, hereby called plantain pseudo-stem pith fluid (PPPF), and a commercially available sodium phosphate.

Some agricultural waste materials have been processed and used as bioadmixtures in mortar and concrete in order to modify the properties of the cement-based material by delaying its hydration process, without necessarily affecting the ultimate performance of the product, to enable easy placement, compaction and finishing to the required texture, or to accelerate the performance of the product within a predicted time frame. Recent investigations have revealed that plant derivatives have the potential to be used as retarding admixtures. The effect of pine (*Pinus canariensis*) tree bark extract on the properties of fresh and hardened concrete was investigated by Chege, Oyawa and Mang'uriu (2014). The pine tree extract was prepared using water, heat and pressure and the resulting mixture was black liquor. The black liquor of up to 20% content by weight of cement was observed to improve the compressive strength of the concrete compared to that of the reference concrete. Woldemariam, Oyawa and Abuodha (2014) conducted a study on cypress tree extract as an eco-friendly admixture in concrete. The plant extract was prepared by boiling the cypress bark in water or by soaking it in cold water. Dosages of 5 - 15% of the extracts in water were used as admixture in the preparation of concrete cubes at constant slump, which were then tested for compressive strength. The outcome of the test showed that the use of cypress plant extract delayed the setting time of cement, hence showing its potential as a concrete retarder in hot climates. Compressive test results demonstrated that increased dosages of the plant extract in water improved the compressive strength of concrete.

Otoko (2014) focused his research on minimizing hot weather effects on fresh and hardened concrete by using cassava powder as an admixture. Peeled cassava tubers grated into slurry and put into bags were subjected to jacking pressure to expel water and the remnant was used in producing 'garri', a stable food in Nigeria. This waste milk water so extracted (which ordinarily pollutes the environment) was allowed to settle for 24 hours, then the clear water was decanted and the remnant was air-dried and crushed to obtain the cassava powder. Concrete cube specimens were then prepared. A small quantity of sugar (0.05% and 0.15% of cement weight) was added to the fresh concrete in one phase as a known retarder, and the cassava powder (0.05% and 0.15% of cement weight) was added to the fresh concrete in another phase, to investigate its suitability as a controlled set-retarder. The results showed that the cassava powder has the potential to increase workability, retard setting time and at the same time increase both the early and long-term strength of the concrete.

Sathya, Bhuvaneshwari, Niranjan and Vishveswaran (2014) similarly carried out a study on the use of extract of water hyacinth as a bioadmixture in cement and concrete. The consistency and setting time of the cement was noted for 0%, 10%, 15% and 20% replacement of water with hydro-extract of water hyacinth, and the mechanical properties of the concrete were also assessed. The results of the study showed an increase in the compressive strength and workability of the concrete with an increase in the percentage of the bioadmixture. Also, the setting time was found to be delayed with an increase in replacement percentage of the bioadmixture.

A study on fresh leaves of *Bambusa arundinacea* (Indian bamboo) as an eco-friendly green inhibitor to improve the strength of concrete was carried out by Abdulrahman and Ismail (2011). They were focused on investigating *Bambusa arundinacea* as a non-toxic and eco-friendly inhibitor, comparing its effectiveness with calcium nitrite and ethanolamine inhibitors. Fresh leaves of *bambusa arundinacea* were collected, washed under running water, shade-dried and ground into powder. Concrete cubes were prepared and calcium nitrite (1.5% and 4.5% weight of cement content), ethanolamine (1.5% and 4.5% weight of cement content) and green *bambusa arundinacea* (2% and 4%) were added. It was noted that *bambusa arundinacea* exhibited superior compressive strength compared to calcium nitrite and ethanolamine; hence, the study concluded that *bambusa arundinacea* is a good substitute for nitrite- and amine-based corrosion-inhibiting admixtures.

Woldemariam, Oyawa and Abuodha (2015) carried out an investigation to determine the suitability of blue gum plant extract as a shrinkage-reducing admixture. The plant extract was prepared by cutting blue gum bark into small pieces and boiling it in water under pressure. Mortar slabs (500 mm × 500 mm × 15 mm) were cast with plant extract percentages of 0%, 5%, 10% and 15%. The slabs were exposed to certain environmental conditions; shrinkage and cracks were studied at 5 hours, 3 days, 7 days and 28 days. Results obtained indicated that the use of blue gum plant extract reduced shrinkage and cracks and thus it can be used as a shrinkage-reducing admixture.

In a related study, *Musa paradisiaca* pseudo-stem pith fluid was investigated as a set-retarding admixture in cement paste and mortar (Umoh & Nnana, 2014). The *Musa paradisiaca* pseudo-stem pith fluid content of 0%, 0.5%, 0.75% and 1.0% by weight of cement was used with a constant water/cement ratio of 0.4. Cement paste was prepared and was tested for consistency and setting times; while mortar cube specimens were produced and tested for compressive and flexural strengths, water absorption and density. The results obtained showed a delay in the setting times of the paste, and an increase in compressive and flexural strength of the mortar specimens with up to 0.75% replacement of *Musa paradisiaca* pseudo-stem pith fluid.

Oladiran, Aderinlew and Tanimola (2012) investigated the effects of orange leaves as a locally sourced water-reducing/retarding admixture on concrete. The orange leaves were collected, sun-dried for about three weeks and ground into powder. The admixture was added to the concrete mix produced in percentages of 1, 2, 5, 10 and 15 by weight of cement. The compressive strength of the concrete cube tested at 28 days increased considerably as the admixture content increased from 1% to 5% beyond that of the reference, and thereafter dropped at 10% and 15% admixture content.

There is little literature on the use of plantain pith fluid as an admixture in the construction industry, apart from the study by Umoh and Nnana (2014) on the use of pseudo-stem pith fluid as a retarder in cement paste and mortar. Therefore, the purpose of this study is to confirm the earlier postulation of the fluid as a retarder by comparing its efficacy to that of sodium phosphate, which is a known retarder.

3.0 MATERIALS AND METHOD

3.1 Materials

The cement used for this work was Portland limestone cement (CEM II/ B-L 32.5R), produced in Nigeria by the United Cement Company of Nigeria Limited in conformity with the Nigerian Industrial Standard (NIS) 444-1: 2003.

The fine aggregate (sand) was obtained from a local supplier in Akwa Ibom State, and the sieve analysis of the sand sample indicated compliance with the requirements of ASTM C 144 (1991) for sand suitable for masonry mortar (Table 1).

Table 1. Sieve analysis of fine aggregate

Sieve sizes (mm)	**Material retained**		**Cumulative percentage retained (%)**	**% passing**	**% passing as per ASTMC 144:1991**
	(g)	**(%)**			
4.75	1	0.16	0.16	99.84	100
2.36	8	1.24	1.40	98.60	95-100
1.18	59	9.18	10.58	89.42	70-100
0.6	289	44.95	55.53	44.47	40-75
0.3	221	34.37	89.90	10.10	10-35
0.15	51	7.93	97.83	2.17	2-15
Pan	14	2.17	100	0.00	

Water used for mixing and curing purposes was fetched from the tap provided in the Building Material Laboratory, University of Uyo; while the commercial retarder was sodium phosphate ($NaH_2PO_4.2H_2O$) purchased from Okstan Laboratory and Scientific Supplies, Ariaria International Market, Aba.

Plantain pseudo-stems were collected from a plantain farm in Uyo after the fruit (plantain) had been harvested and the stems left as waste (Figure 1). They were cut into 300 mm pieces for easy conveyance to the building materials laboratory of the University of Uyo, as well as to facilitate the removal of the pith. After this, the folded leaves of the pseudo-stem were removed and the pith was collected (Figure 2), pound and squeezed to obtain the fluid. The collected fluid was filtered twice to give a clear fluid and was thereafter stored in plastic bottles for use. The physical and chemical properties of the plantain pseudo-stem pith fluid (PPPF) are presented in Table 2.

Table 2. Physical and chemical composition of PPPF

Description	**Value/unit**
Physical Properties	
PH	6.80
Moisture content (%)	87.9
Color	Light Brown
Odor	Pungent smell
Chemical Composition	
Elements	Mg/L
Potassium	116.5990
Iron	13.78
Arsenic	<0.0001
Sodium	67.105
Nitrate	3.54
Sulfate	0.18
Insoluble water	5.63
Calcium	8.21
Chloride	3.66

Figure 1. Plantain pseudo-stems as waste after fruit harvesting

Figure 2. Plantain pseudo-stem pith after removal of folded leaves

3.2 Specimen Preparation and Production

The cement pastes were prepared with a mixture of cement and water as the reference. Retarding admixtures of PPPF and sodium phosphate in proportions of 0%, 0.5%, 0.625%, 0.75%, 0.875% and 1.0% by weight of water were added as replacements for the mixing water, and tested for consistency and setting times. A mortar mix of 1: 3 (cement: Fine aggregate) by weight with a water-cement ratio of 0.45 was employed as the reference. The retarders (PPPF and sodium phosphate) of 0%, 0.5%, 0.625%, 0.75%, 0.875% and 1.0% by weight of the water were used to replace the prescribed quantity of water in the mix. The admixtures were added with the water during the mixing operation, and mixed thoroughly. The fresh mortar mixes were placed in cube molds of size 50 mm and prism molds of size 160 mm × 40 mm × 40 mm, in two equal depths, and each depth tamped for 25 strokes with a tamping rod evenly spread over the surface of the mold. The cast specimens were covered with a jute bag and left undisturbed for 24 hours, and thereafter the specimens were removed from the molds and cured in a curing tank prior to testing.

3.3 Testing of Paste and Specimens

The consistency of standard cement paste and the initial and final setting times were determined using Vicat apparatus in accordance to BS EN 196-3 (2005) and as shown in Figure 3.

Figure 3. Vicat apparatus for consistency and setting times of cement paste

The compressive strength was assessed using a digital crushing machine of 250 N/mm^2 capacity and in accordance to ASTM C109 (2001) and tested at 3, 7, 14 and 28 days of curing. Three specimens were tested for each curing age and a mean computed and used for the calculation of the compressive strength, CS from the expression as given in Equation (1):

$$CS = \frac{P}{A} \tag{1}$$

where P is the load at failure and A is the area of specimen.

The flexural strength of the hardened mortar was conducted in accordance to ASTM C348 (2008). The flexural strength, FS was calculated using an expression as given in Equation (2):

$$FS = \frac{1.5\ WL}{bd^2} \tag{2}$$

where FS is the flexural strength in N/mm^2, W is the load applied to the specimen, b and d are the lateral dimensions of the prism mold, and L is the distance between the supporting rollers.

4.0 RESULTS AND DISCUSSION

4.1 Consistency and Setting Times of Cement Paste

The consistency and setting times of cement paste with varying contents of sodium phosphate and PPPF ranging from 0 - 1% content replacing water in the mix are presented in Tables 3 – 6. The consistency results for the pastes, as presented in Table 3, indicated that the consistency for the mixes containing sodium phosphate ranges between 27.9% and 30.4%, which is slightly more than the value of consistency for the reference mix; while that of the PPPF mixes ranges between 26.7% and 27.5%, which is slightly less than that of the reference mix. However, all the values obtained fall within the recommended values of 26 to 33%.

Table 3. Consistency and initial setting time of cement paste incorporating retarders

Dosage replacement (%)	**Consistency (%)**		**Initial setting time (Minutes)**	
	Sodium phosphate	**PPPF**	**Sodium phosphate**	**PPPF**
0.0	27.7	27.7	85	85
0.5	28.4	26.7	127	122
0.625	27.9	27.4	162	165
0.75	29.3	26.9	119	117
0.875	29.3	27.5	174	184
1.0	30.4	27.2	120	126

The initial setting time, as presented in Table 3, was higher with pastes containing sodium phosphate and PPPF than the reference. The initial setting time increased by 42, 77, 34, 89 and 35 minutes over the reference for sodium phosphate, and 37, 80, 32, 99 and 41 minutes above the reference for PPPF of dosage 0.5, 0.625, 0.75, 0.875 and 1.0%, respectively. However, all the pastes fall within the minimum recommended range of 45 minutes for the initial setting time (NIS 447, 2003; BS EN 197-1, 2009).

Statistical analysis (t-test) carried out to find out if there is any significant difference in the initial setting time between mixes containing varying dosages of sodium phosphate and that of PPPF, as presented in Table 4, shows that the calculated t-value of 0.894 is less than the table value of 2.57; therefore, there is no significant difference in their initial setting times.

Table 4. T-Test on initial setting time of sodium phosphate and PPPF

Paired sample	**Paired Differences**							
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence interval of the Difference** **Lower**	**Upper**	**T**	**DF**	**Sig. (2-tailed)**
Sod - PPPF	-2.00000	5.47723	2.23607	-7.74800	3.74800	-.894	5	.412

Sod = Sodium phosphate; PPPF = Plantain pseudo-stem pith fluid.

The final setting times, as presented in Table 5, is noted to be higher than the reference mix by 78, 180, 151, 151 and 150 minutes for sodium phosphate and 73, 172, 140, 153 and 153 minutes for PPPF with respect to 0.5, 0.625, 0.75, 0.865 and 1.0% dosage, respectively. Mixes containing 0.625% and 0.875% of sodium phosphate and PPPF attained the highest final setting times of 326 minutes and 299 minutes, respectively. However, all the pastes fall within the maximum of 10 hours for final setting time as approved by NIS 447 (2003) and BS EN 197-1 (2009).

Table 5. Final setting time of cement paste incorporating retarders

Dosage replacement (%)	**Final setting time (minutes)**	
	Sodium phosphate	**PPPF**
0.0	146	146
0.5	224	219
0.625	326	318
0.75	297	286
0.875	297	299
1.0	296	299

Statistical analysis (t-test) carried out to find out if there is any significant difference in the final setting time between mixes containing varying dosages of sodium phosphate and that of PPPF, as presented in Table 6, shows that the calculated t-value of 1.359 is less than the table value of 2.57; therefore, there is no significant difference in their final setting times.

These higher setting time values for the pastes containing PPPF over the reference could be attributed to the presence of Ca^{2+}, Na^{+}, sugar, sulfate and carbohydrate derivatives, which are some of the primary constituents in retarding admixtures as spelt out by BS EN 934-2 (2001), and thus PPPF could be classified as a retarder.

It is also suggested that the formation of tricalcium aluminate ($3CaO.Al_2O_3$) and tetracalcium aluminoferrite ($4CaO.Al_2O_3.Fe_2O_3$) compounds during the reaction of cement and water, and which are responsible for fast setting of the cement paste, may have been hindered by the presence of the admixtures. This affirms the assertion that most commercial lignosulfonate used in admixture formulations is predominately calcium – sodium based with sugar content (Rixon & Mailvaganam, 2007).

Table 6. T-Test on final setting time of sodium phosphate and PPPF paired sample

Paired sample	**Paired Differences**					**T**	**DF**	**Sig. (2-tailed)**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	**Upper**			
sod - PPPF	3.16667	5.70672	2.32976	-2.82217	9.15550	1.359	5	0.232

Sod = Sodium phosphate; PPPF = Plantain pseudo-stem pith fluid.

4.2 Compressive Strength of Hardened Mortar

The mean compressive strength tests of the hardened mortar at 3, 7, 14 and 28 days of curing are presented in Figures 4-7. The results of the compressive strength of hardened mortars at three days with different dosage replacements of water with sodium phosphate and PPPF are presented in Figure 4. The mortar incorporating retarders (sodium phosphate or PPPF) indicated an increase in the compressive strength over the control. A strength increment over the control in the range of 2.40 N/mm^2 to 3.73 N/mm^2 was recorded for sodium phosphate and 1.40 N/mm^2 to 4.66 N/mm^2 for PPPF. The lowest strength increments of 2.40 N/mm^2 and 1.40 N/mm^2 were recorded with dosages of 0.5% and 1.0% for the sodium phosphate, and 0.5% for the PPPF; while the highest occurred with dosages of 0.625% and 0.875% for sodium and PPPF, respectively.

The seven days' compressive strength as presented in Figure 5 shows that the compressive strengths of the mortar incorporating retarders were higher than that of the control irrespective of the retarder dosage. The highest compressive strength was attained with mortar specimens containing 0.625% and 0.875% dosage of retarder for sodium phosphate and PPPF, respectively, corresponding to a strength of 22.27 N/mm^2 and 23.40 N/mm^2 in that order. This shows a strength improvement of 26.54% and 32.95% for sodium phosphate and PPPF, respectively, over the control.

The results of the compressive strength tests for the hardened mortar at 14 days with different dosage replacement of phosphate and PPPF are presented in Figure 6. The results indicated that the sodium phosphate retarder had increased the compressive strength at 0.625% dosage over the control by 25.80%, while that of the PPPF retarder at 0.875% is 21.08% greater than the control specimen.

At 28 days, the sodium phosphate dosage of 0.625% achieved peak compressive strength of 26.93 N/mm^2 while that of the PPPF was 27.33 N/mm^2 at 0.865% dosage, corresponding to compressive strength increase over the control by 18.79% and 20.56%, respectively (Figure 7). The peak compressive strengths of 26.93 N/mm^2 and 27.33 N/mm^2 for the sodium phosphate and PPPF mortar at 28 days met the minimum strength required for type 'M' mortar (ASTM C 270, 2006).

A test of significant difference between the compressive strengths of mortar mixes containing the same varying dosages of sodium phosphate and that of PPPF is presented in Table 7. The result indicated a calculated t-value of 1.088, which is less than the table value of 1.988; therefore, there is no significant difference between compressive strength values of the mortar containing sodium phosphate and that of the mortar containing PPPF at the same dosages. This indicates that PPPF is a retarding admixture just as sodium phosphate is.

Table 7. T-Test on compressive strength of sodium phosphate and PPPF

Paired sample	**Paired Differences**					**t**	**DF**	**Sig. (2-tailed)**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	**Upper**			
sod - PPPF	0.37333	1.68082	0.34310	-0.33642	1.08308	1.088	23	0.288

Sod = Sodium phosphate; PPPF = Plantain pseudo-stem pith fluid.

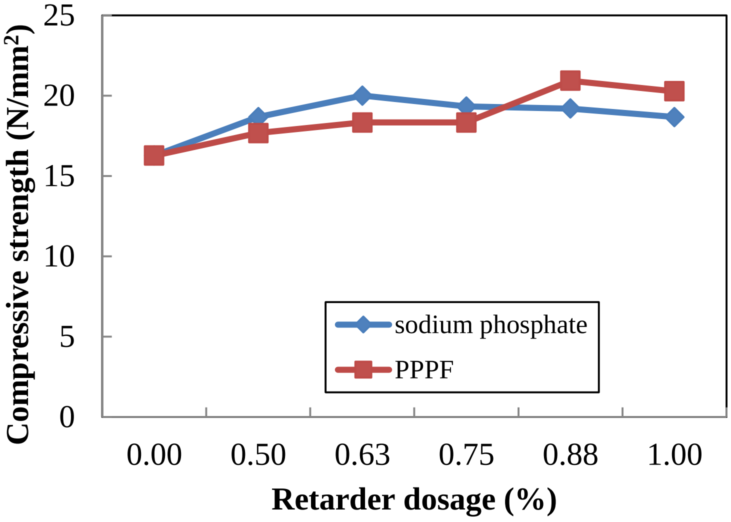

Figure 4. Mortar compressive strength with varied dosages of retarders at 3 days' curing

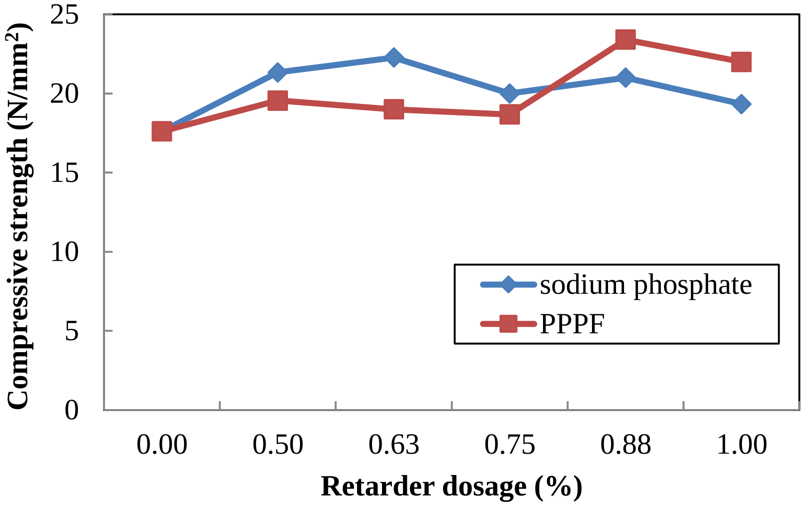

Figure 5. Mortar compressive strength with varied dosages of retarders at 7 days' curing

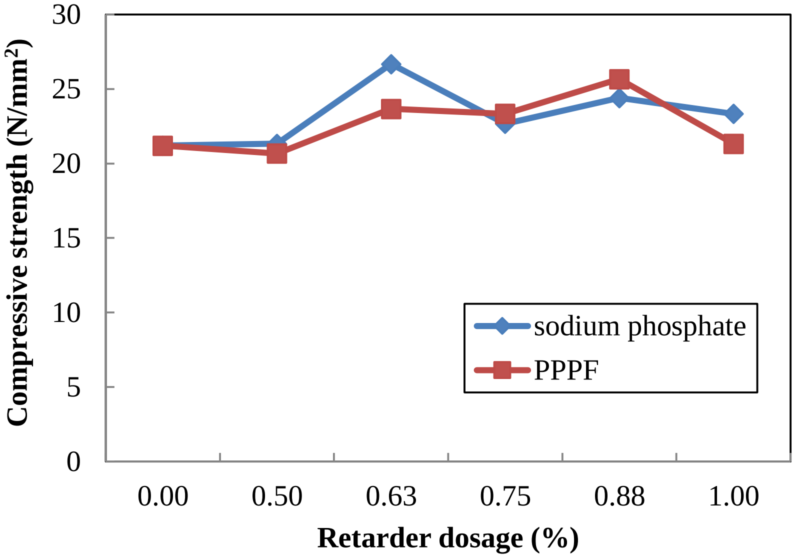

Figure 6. Mortar compressive strength with varied dosages of retarders at 14 days' curing

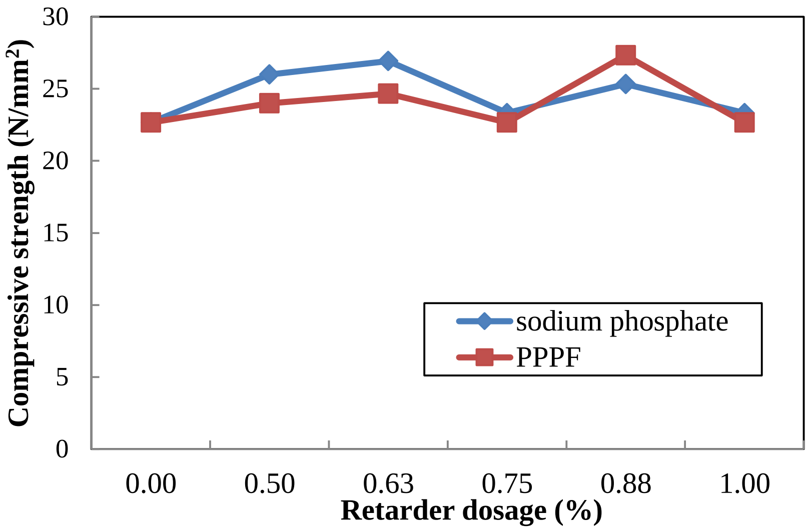

Figure 7. Mortar compressive strength with varied dosages of retarders at 28 days' curing

4.3 Flexural Strength of Hardened Mortar

The results of the flexural strength at 7 and 28 days' curing are presented in Table 8. It is noted that the flexural strengths of the reference specimens are 1.86 N/mm^2 and 1.88 N/mm^2 for 7 and 28 days, respectively; and that at seven days only specimens containing 0.625% and 0.75% of sodium phosphate had flexural strength higher than the reference, while those with PPPF could not attain the flexural strength of the reference. There is an increase in the flexural strength attainment of specimens containing sodium phosphate at 28 days, as they attained higher values than the reference specimen; whereas those of PPPF were not greater than the reference. This shows that PPPF does not contribute to enhancement of the flexural strength of mortar, unlike the sodium phosphate. This is further portrayed by the test of significance difference between the two retarders, as it indicated that the calculated t-value of 4.728 is greater than the table value of 2.20 (Table 9), and therefore there is a significant difference between the flexural strength values of mortar containing sodium phosphate and those of the mortar containing PPPF at the same dosages.

Table 8. Flexural strength of hardened mortar at 7 and 28 days

	7 Days (N/mm^2)		**28 Days (N/mm^2)**	
Dosage replacement (%)	**Sodium phosphate**	**PPPF**	**Sodium phosphate**	**PPPF**
0.0	1.86	1.86	1.88	1.88
0.5	1.48	1.30	2.00	1.53
0.625	2.22	1.24	2.29	1.41
0.75	1.98	1.29	1.94	1.39
0.875	1.85	1.49	1.99	1.87
1.0	1.81	1.35	2.18	1.48

Table 9. T-Test on the flexural strength of sodium phosphate and PPPF

Paired sample	Paired Differences					t	DF	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
sod – PPPF	0.44917	0.32909	0.09500	0.24007	0.65826	4.728	11	0.001

Sod = Sodium phosphate; PPPF = Plantain pseudo-stem pith fluid.

5.0 CONCLUSION

The study reveals that the consistency for the mixes containing sodium phosphate is slightly more than the consistency value for the reference; while that of the PPPF mixes is slightly less than that of the reference. However, all the values obtained fall within the recommended values. The initial and final setting times of pastes with dosages of 0.625% sodium phosphate and 0.875% of PPPF had the highest delayed time over the reference, indicating that sodium phosphate and PPPF are set-retarding admixtures. The highest compressive strength was achieved with a sodium phosphate dosage of 0.625% and a 0.865% dosage of PPPF, respectively, at 28 days' hydration, corresponding to compressive strength increase. It means that the retarders at the specified dosages of sodium phosphate and PPPF, respectively, contribute to strength development of the mortar. There was no significant difference in the values obtained by the two retarders, showing that plantain pseudo-stem pith fluid is a good retarder that could be used in mortar. The flexural strength of the mortar incorporating sodium phosphate at 28 days was higher than that of the reference and much higher than that of the PPPF. This shows that PPPF does not contribute to the enhancement of the flexural strength of mortar, unlike the sodium phosphate. The study recommends that plantain pseudo-stem pith fluid is a bioadmixture that could be used to achieve a needed retarding effect in cement mortar. Further study to examine its performance in concrete is ongoing.

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