Characteristics of Concrete Produced with Lagoon and Atlantic Ocean Water.

Akeem A. Raheem, Ph.D.[1*]; Olumide A. Adenuga, Ph.D.[2]; and Olushola A. Afolabi, B.Sc.[2]

[1]Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
[2]Department of Building, University of Lagos, Akoka, Yaba, Lagos, Nigeria.

E-mail: raheemayinde@yahoo.com*

ABSTRACT

Dwellers along the coastline area of Lagos State, Nigeria, are exposed to abundant supply of the natural resources of Atlantic Ocean and Lagoon water and may not have the privilege of having potable drinking water at their disposal for producing concrete. This study evaluates the characteristics of concrete produced with Atlantic Ocean and Lagoon water. Concrete produced with Tap water (regarded as potable drinking water) serves as the control experiment. Compressive strength, Workability and Density, were used to evaluate the characteristics of concrete specimens. All the concrete samples have true slump with Lagoon water concrete having low workability and both Tap and Atlantic Ocean water concrete having medium workability. The concrete specimens produced with the three types of water fall into the category of normal weight concrete as their densities lie within the range of 2200 to 2600 kg/m^3 specified. The 28th day compressive strength of concrete specimens produced with Atlantic Ocean, Tap and Lagoon water are 25.0 and 33.5 N/mm^2, 17.9 and 28.6 N/mm^2 as well as 15.1 and 19.4 N/mm^2 for mix ratios 1:3:6 and 1:2:4, respectively. The very high compressive strength of concrete specimens produced with Atlantic Ocean water notwithstanding, the high chloride content in it is detrimental to its use where reinforced steel bars are required. It was concluded that Tap water should be used in mixing concrete where strength is of major concern and Lagoon water may be used for general concrete works where strength is of less importance such as in mass concrete, floor screed and mortar.

(Keywords: Atlantic Ocean water, lagoon water, tap water, concrete, density, compressive strength)

INTRODUCTION

Lagos State of Nigeria consists of a large lagoon and an archipelago of large islands. The coastline is bound by the Atlantic Ocean which is the second largest ocean in the world [1]**.** Thus, Lagos state is blessed with two great natural sources of water - Lagoon water and Atlantic Ocean water. Dwellers along the coastline area of Lagos state are exposed to the abundant supply of these natural resources and may not have the privilege of having potable drinking water at their disposal for producing concrete. This research investigates the characteristics of concrete produced with these available sources of water for construction works along the coastal line area of Lagos state, with a view to ascertaining their adequacy or otherwise.

Concrete for many years, has been one of the major materials used in the construction of buildings and other engineering structures. It is a construction material which composed mainly of three constituents, namely, cement, fine and coarse aggregates and water. Cement is the chemically active constituent but its reactivity is only brought into effect on mixing with water. Thus, water is an important ingredient of concrete as it actively participates in the chemical reaction with cement [2].

Water used in concrete, in addition to reacting with cement and thus causing it to set and harden, also facilitates mixing, placing and compaction of the fresh concrete. According to [3], water for concrete should be reasonably free from such impurities as suspended solids, organic matter and dissolved salts which may adversely affect the properties of concrete. There is the popular saying that only water fit for drinking is acceptable as being satisfactory for mixing concrete. However, in [2] argument, some waters containing a small amount of sugar would be suitable for drinking but not for mixing concrete. A simple way of determining the suitability of such water is to compare the setting time of cement and the strength of the mortar cubes using the water in question with the corresponding results obtained using known 'good' water or distilled water. A tolerance of about 10 percent is usually permitted to allow for chance variations in strength (BS 3148: 1980) [4]. Table 1 shows the tolerance of concentrations of some impurities in mixing water [2].

The objectives of this study are to:

(i) determine the physical and chemical characteristics of the Lagoon water and Atlantic Ocean water and compare them with known standards such as the World Health Organization (WHO) and Nigerian Industrial Standard (NIS);

(ii) produce concrete specimens using Lagoon and Atlantic Ocean water for mixing and curing purposes;

(iii) produce another set of concrete specimens with Tap water (regarded as potable drinking water) as the control experiment and

(iv) evaluate the workability, density, and compressive strength of the concrete specimens produced and compare them with available standards.

MATERIALS AND METHODS

Materials

Burham Portland cement was used in the production of the concrete and it was obtained from a local dealer at Costain, Orile Iganmu in Lagos State. The fine aggregate is sharp sand with sizes not greater than 5mm diameter and it was obtained from Tin Can Island, Lagos. The coarse aggregate is granite from crushed quarried rocks. The size of the granite is not greater than 19mm and it was bought from local granite seller at Costain, Orile Iganmu in Lagos State. Three types of water were used in mixing the concrete namely: Atlantic Ocean water which was obtained from Lagos Bar Beach, Lagoon water which was obtained from Lagoon front at University of Lagos, Akoka and Tap water which was obtained from Civil Engineering Concrete Laboratory, University of Lagos, Akoka, Lagos State.

Table 1: Tolerable Concentrations of Some Impurities in Mixing Water.

Impurity	Tolerable consideration
Sodium and potassium carbonates and bicarbonates	1,000 ppm (total). If this is exceeded, it is advisable to make test both for setting time and 28 days strength.
Chlorides	10,000ppm
Sulfuric anhydride	3,000 ppm
Calcium chloride	2 % by weight of cement in non pre-stressed concrete.
Sodium iodate, sodium sulfate, sodium	Very low
Arsenate, sodium borate, sodium sulfide	Even 100 ppm warrants testing
Sodium hydroxide	0.5 % by weight of cement, provided quick set is not induced.
Salt and suspended particles	2,000 ppm. Mixing water with a high content of suspended solids should be allowed to stand in a setting basin before use.
Total dissolved salts.	15,000 ppm.
Organic material	3,000 ppm. Water containing humic acid or such organic acids, may adversely affect the hardening of concrete, 780 ppm .of humic acid are reported to have seriously impaired the strength of concrete. In the case of such water therefore, further testing is necessary.
pH	Shall not be less than 6.

Source: Shetty (2001).

Sieve Analysis of Aggregates

The sieve analysis of the fine and coarse aggregates used were carried out in accordance with the procedure in BS 1377-2: 1990 [5].

Water Analysis

Water analysis was carried out on the three samples of water used to determine their physical and chemical properties. The physical properties determined include appearance, color, odor, pH at 20^0 C, turbidity, and conductivity. The chemical properties determined include acidity, alkalinity, total hardness, chloride, sulfite, sulfate, nitrite, Ammonia and Silica. The water analysis was performed in Chemistry laboratory in University of Lagos, Akoka.

Specimen Preparation

Concrete specimens were produced using Lagoon and Atlantic Ocean water for mixing and curing purposes. Another set of concrete specimens with potable drinking water as the matrix serves as the control experiment.

Specimen preparation for compressive strength test was performed using 150mm cube steel molds. The mix proportions of cement: sand: granite used are 1:2:4 and 1:3:6 with 0.5 and 0.6 water-to-cement ratios, respectively. After casting, the specimens were stored in the curing room at 27 ± 5^oC with 90% relative humidity for 24hours and then de-molded and placed under water until the testing ages of 7, 14, 21 and 28 days. The compressive strength was determined with Compressive Strength Testing Machine (Clock house Model) with maximum capacity of 3000KN. The strength value was the average of three specimens. Slump test was carried out to check the workability of concrete. The test was carried out in accordance with the requirements of BS 1881: Part 102 (1983) [6].

RESULTS AND DISCUSSION

Sieve Analysis

The result of the sieve analysis for both fine and coarse aggregates is shown in Figure 1.

The uniformity coefficient (Cu) of the sand is 2.40 which is less than 4 as suggested by [7]. This indicates a uniform soil. Also, the coefficient of curvature (Cc) is 0.82 which is between 0.5 and 2.0 as suggested by [2], therefore this indicates a well graded soil.

Similarly, the uniformity coefficient of the granite is 2.14 while the coefficient of curvature is 1.15 indicating that it is uniform and well graded too. Thus, the fine and coarse aggregates used are quite adequate for producing good concrete.

Water Analysis

The results of the physical and chemical characteristics of the three water samples used are presented in Tables 2 and 3, respectively. Table 2 showed that Tap water has a clear appearance, odorless, and a pH of 6.4. For Lagoon water, it showed a clear sample, green in color and the odor is pungent indicating the presence of organic matters, and a pH of 6.2 which is acidic. The Atlantic Ocean water was clear in appearance, odorless, and a pH of 8.0 indicating alkalinity. Only tap water nearly satisfied the WHO and NIS requirements for drinking water [8]. The Lagoon water was acidic while the Atlantic Ocean water was alkaline.

Table 3 indicated that Tap water has chlorine content of 70 ppm, total hardness of 20ppm $CaCO_3$ and sulfate of 0.04ppm. Lagoon water has chlorine content of 150ppm, total hardness of 104ppm $CaCO_3$, and sulfate of 0.17ppm while Atlantic Ocean water has chlorine content of 15250ppm, total hardness of 550ppm $CaCO_3$, and sulfate of 1.15ppm. Only Atlantic Ocean water failed to meet the tolerable concentrations in mixing water as specified in Table 1.

Workability

The result of the slump test indicating the workability of the concrete specimens is shown in Table 4. All the concrete samples have true slump with Lagoon water concrete having low workability (slump between 15 – 30mm) and both Tap water and Atlantic Ocean concrete having medium workability (slump between 35 – 75mm) as specified by [9]. The low workability of the Lagoon water could be attributed to the presence of organic matter in it.

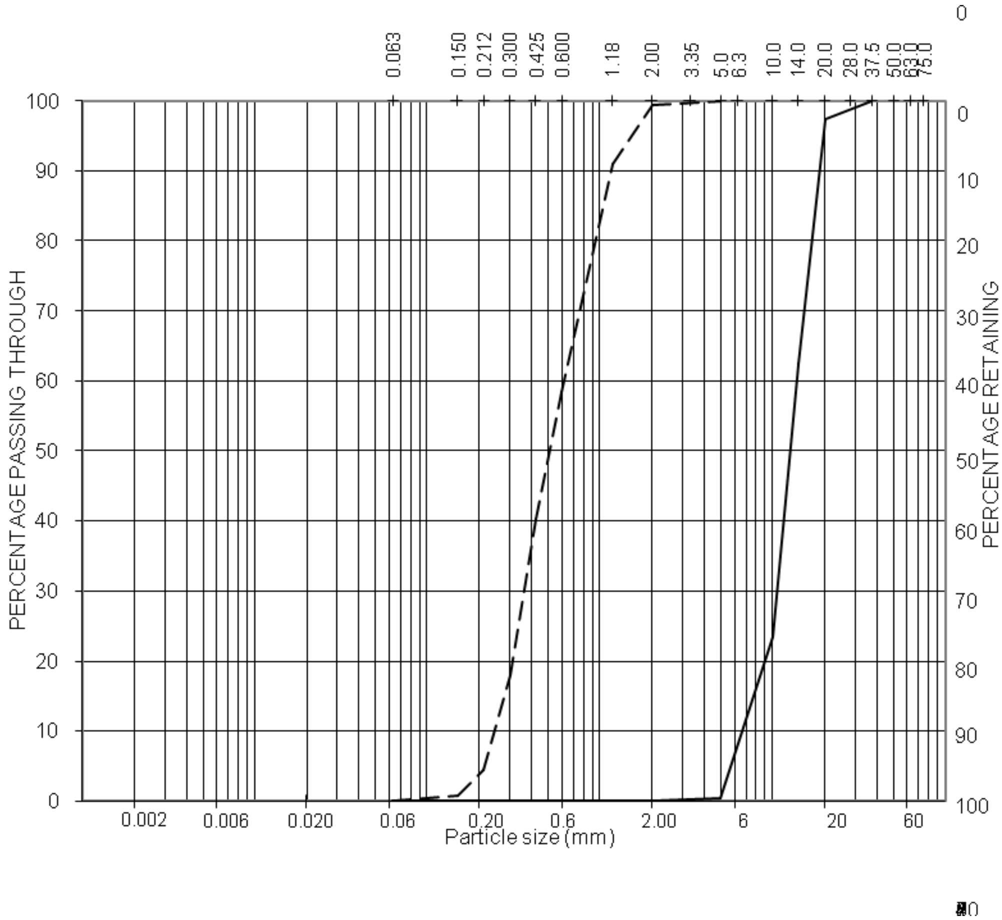

Figure 1: Grading Curves for Sand and Granite Used.

Table 2: Physical Characteristics of Water Samples.

S/N	Parameter	Tap Water	Lagoon Water	Atlantic Ocean Water	WHO Standard for Drinking Water		NIS Standard for Drinking Water
					Minimum acceptable	Maximum acceptable	Maximum permitted
1.	Appearance	Clear	Clear	Clear	Clear	Clear	Clear
2.	Color	-	Green	-	-	-	-
3.	Odor	Odorless	Pungent	Odorless	Odorless	Odorless	Unobjectionable
4.	pH at 20^{o} C	6.4	6.2	8.0	6.50	9.20	6.5 – 8.5
5.	Turbidity (FTU)	0.0	0.0	0.0	-	-	5
6.	Conductivity (µScm $^{-1}$)	85	485	49000	0.9 x 10^{-4}	1.20 x 10^{-1}	1000

Density

The results of the densities of the three concrete specimens are presented in Figures 2 to 4. Figure 2 showed that the density of concrete made with Tap water (The control) ranges from 2421 kg/m^3 to 2459 kg/m^3 and 2459 kg/m^3 to 2637 kg/m^3 for 1:3:6 and 1:2:4 mix ratios respectively, as the curing age increases from 7 to 28 days. As expected, the density increases as the curing age increases. This is in line with previous studies [2, 10]. From Figure 3, the density of concrete made with Atlantic Ocean water followed a similar pattern with values ranging from 2370 kg/m^3 to 2519 kg/m^3 and 2489 kg/m^3 to 2569 kg/m^3 for 1:3:6 and 1:2:4 mix ratios respectively, during the same period. However, concrete made with Tap water are denser than those with Atlantic Ocean water.

Table 3: Chemical Characteristics of Water Samples.

S/N	Parameter	Tap Water	Lagoon Water	Atlantic Ocean Water	WHO Standard for Drinking Water		NIS Standard for Drinking Water
					Minimum acceptable	Maximum acceptable	Maximum permitted
1.	Acidity- P (ppm $CaCO_3$)	8.0	4.0	ND	Nil	Nil	Nil
2.	Alkalinity-M (ppm $CaCO_3$)	12.0	48.0	60.0	30	500	Nil
3.	Total Hardness (ppm $CaCO_3$)	20.0	104.0	550.0	30	200	150
4.	Chloride, Cl^- (ppm)	70.0	150.0	15250	200	600	250
5.	Sulfite, SO_3^{2-} (ppm)	ND	ND	ND	200	400	Nil
6.	Sulfate, SO_4^{2-} (ppm)	0.04	0.17	1.15	200	400	200
7.	Nitrate, NO_3 (ppm)	1.20	1.50	5.5	5	30	50
8.	Ammonia (ppm)	ND	ND	ND	-	0.5	Nil
9.	Silica, SiO_2 (ppm)	ND	ND	ND	-	-	-

Note: ND= Not Detected

Table 4: Slump of Concrete Specimens.

S/N	Specimen	Slump (mm)
1.	Atlantic Ocean water (1:3:6)	50
2.	Atlantic Ocean water (1:2:4)	55
3.	Lagoon water (1:3:6)	25
4.	Lagoon water (1:2:4)	20
5.	Tap water (1:3:6)	70
6.	Tap water (1:2:4)	60

Figure 4 indicated that the density of concrete made with Lagoon water does not follow a regular pattern with values actually decreasing at 28 days. This could be due to the presence of organic matter in the mixing water. The concrete specimens produced with the three types of water fall into the category of normal weight concrete as their densities lie within the range of 2200 to 2600 kg/m^3 specified by [9].

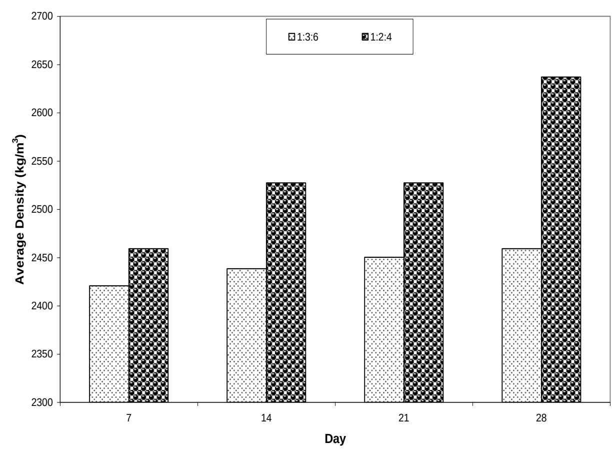

Figure 2: Density of Concrete Specimens Produced with Tap Water.

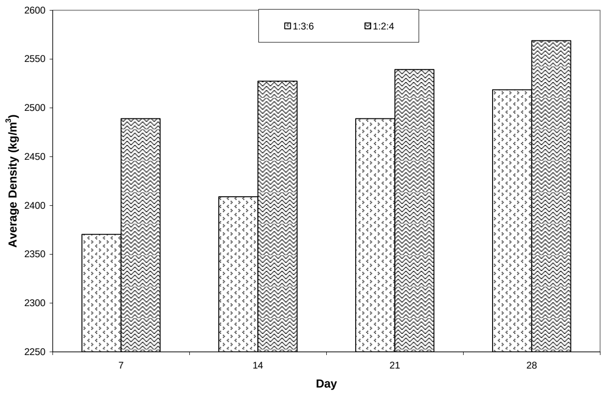

Figure 3: Density of Concrete Specimens Produced with Atlantic Ocean Water.

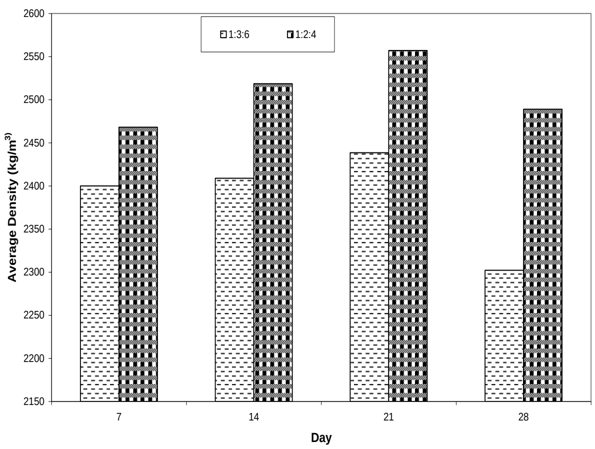

Figure 4: Density of Concrete Specimens Produced with Lagoon Water.

Compressive Strength

The results of the compressive strength of the three concrete specimens at curing ages of 3, 7, 21 and 28 days are presented in Figures 5 to 7.

The result of concrete made with Tap water as presented in Figure 5 showed that the compressive strength gradually increases from 12.7 to 17.9 N/mm^2 and 19.3 to 28.6 N/mm^2 for 1:3:6 and 1:2:4 mix ratios respectively, as the curing age rises from 7 to 28 days. This is in line with previous findings on concrete made with potable drinking water [11, 12, 13].

For concrete made with Atlantic Ocean water, the compressive strength as indicated in Figure 6 followed a similar pattern to that of Tap water but with higher values. The strength increases from 23.3 to 25.0 N/mm^2 and 28.0 to 33.5 N/mm^2 for 1:3:6 and 1:2:4 mix ratios, respectively.

The increase in strength is more pronounced at early ages as 46% and 32% increases were recorded for 1:3:6 and 1:2:4 mix ratios, respectively, at 7 days. This increase in strength may be attributed to the high alkalinity and high total hardness of the mixing water indicating a large quantity of calcium. The high chlorine content may be responsible for the early strength of concrete specimens. However the long term strength of the concrete may be adversely affected as claimed by [9].

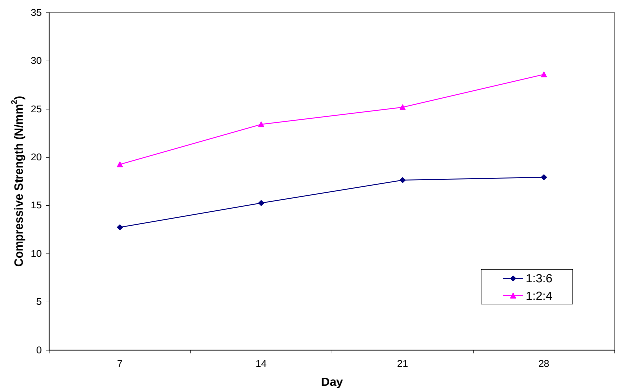

Figure 5: Compressive Strength of Concrete Specimens Produced with Tap Water.

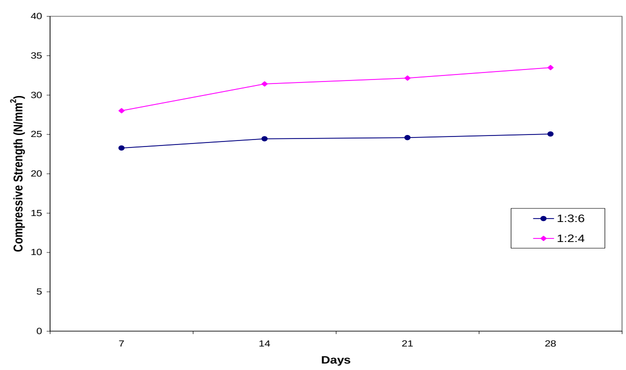

Figure 6: Compressive Strength of Concrete Specimens Produced with Atlantic Ocean Water.

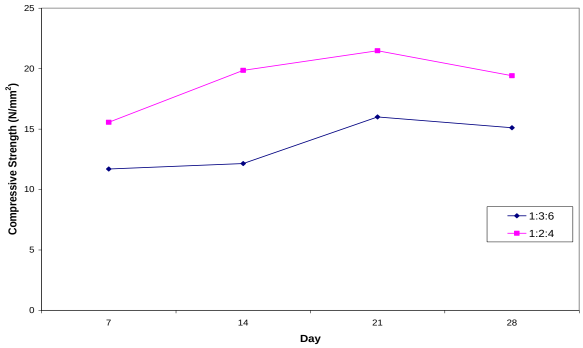

Figure 7: Compressive Strength of Concrete Specimens Produced with Lagoon Water.

Figure 7 showed that the compressive strength of 1:3:6 and 1:2:4 concrete specimens produced with Lagoon water were 11.7N/mm^2, 12.2N/mm^2, 16.0 N/mm^2 and 15.1 N/mm^2 as well as 15.6 N/mm^2, 19.9 N/mm^2, 21.5 N/mm^2 and 19.4 N/mm^2 for ages 7, 14, 21 and 28 days respectively. The strengths are generally lower than those obtained for Tap water and Atlantic Ocean water concrete. A decrease in strength was also observed between 21 and 28 days for both mix ratios. The reduction in compressive strength of the specimens may be attributed to the acidic nature of the mixing water as well as the presence of organic substance as depicted by its green color and pungent odor.

The effect of the three types of water on the compressive strength of concrete with mix ratios 1:3:6 and 1:2:4 are presented in Figures 8 and 9 respectively. As can be observed from these figures, concrete specimens produced with Atlantic Ocean water have highest values followed by those produced with Tap water, while the ones with Lagoon water recorded the lowest values. The NIS 439: 2000 [14] requirement for minimum compressive strength of 26N/mm^2 at 28 days was satisfied by only 1:2:4 concrete specimens produced with Tap water and Atlantic Ocean water. The very high compressive strength of concrete specimens produced with Atlantic Ocean water notwithstanding, the high chloride content in it is detrimental to its use where reinforced steel bars are required. It would also be unsuitable in places where appearance is of great importance due to staining.

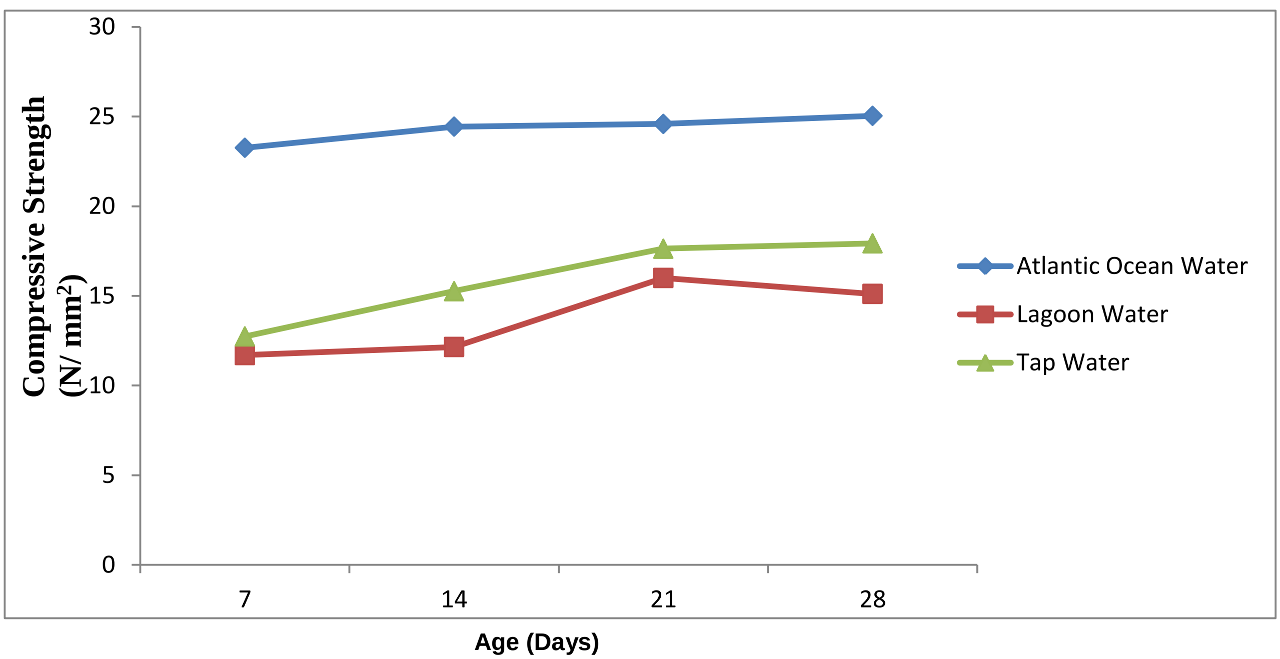

Figure 8: Effect of Mixing Water on the Compressive Strength of Concrete (Mix ratio 1:3:6).

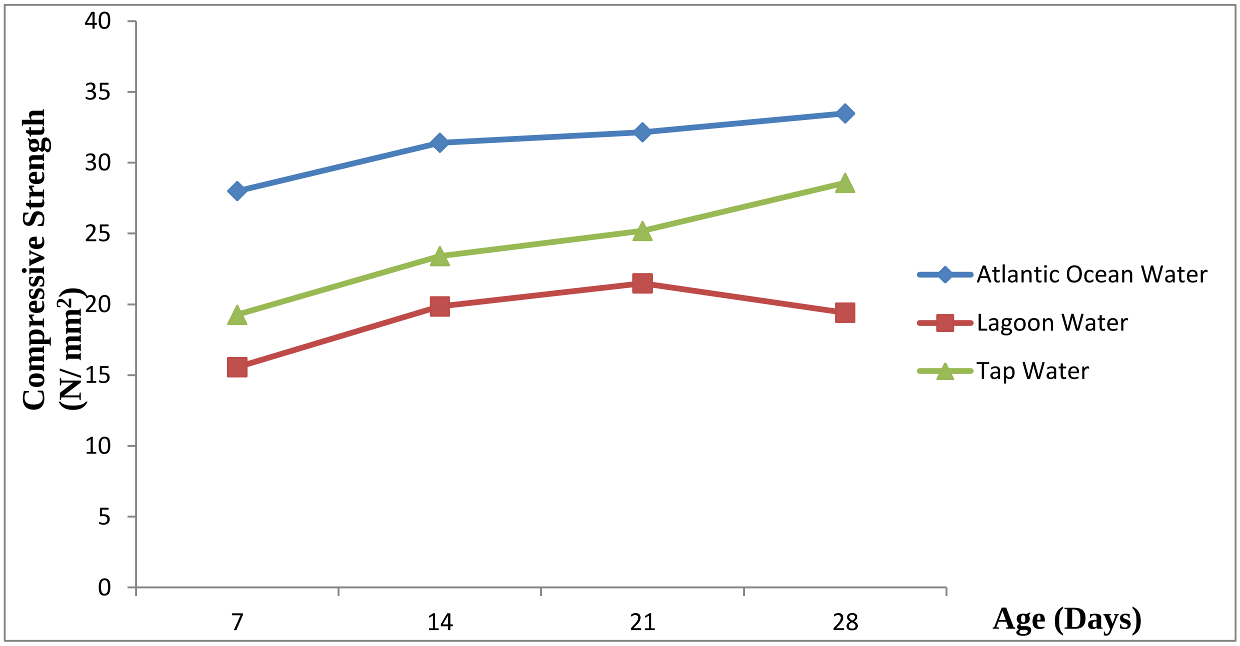

Figure 9: Effect of Mixing Water on the Compressive Strength of Concrete (Mix ratio 1:2:4).

Lagoon water concrete specimens showed a decrease in the compressive strength on the 28 day. This is an indication that it should not be used on construction sites for concrete works requiring strength, as this will lead to failure of the structure.

The implication of these findings is that only Tap water is recommended for use in mixing concrete where strength is of major concern. However, since all the specimens meet the minimum strength of 6 N/mm^2 after 28 days of curing recommended by BS 5224: 1976 [15], all the three types of water could be used for general concrete works where strength is of less importance such as in mass concrete, floor screed and mortar.

CONCLUSION

From the results of the various tests performed, the following conclusions can be drawn:

1. Only tap water nearly satisfied the WHO and NIS requirements for drinking water. The Lagoon water was acidic while the Atlantic Ocean water was alkaline.
2. All the concrete samples have true slump with Lagoon water concrete having low workability and both Tap water and Atlantic Ocean concrete having medium workability.
3. Based on their densities, concrete specimens produced with the three types of water fall into the category of normal weight concrete.
4. The very high compressive strength of concrete specimens produced with Atlantic Ocean water notwithstanding, the high chloride content in it could be detrimental to its use where reinforced steel bars are required.
5. Tap water is recommended for use in mixing concrete where strength is of major concern.
6. Lagoon water may be used for general concrete works where strength is of less importance such as in mass concrete, floor screed and mortar.

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