Effect of Water Quality on Compressive Strength of Concrete

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Abstract

The effect of water quality on the compressive strength of concrete was evaluated in this study. A total of 100 concrete cubes (150 x 150 x 150 mm) were cast using a mix ratio of 1:2:4. The hardened concrete cubes were de-moulded 24 hours after the cubes were cast and were submerged carefully in a curing tank filled with water. The physico-chemical characteristics of the water used in mixing the concrete was determined according to standard procedures. A slump test was conducted to determine the workability of concrete. Compressive test was carried out on the hardened concrete at 7, 14, 28 days, respectively. Results showed that the physiochemical characteristics of the all the water samples examined fell within acceptable limits set by the World health Organization (WHO) except for the iron, magnesium, and lead contents which were grossly out of acceptable limits. From the slump result obtained, the source of water in mixing concrete doesn't affect the workability of concrete. The study also revealed that irrespective of the type of water used in making concrete, the development in strength increases with an increase in age.

Keywords: Water quality, compressive strength, workability, hardened concrete

Introduction

Concrete is an artificial material resulting from a carefully-controlled mixture of cement, water and aggregate which takes the shape of its container or formwork when hardened (Alawode and Idowu, 2011). As a result of rapid urbanization worldwide, concrete was and still is one of the most extensively consumed construction materials (Granem and Obeid, 2015) In recent times, concrete has gained wide use in many countries for different applications and structural configurations (Pai *et al.*, 2014). Concrete is brittle and weak in tension but strong under compression.

The quality of the water plays an important role in the preparation of concrete. The chemical constituents present in water may participate in the chemical reactions and thus affect the setting, hardening and strength development of concrete. A popular yard stick to the suitability of water for making concrete is that if it is fit for drinking, it is fit for making concrete (Rao *et al.*, 2004). Several authors have worked on concrete. Umoru *et al.* (2003) investigated and compared the corrosion characteristics of reinforcement bars in concrete exposed to selected acidic, saline and alkaline media. Prascal *et al*. (2006) studied the chemical action of seawater on concrete and found out that it is mainly due to attack by magnesium sulphate (MgSO4).

In Nigeria, different sources of water are used in concrete mixing even though the standard prescribed for water in concrete mixing is "potable water". Most regions within the country hardly get potable water in mixing concrete, as a result of scarcity of potable water. This study intends to check the extent to which the type of water used in mixing concrete can affect its strength. The objective of this work is to compare the compressive strength of concrete using different qualities of water obtained from five sources namely borehole, rain, river, wastewater and well.

Methodology

In this study, the compressive strength of concrete was determined by carrying out compression tests on 7, 14, 21, and 28-day-old concrete cubes. The concrete cubes were prepared using a prescribed concrete mix ratio of 1:2:4 using waters of different quality. Batching was carried out based on predetermined specifications, the mix ratio was taken as 1:2:4 and was batched by weight. Coarse aggregates of 19 mm maximum size was used and the water cement ratio was taken as 0.6. A total of 100 numbers of 150 x150x 150mm concrete cubes were cast. The mixing of concrete was carried out manually by hand. 24hrs after the cubes were cast, the hardened concrete cubes were de-moulded, and the cubes were submerged carefully in the curing tank filled with water to prevent evaporation till hydration was completed.

After stripping of the formwork, the cubes were placed in a curing tank for specified numbers of days (7, 14, 28 days, respectively). At each specified period of days, the cubes were crushed to determine the compressive strength of the concretes. The bearing surfaces of the crushing machine were wiped clean and the test cubes well placed for the load to be applied to the opposite side of the concrete cube. Also, the axes of the cubes were carefully aligned to the centre of the plates. Plate 1 shows the completed formwork used in moulding the concrete. Plate 2 shows the concrete cubes compacted in the formworks and labelled. Plate 3 shows the concrete cubes immersed in water in a curing tank.

Plate 1: Completed formwork to receive concrete

Plate 2: Concrete compacted in formwork and labelled

Plate 3: Concrete cubes immersed in water in a curing tank

The quality of water and waste water is often assessed by the physiochemical characteristics of the samples to ascertain the suitability for various purposes. Some physiochemical parameters that are determined include the following: Appearance, temperature, pH, acidity, alkalinity, total solids, total dissolved solids (TDS), suspended solids, colloids, water hardness, dissolved oxygen, conductivity, biochemical oxygen demand

(B.O.D), chemical oxygen demand (C.O.D), nitrates, phosphates, and the heavy metals.

A slump test was conducted to determine the workability of concrete. Workability is the ease with which concrete can be compacted fully without aggregating or bleeding. A compressive test was carried out on the hardened concrete using a compressive testing machine shown in Plate 5. The purpose of this test is to determine if the hardened concrete meets required standard or falls within permissible limits. There are specified values of compressible strength of concrete cubes properly cured for the periods of 7 days, 14 days, 21 days and 28 days.

Plate 4: Manual and automatic compressive testing machines

Results and Discussion

Physico-chemical characteristics of the water samples

The physico-chemical analysis and the microbiological analysis of the five water samples used in the research study are presented in Table 1.

Table 1: Physico-Chemical Examination of Water Samples

S/N	Parameters	Unit	Borehole	Rain	River	Waste Water	Well	WHO (2008 and 2011) Standard
1	Appearance	-	Clear	Clear	Fairly clear	Brown	Fairly clear	-
2	Odor	-	Unobjectionable	Unobjectionable	Objectionable	Objectionable	Objectionable	Unobjectionable
3	Temperature	°C	26.55	25.70	26.10	25.70	26.50	NA
4	Salinity	mg/l	05.70	02.00	07.25	06.02	05.91	NA
5	pH @ 20°C	-	6.70	6.50	8.30	9.40	7.60	6.5 - 8.5
6	Turbidity	NTU	0.15	0.11	0.40	0.71	0.35	5
7	Conductivity	-	2.37	2.00	3.32	3.41	2.94	1000
8	Total Solids	mg/l	64.50	54.20	83.20	96.00	77.20	1000
9	Total Suspended Solids	mg/l	0.002	0.001	0.005	0.007	0.004	NA
10	Total Dissolved Solids	mg/l	71.50	63.00	84.41	98.01	79.57	500

11	Total Hardness	mg/l	36.20	32.20	47.20	52.00	44.82	150
12	Total Alkalinity	mg/l	22.80	17.00	30.00	33.50	27.00	200
13	Sulphate	mg/l	07.29	06.39	11.50	16.23	08.20	100
14	Chloride	mg/l	0.30	0.31	0.60	0.60	0.41	250
15	Residual Chlorine	mg/l	0.15	0.12	0.5	0.30	0.30	0.2
16	Calcium	mg/l	0.33	0.28	0.42	11.40	0.38	75
17	Magnesium	mg/l	05.44	05.36	08.22	10.20	06.00	0.2
18	Iron	mg/l	05.20	04.84	11.31	13.30	09.21	0.3
19	Lead	mg/l	0.04	0.03	0.03	0.05	0.03	0.01
20	Manganese	mg/l	0.06	0.02	0.02	0.02	0.04	0.2
21	Copper	mg/l	0.03	< 0.01	< 0.01	0.01	0.02	1
22	Nitrate	mg/l	0.01	< 0.01	< 0.01	< 0.01	0.02	50
23	Nitrite	mg/l	<0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.2

Note: NA – Not Available

The results of the five water samples investigated showed that the pH values ranged from 6.5 - 9.4. The values fell within the range permitted by WHO (6.5 - 8.5) except for waste water which had a pH of 9.40. According to BS EN 1008 (2004), the permissible limit of TDS is 2000 ppm (part per million). Also, SON acceptable limit for TDS is 500mg/l. Table 1 showed that all values fell below the recommended level of TDS for potable water as specified by WHO. Analyses also revealed that metallic constituents in all samples were within the permissible limit of the WHO standard except for iron, magnesium, and lead. Table 1 also revealed that chloride, sulphate, hardness, and alkalinity all fell within acceptable limits.

Test Results on Concrete in Fresh State

Slump test, compacting factor test and air entrainment test were carried out on fresh concrete and the results are presented in Table 2.

Table 2: Test Results on Concrete in Plastic State

Water Sample	Slump (mm)	Compacting factor	Air entrainment %	Water-cement ratio
Borehole	66	F.C = 17.00 P.C = 16.21 C.F = 0.95	2.1 1.5 bar	0.6
Rain	65	F.C = 16.90 P.C = 16.00 C.F = 0.95	2.0 1.5 bar	0.6
River	65	F.C = 16.75 P.C = 15.90 C.F = 0.95	2.5 1.5 bar	0.6
Waste	63	F.C = 17.20 P.C = 16.01 C.F = 0.93	2.5 1.5 bar	0.6
Well	60	F.C = 17.00 P.C = 15.95 C.F = 0.94	2.0 1.5 bar	0.6

Note: FC = Fully Compacted, PC = Partially Compacted, CF = Compacting Factor

The slump test results ranged from 60 mm – 66 mm with the borehole having the highest value of 66 mm, followed by rain and river water which both have 65 mm slump value, the waste and well water have 63 mm and 60 mm slump value respectively. All the values fell within class S2 (that is 50-90 mm slump value) in accordance with BS EN 206 – 1 (2000). From table 2, the compacting factor value of borehole, rain, river, waste and well water are 0.95, 0.95, 0.95, 0.93, and 0.94 respectively. For normal range of concrete the compacting factor lies between 0.78 and 0.95, values less than these are regarded as unsuitable mix. The value percentage void of the mixes fell between 2.0 and 2.5, the pressure for all the mixes using different water samples was 1.5 bar.

Test results of Concrete in Hardened State

The 7, 14, 21 and 28 day compressive strength of concrete are shown in figures 1, 2, 3, and 4 respectively. While a comparison of the compressive strength at different ages is presented in figure 5.

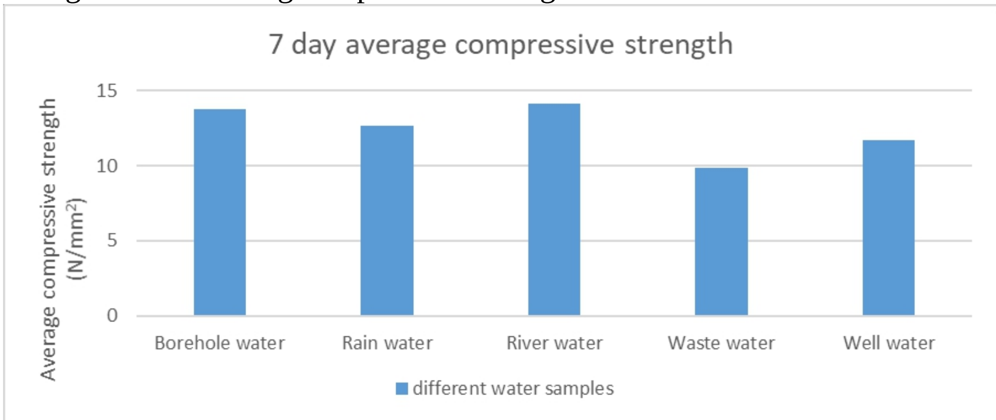

Figure 1: 7 days average compressive strength result

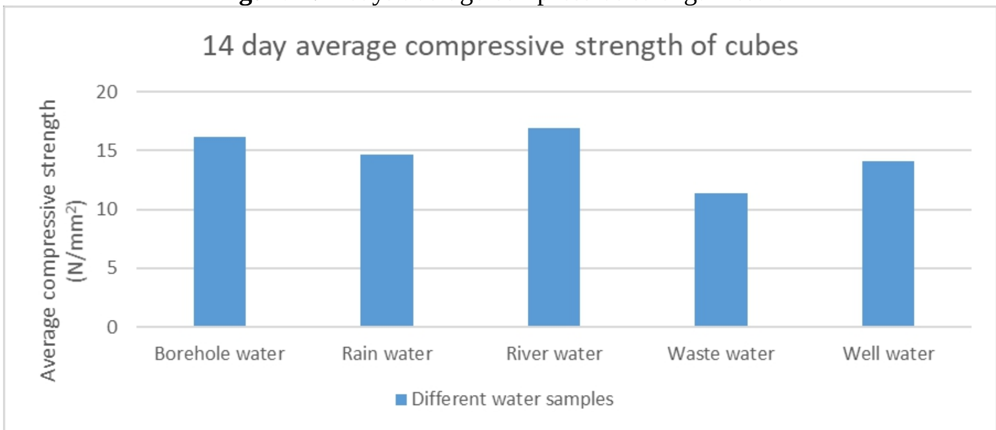

Figure 2: 14 day average compressive strength result

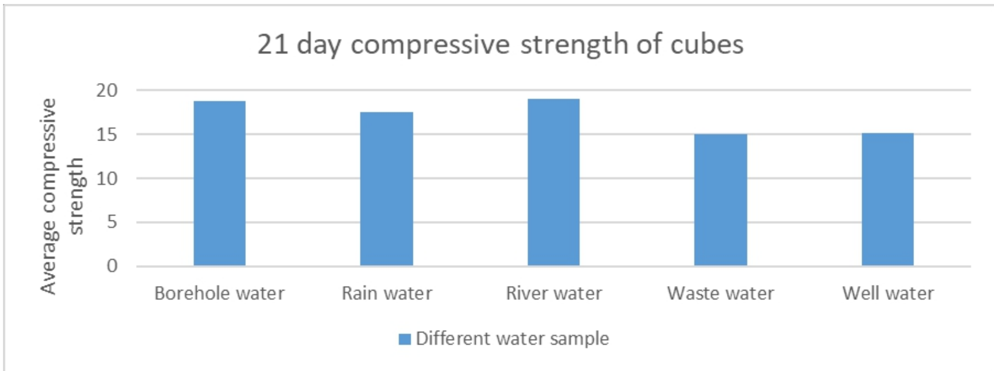

Figure 3: 21 day average compressive strength result

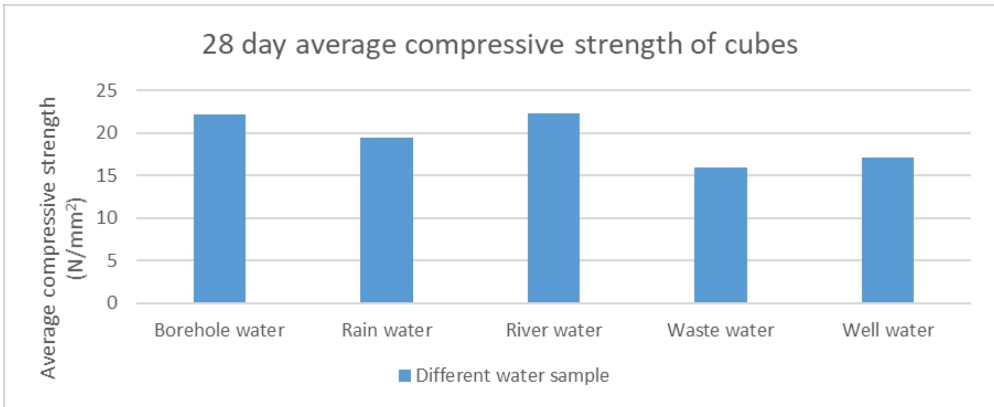

Figure 4: 28 day average compressive strength result

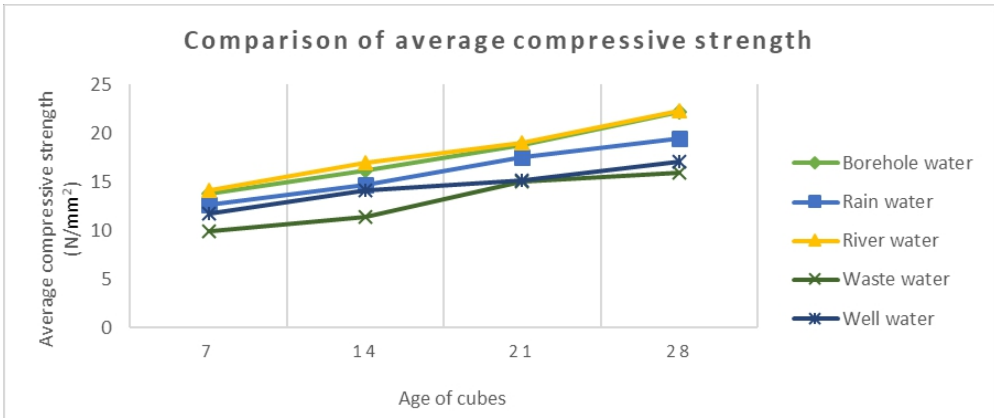

Figure 5: Comparison of compressive strength result

The result of the average compressive strength for 7 days ranged from 9.87 -14.13 N/mm^2, with the river water having the highest value. The 14 days result ranged from 11.33 -16.93 N/mm^2. The 21 days values were between 14.98 and 19.02 N/mm^2. The 28 days average compressive strength ranged from 15.91 - 22.27 N/mm^2. Figure 4.9 shows the comparison of the average compressive strength, the chart shows that concrete strength increased with age and fell within acceptable standards. The results obtained are acceptable for a M20 grade of concrete which has a minimum compressive strength of 13.5 N/mm^2 at 7 days and 20 N/mm^2 at 20 days.

Conclusion and Recommendation

The following conclusions are drawn from this study:

i. Water from other sources aside potable water can be used for concrete production;
ii. Borehole water, river water, rain water, and well water are good for mixing concrete;
iii. The use of waste water in mixing concrete should not be encouraged due to health and environmental issues;
iv. Irrespective of the type of water used in making concrete, the development in strength increases with an increase in age.
v. From the slump result obtained, the source of water in mixing concrete doesn't affect the workability of concrete;
vi. The initial and final setting time of cement is utterly affected by the quality of water in mixing concrete. The high level of impurities in waste water contributes to the higher setting time of the cement which in turn reduces the strength.

It is recommended that due to scarcity and insufficient water supply, other sources of water for mixing concrete should be adopted in order to reduce the stress on potable water, which is inadequate for drinking. Nevertheless, the source of water to be used in making concrete should be examined and approved by required authority prior to casting.

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