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Effects of Water Quality on Strength Properties of Concrete

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Abstract— *This research investigated the effect of different sources of water on the compressive strength of concrete. The waters samples used for the analysis were rain, river and potable water.The chemical compositions of these water qualities and sources were determined, while 18 concrete cubes were produced in the ratio of 1:2:4 using each water quality type. The cubes were cured and crushed at 7, 14 and 28 days using the Farnell Crushing Machine. The compressive strength test was carried out on the cubes and the findings were statistically processed.It was observed that the concrete produced with potable water and river water had their compressive strengths gradually increased with age while the concrete produced with rain water gradually increased too but later decreased in strength at 28 days age. The results indicated that sources of water used in mixing concrete have a significant impact on the compressive strength of the resulting concrete. It concluded by suggesting that potable water is the best water type for concrete production since the concrete cubes obtained from it gained appreciable strength with age. River water could be used for mixing where potable water is scarce. However, other properties such as durability and shrinkage should be considered before use. It was recommended that potable water and water without obvious concrete-inimical substances be used in concrete production.*

Keywords— ***Effects, Water Quality, Water Source, Strength Properties, Concrete.***

I. INTRODUCTION

Concrete is a composite construction material made up of water, cement, aggregates (fine and coarse) and sometimes extra materials called admixtures. Generally concrete finds its use in virtually all Civil Engineering works. Concrete is the most widely used material in the world next to water (Orie, 2015).

Water serves the following purposes:

1. To wet the surface of aggregates to develop adhesion because the cement pastes adheres quickly and satisfactory to the wet surface of the aggregates than to a dry surface.
2. To prepare a plastic mixture of the various ingredients and to impact workability to concrete to facilitate placing in the desired position.
3. Water is also needed for the hydration of cementing materials to set and harden during the period of curing. The quality of water in the mix plays a vital role on the strength of the concrete. Some water which have adverse effect on hardened concrete sometimes may not be harmless or even beneficial during mixing, so clear distinction should be made between the effect on hardened concrete and the quality of mixing water.

Water approved for drinking is generally satisfactory for usage in concrete production, but there are exceptional cases, for instance, in some arid areas, where local drinking water is saline and may contain an excessive amount of chloride, undesirable amount of alkali carbonates and bicarbonates, which could contribute to the alkali silica reaction (Neville, 1996). However, some water that is not for drinking may be fitted or suitable for concrete production (Portland Cement Association, 2005). Gupta et al (2012) opined that water with pH range of 6.0 to 8.0 is good for concreting.

For hand mixing, a water cement ratio of 0.6 is recommended. When the concrete has to be pumped into position, the water cement ratio may be increased to 0.7 (Lawrence, 2016). Using water with high content of suspended solid needs to be done with caution and should be allowed to stand in a settling basin before use; a turbidity limit of 2000ppm has been suggested by U.S Bureau of Reclamation (1975). Natural water that are slightly acidic are harmless, but water containing humid or other organic acids may adversely affect the hardening of concrete (Neville, 1996). Steinour, (1960) describes that impurities in water may interfere with the setting of the cement, adversely affect the strength of the concrete or cause staining of its surface, and also lead to corrosion of the reinforcement.

Sea water generally contains 3.5salinity but slightly accelerates the setting time of cement. This salinity

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contains about 78% sodium chloride 15% chlorides and sulphates of magnesium. The presence of chlorides in reinforced concrete can lead to steel corrosion and reduced concrete strength (Gupta et al, 2012; Orie, 2015). Thomas and Lisk, (1970) suggested that the sea water slightly accelerates the setting time of cement. Impurities in water can also reduce the durability of concrete (Neville, 1995).

Al-Manaseer et al (1988) observed that water containing salts of sodium, calcium, potassium and manganese did not affect the strength of concrete made from Portland cement and fly ash. Ghosh et al (2001) reported that presence of micro-organism in mixing water increases the compressive and tensile strength of concrete samples. Excessive impurities in mixing water not only may affect setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, key volume instability, and reduced durability. Therefore, certain optional limits may be set on chlorides, sulfates, alkalis and solids in the mixing water or appropriate tests can be performed to determine the effect of the impurity has on various properties. Some impurities may have little effect on strength and setting time, yet they can adversely affect durability and other properties (Onesmus et al, 2016).

In a similar way, water used for curing concrete can impair the strength of the concrete (Smith, 1976). With the current water shortage in Nigeria, there is a need to look for alternative sources of water for use in concrete production. It is significant to determine the suitability of water for mixing concrete (Ullman, 1973).

Even though other criteria attempting to ensure the suitability of water for batching fresh concrete require that the water be clean and free from deleterious material, these specifications may not be the best basis for evaluation of the suitability of water as mixing water. Some waters which do not meet these criteria have been found to produce concretes of satisfactory quality (Sandorolini and Franzoni, 2001).

Paulo et al, (1999) specify that, any water with pH value less than 12.5 may be aggressive in there action because a reduction of the alkalinity of the pore fluid would, eventually lead to removal of the cementitious material. However, the rate of chemical attack will be function of the pH of the aggressive fluid and the permeability of concrete. When the permeability of concrete is less and the pH of the fluid is above 6, the rate of chemical attack is too slow. Again the chemical attack on concrete results into detrimental physical effects, such as porosity, decrease in strength, cracking and breaking into pieces.

Currently there are no special tests developed to determine the suitability of mixing water except compressive tests. Generally, compressive tests require that, if the quality of water is not known, the strength of the concrete made with water in question should be compared with the strength of concrete made with water of known suitability. Both concretes should be made with cement proposed to be used in the construction works (Olugbenga, 2014).

Chatveera et al, (2006) utilized and recycled sludge water as mixing water for concrete production and found that concrete slump and strength reduced drastically. The carbonate sand bicarbonates of potassium and sodium affect setting time of concrete. The presence of sodium carbonate accelerates the setting time of concrete while bicarbonates may either accelerate or retard the setting time.

Hence the objective of this work is to compare the compressive strength of concrete mixed with different sources and qualities of water such as potable water, river water, and rain water.

II. MATERIALS AND METHODS

The research was concentrated on sources of water from Nsukka environs. The sources are rain, river and potable water. At each of the water locations a 25kg gallon was used to collect water samples. Also these samples were taken to a water analysis laboratory "Divine Chemical and Analytical Laboratory" at Ibagwa-Road, Nsukka and the physico-chemical compositions of these water qualities were analyzed and ascertained using standard methods. The coarse aggregate used was granite with an average size of 20mm, the fine aggregate was river sand; the cement used was Ordinary Portland Cement (OPC). Particle size distribution of aggregates was performed according to BS 8121(1975) at the Civil Engineering Laboratory, University of Nigeria, Nsukka. Slump test was carried out using the slump cone. Aggregate impact value was done using Aggregate impact value machine. Moisture content was ascertained with moisture content apparatus and finally the compressive strength test was carried out.

The total quantity of materials used in the concrete production were 23.22kg of cement, 11.88kg of water, 46.26kg of fine aggregate and 92.52kg of coarse aggregate to produce concrete cubes of mix 1:2:4. The batching was done by weighing. The mixing of concrete was manually done at cement water ratio of 0.5. Concrete cubes production was carried out in accordance with BS 1881: part 108:1983 using cubical moulds of size 15cm x 15cm x 15cm. This concrete was poured in the mould and tempered properly so as not to have any voids. Each layer of concrete received 25 strokes of a 25mm square steel runner. The top surfaces of these specimens were made even and smooth by putting cement paste and spreading smoothly on whole area of specimen. After 24 hours these moulds were removed and test specimens immersed in water for curing. These specimens were tested by

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compression testing machine after 7, 14 or 28 days curing. Loads were applied gradually at the rate of 140 kg/cm^2 per minute till the specimens failed. Load at the failure divided by area of specimen gave the compressive strength of concrete. Tests on specimen were carried out in duplicate and average values taken.

III. RESULTS AND DISCUSSIONS

The result of the physico-chemical analysis is presented in table 1.

Table.1: Physico-chemical Parameters of Water Samples

Water parameters/ Chemical constituents	Rain water	River water	Potable water
pH level	6.2	5.9	7.1
Dissolved Oxygen (DO) (mg/l)	6.2	4.8	8.9
Chloride Content (mg/l)	73.842	78.396	62.130
Nitrate content (mg/l)	0.347	0.264	0.226
Biochemical Oxygen Demand (BOD) (mg/l)	4.42	4.970	1.620
Total Hardness (mg/l)	14.0	8.00	1.40
Aluminum content (mg/l)	0.058	0.073	0.012
Total Suspended Solids (TSS) (mg/l)	180.00	300.00	0.070
Total Dissolved Solids (TDS) (mg/l)	460.00	660.00	158.30

The graph of sieve analysis of fine aggregate is presented in figure 1 below:

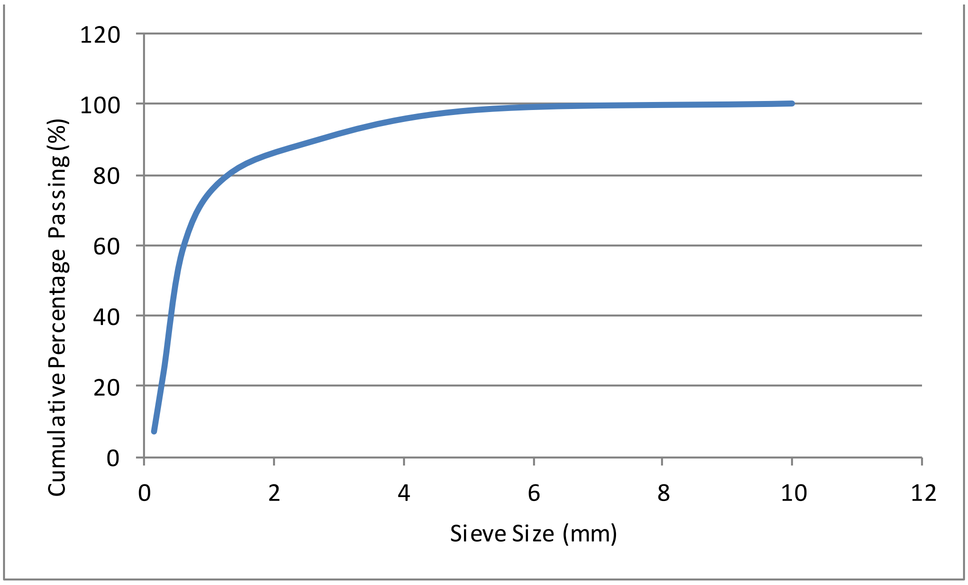

Fig.1: Graph of Sieve Analysis of Fine Aggregate

SIEVE ANALYSIS RESULTS

Fineness modulus of sand (fine aggregate).

This is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve added and divide by 100 gives the value of fine aggregate. From figure 1, the fineness modulus for the fine aggregate is 2.46, implying a “zone 2” fine sand of particle size ranging between 2.36 and 4.75mm (IS 383-1970).

Engineering properties of concrete cubes made from the different sources of water are shown in table 2.

Table.2: Properties of Concrete Cubes made from the Different Sources of Water

Property	Value
Cumulative % Retained	246
Fineness modulus of fine aggregate	2.46
Total Moisture Content of fine aggregate	0.39%
Aggregate Impact Value	25%
Slump value of concrete made with potable water	20mm
Slump value of concrete made with river water	240mm
Slump value of concrete made with rain water	120mm

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The results for the Concrete Cube Compressive Strength test conducted are presented in figure 2 as follows:

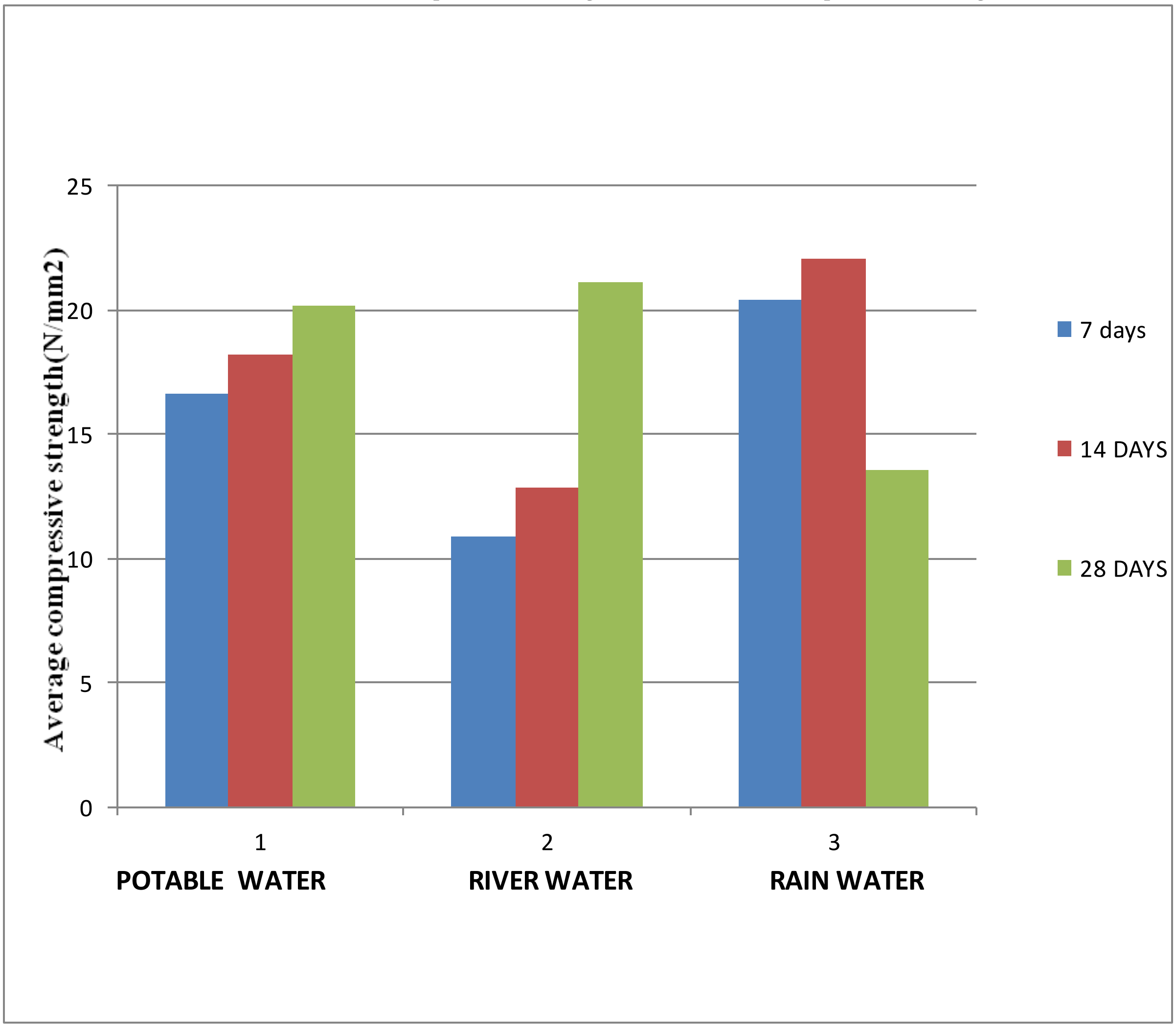

Fig.2: Average Compressive Strength Test of concrete cubes made with the different water sources

Discussion on Physico-chemical parameters of the water sample sources

The results onphysico-chemical Analysis(table 1) showed that the three water samples have different concentrations of chemical compositions. It can be observed that the River water had the highest concentration of Chlorides (78.396 mg/L) and Aluminum(0.073 mg/L) as compared with Rain water, Chlorides (73.842 mg/L) and Aluminum(0.058 mg/L) and Potable water with Chlorides (62.130 mg/L) and Aluminum(0.012 mg/L).

It was observed from the results that the potable water which is on a neutral pH scale (7.1), had more dissolved oxygen (8.9 mg/L) than the other water sources.

Also the potable water had the least Nitrate content (0.226 mg/L), Biochemical Oxygen Demand (BOD=1.620 mg/L),Total-hardness(1.40 mg/L), Total dissolved solids (TDS=158.30 mg/L), Total suspended solids (TSS=0.070 mg/L) compared with the River Water which had Nitrate content(0.264 mg/L), Biochemical Oxygen Demand (BOD=4.970 mg/L), Total-hardness(8.0 mg/L), Total dissolved solids (TDS=660.00 mg/L), Total suspended solids (TSS=300.00 mg/L) and Rain Water which had Nitrate content(0.347mg/L), Biochemical Oxygen Demand (BOD=4.42 mg/L), Total-hardness (14.00 mg/L), Total dissolved solids (TDS=460.00 mg/L), Total suspended solids (TSS=180.00 mg/L), implying that there were considerable presence of impurities in Rain Water and River Water.

The level of acidity from pH, in Rain Water (6.2) and River Water (5.9) were higher than that of Potable Water (7.1).

DISCUSSION ONSLUMP TEST RESULTS

Table 2 shows result for slump test. It can be seen that concrete made with Potable Water had a slump value of 20mm which indicates a True Slump and signifies low workability (California Test 555). This means that when unsupported, concrete after lifting mould, slumps uniformly all around (the area of top surface of mould is equal to top surface of unsupported concrete after slump). Due to this very low workability, this concrete is suitable in road making and roads vibrated by power operated machines. Concrete made with rain water had a slump value of 120mm which indicates a shear slump; signifying high workability. This means that one half of unsupported concrete (frustum of cone) will slide down along inclined plane. If shear slump continues; the concrete can be described as having a harsh mix i.e. mix that shows lack of cohesion (California Test 555). This concrete is suitable is for sections with congested reinforcement. It is not normally suitable for vibration. Concrete made with river water had a slump value of 240mm which indicates a collapse slump signifying very high workability.

AGGREGATE IMPACT VALUE TEST RESULT

Table 2 shows the Aggregate Impact Value test. The value obtained from the Aggregate Impact Value (AIV) test conducted was 25%. An AIV of 25% falls into the category of classification as satisfactory for road surfacing and wearing course (IS 2386-Part IV-1963). This value of the AIV can give us a level of assurance that when used in concrete production during execution of construction activities, the aggregate is capable of resisting and withstanding sudden harsh condition of exposure as well as possessing adequate toughness property (that is, the property of a material to resist impact).

TOTAL MOISTURE CONTENT TEST RESULTS

Table 2 shows the Total Moisture Content test. The value obtained from the Total Moisture Content test carried out was 0.39%. This implies that the amount of moisture (water) contained in the fine aggregate was about 0.39%, implying an Air-dry (AD) fine aggregate(that is, all moisture are removed from surface, but internal pores are partially full). The AD represents the variable moisture contents that will exist in stockpiled aggregates (BS, 1999).

AVERAGE COMPRESSIVE STRENGTH TEST RESULTS

Figure 2 shows the result for the Average Compressive Strength test. The Average Compressive Strength for concrete made with potable water increased with age (which are 16.67N/mm^2, 18.22N/mm^2, 20.22N/mm^2 corresponding to strength at 7days, 14days and 28days respectively). This implies that the 7days strength is less than the 14 days strength and also the 14 days strength is less than the 28 days strength, signifying that the strength increased or appreciated with age and the maximum strength was achieved on the 28th day, This gradual increase in strength indicates that this concrete is reliable, durable and has long term strength on structures made by it (BS, 1983).

The Average Compressive Strength for concrete made with river water increased with age, 10.89 N/mm^2, 12.89 N/mm^2, 21.11 N/mm^2 corresponding to strength at 7days, 14days and 28days respectively. This implies that the 7days strength is less than the 14 days strength and also the 14 days strength is less than the 28 days strength, signifying that the strength increased or appreciated with age and the maximum strength was achieved on the 28th day. It is to be noted that even though the compressive strength of concrete made using river water increased with age as that of potable water, in the case of river water the increment was very sharp after the 14th day. This concrete can also be reliable, durable and also has long term strength on structures made by it (BS, 1983).

The Average Compressive Strength for concrete made with rain water increased with age at 7days (20.45 N/mm^2) and 14 days (22.11 N/mm^2) but there was a drastic reduction in strength on the 28th day (13.56 N/mm^2) i.e. (strength at 28days<<7days and 14days). This implies that the 7days strength is less than the 14 days strength and also the 28days strength is less than the 7days and 14days strength, signifying that the strength increased or appreciated with age and the maximum strength was achieved on the 28th day, This indicates that this concrete cannot be reliable to show durability and long term strength on structures made by it (BS, 1983).

IV. CONCLUSION

The results indicated that sources of water used in mixing concrete have a significant impact on the compressive strength of the resulting concrete.

Concrete cubes obtained from potable water gained appreciable strength with age; this implies that there is reliable assurance of long term strength on concrete made with this water source.

The Compressive Strength of concrete made with rain water increased with age at 7days and 14 days but there was a drastic reduction in strength on the 28th day this implies that there is no reliable assurance of long term strength on concrete made with this water source. It concluded by suggesting that potable water is incomparably the best water type for concrete production, Also river water could be used for mixing where potable water is scarce.

V. RECOMMENDATIONS

The characteristics of water used in mixing concrete must be such that the chemical reactions, which take place during the setting time of the cement, are not impaired.

Rain water normally contains suspended solid (e.g. silt soil particles) and when used in the production of concrete, it tends to increase the strength of concrete at the early stage precisely at 7 days and 14 days of curing but at the latter stage when the impurities present in it start attacking the concrete it begins to loss its strength. Rain water which contains suspended solids must be allowed to settle in the settling basin and the water decanted before it is used for concrete production, to prevent impurities such as suspended solids, organic matters and salts which may affect the setting of the cement and the strength properties of the concrete.

River water can also be used in concrete production but much effort should be made to purify or get it treated to make it as clean as possible so as to prevent the introduction of particles into the concrete produced as this might gradually and slowly harm the concrete as time goes by.

It has been established that potable water tends to be constant in their effect on concrete compressive strength at the early stage and at the later stage their strength increases without any adverse drastic effect. It is therefore necessary to use water free from impurities such as potable water for concreting.

This work has the following recommendations:

1. Potable or fresh water should always be employed in the production of concrete to enable it attain maximum compressive strength over time.
2. All water intended to be used for production of concrete must be evaluated to make sure it conforms to the laid down standards.
3. Strict adherence should be given to specifications most especially in any issue concerning reinforced concrete structure.
4. Water without obvious concrete-inimical substances should be used in concrete batching.

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