Effects of Different Sources of Water on Concrete Strength: A Case Study of Ile-Ife

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Abstract
This research investigated the effect of different types of mixing water on the compressive strength of concrete. It analysed the effect of impurities such as salts of sodium, manganese, tin, zinc, copper and lead on the compressive strength of concrete. The effects of the presence of some other impurities like silt and suspended particles on concrete strength were also investigated. Samples of water from six sources in Ile-Ife environ were chemically analysed to ascertain their chemical constituents. 100mm cube samples were cast with these water samples. Compressive strength test was carried out on the cubes and the findings were statistically processed. 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 river water could be used for mixing where tap water is scarce. However, other properties such as durability and shrinkage should be considered before use.
Keywords: compressive strength, concrete, mixing water

1. Introduction

Concrete is a construction material composed of cement (commonly Portland cement and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and chemical admixtures. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material.

There are many types of concrete available, created by varying the proportions of the main ingredients. By varying the proportions of materials, or by substitution for the cemetitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties. The *mix design* depends on the type of structure being built, how the concrete will be mixed and delivered, and how it will be placed to form this structure.

Water is an essential component of concrete. Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and allows it to flow more freely. Less water in the cement paste will yield a stronger, more durable concrete; more water will give an freer-flowing concrete with a higher slump.

Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. And it has been found (Abram, 1924) that impurity in water samples used in mixing concrete can impair the strength of concrete especially the compressive strength of concrete. In a similar way, water used for curing concrete can impair the strength of the concrete (Smith, 1976). Impurities and deleterious substances which are largely introduced from water used in mixing concrete are likely to interfere with the process of hydration, preventing effective bond between the aggregates and matrix. The impurities sometimes reduce the durability of the aggregate (Neville, 1995).

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. The assumption that if water is fit to drink it is suitable for making concrete is not always correct (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).

Currently there are no special tests developed to determine the suitability of mixing water except comparative tests. Generally, comparative 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. The American Standard ASTM C 94 requires that age of 28days mortar strengths made with test water to be a minimum of 90% of the strength of cubes made with distilled water. And this approach was employed in this work.

Two criteria should be considered in evaluating the suitability of water used for mixing concrete (Borger, *et al*, 1994; Sandrolini and Franzoni, 2001). One is whether the impurities in the waste water from questionable sources will affect the properties and quality of concrete and the other is the degree of impurity which can be tolerated. Both of these criteria have been studied to some extent in this work.

This study analysed the quality of water from different sources. Then, tests were conducted on mortar and concrete. Particular attention was focussed on various portable surface waters used for concrete mix in regional parts of Ile-Ife including the campus of Obafemi Awolowo University Ile- Ife, Osun State Nigeria.

Various factors affect the strength of concrete; some of which include:

The degree of purity of the water used for mixing concrete;

The presence of impurities, deleterious substances and organic matter in the fine and coarse aggregates used in concreting affect the compressive strength of concrete. For instance, impurity like Mica in fine aggregate has been found to reduce considerably compressive strength of concrete.

The manner of carrying out curing process: properly cured concrete leads to increased strength and lower permeability, and avoids cracking where the surface dries out prematurely. Care must also be taken to avoid freezing, or overheating due to the exothermic setting of cement. Improper curing can cause scaling, reduced strength, poor abrasion resistance and cracking.

The purity of the water used for curing and the curing process: this curing process develops physical and chemical properties. Among other qualities are: mechanical strength, low moisture permeability, and chemical and volumetric stability.

The rate of hydration: hydration of concrete is an exothermic reaction, in which heat is given out. This heat is called the heat of hydration. The environment in which this reaction takes place determines the rate of hydration of the concrete hence the strength of the concrete. For instance, cement requires a moist, controlled environment to gain strength and harden fully.

The presence of reinforcement bars in the concrete: this improves the tensile strength of the concrete. Concrete has relatively high compressive strength, but significantly lower tensile strength, and as such is usually reinforced with materials that are strong in tension (often steel).

The manner of mixing of the concrete: for instance, separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete. It has been found for instance that, High-energy mixed concrete (HEM concrete) is produced by means of high-speed mixing of cement, water and sand with net energy consumption at least 5 kilojoules per kilogram of the mix. It s the added to a plasticizer admixture and mixed after that with aggregates in conventional concrete mixer.

2. Experiment

2.1 Materials

Ordinary Portland cement (OPC) meeting the requirements of BS EN 197-1 (2001) was used in the preparation of the 100mm concrete cube specimens. Clean river sand with water absorption of 0.8% and a specific gravity of 2.70 was used as fine aggregate. Crushed stone of with nominal maximum size of 12.5mm was used as coarse aggregate. The coarse aggregate met the grading requirements of BS EN 932 (1999); its water absorption was 0.6% and its specific gravity was 2.65. The water samples used for the research work were obtained from the following sources and labelled samples 1-6 sequentially as follows:

Sample 1: The River flowing behind the Building Laboratory of O.A.U. (tagged BL)
Sample 2: Water sample from Opa River (Raw water sample from O.A.U Opa Dam (tagged OD)
Sample 3: The River flowing in front of Mountain of Fire and Miracles Church along Ede- Osogbo road, Ile-Ife. (tagged ED)
Sample 4:The River flowing in front of C.A.C Mount Bethel Church Near Mayfair along Ede- Osogbo road, IleIfe. (Tagged MF)
Sample 5: The River flowing behind the Magistrate Court along Ibadan road Ile - Ife (tagged IB)
Sample 6: The treated water sample supplied from OAU water works which serves as the control sample in this experimental work. (Tagged CR)

2.2 Specimens preparation and test method

100mm cubes were prepared according to BS EN 12390-2. 1:3:6 and 1:2:4 mix ratios were adopted for this research work. Being the most accurate; the method of batching by weight was adopted and used for all the test samples. The specimens were cured in accordance with BS EN 12390-2. The curing method that was adopted in this research was wholly water-submerged as it has been adjudged to be the best method for laterized concrete (Falade, 1991). The specimens were protected against shock, vibration and dehydration.

Compressive strength gained was determined for all samples by using a compression testing machine conforming to BS EN 12390-4 in accordance with BS EN 12390-3. The test specimen was 100mm cube meeting the requirements of BS EN 12350-1, EN 12390-3 and EN 12390-2. Specimens were loaded to failure at 7, 14, 28 and 56 days. The maximum load sustained by the specimen was recorded and the compressive strength of the sample was calculated.

3. Test results and discussion

All the water samples have pH range of between 6.7 and 7.0 (Table 1). Going by findings of Neville (1995), that pH range between 6.0 and 8.0 have no significant effect on the compressive strength of concrete. And according to BS 3148: Methods of test for water for making concrete, the permissible limit of total dissolved solids (TDS) is 2000 ppm (part per million). From Table 1; it is clearly shown that all water samples tested have their TDS within the acceptable limit. For the other metallic ions shown as constituents of water used in the research work as shown in the Table, they are all regarded as impurities as pure water is expected to contain only two elements; Hydrogen and Oxygen. (with allowance for negligible amount of other non deleterious elements).

Table 1: Constituents of water from various sources in Ile-Ife environ

Lab ID	Sample ID	pH	TDS (ppm)	K (ppm)	Na (ppm)	Mn (ppm)	CU (ppm)	Zn (ppm)	Pb (ppm)
201009132	S1/BL	6.7	104	6.58	3.03	0.00	0.02	0.07	0.16
201009133	S2/OD	6.9	88	8.27	2.72	0.01	0.01	0.06	0.18
201009134	S3/ED	6.8	127	9.12	3.33	0.00	0.01	0.11	0.22
201009135	S4/MF	6.5	84	7.24	2.90	0.07	0.01	0.15	0.24
201009136	S5/IB	7.0	174	18.22	3.99	0.05	0.01	0.15	0.16

*ppm = part per million, TDS= total dissolved solids
Source: Laboratory analysis

Table 2 Compressive strength corresponding to different water samples.

Water samples	**Compressive Strength N/mm^2**				
	7 days	**14 days**	**21 days**	**28days**	**56 days**
SAMPLE1/BL	4.50	7.67	10.20	11.83	12.47
SAMPLE2/OD	9.00	9.93	11.60	12.03	13.80
SAMPLE3/ED	5.33	6.37	9.00	12.80	13.10
SAMPLE4/MF	7.20	8.73	9.93	11.23	13.23
SAMPLE5/IB	8.50	10.67	12.53	13.03	13.27
SAMPLE6/CR	6.00	7.80	10.73	11.30	14.00

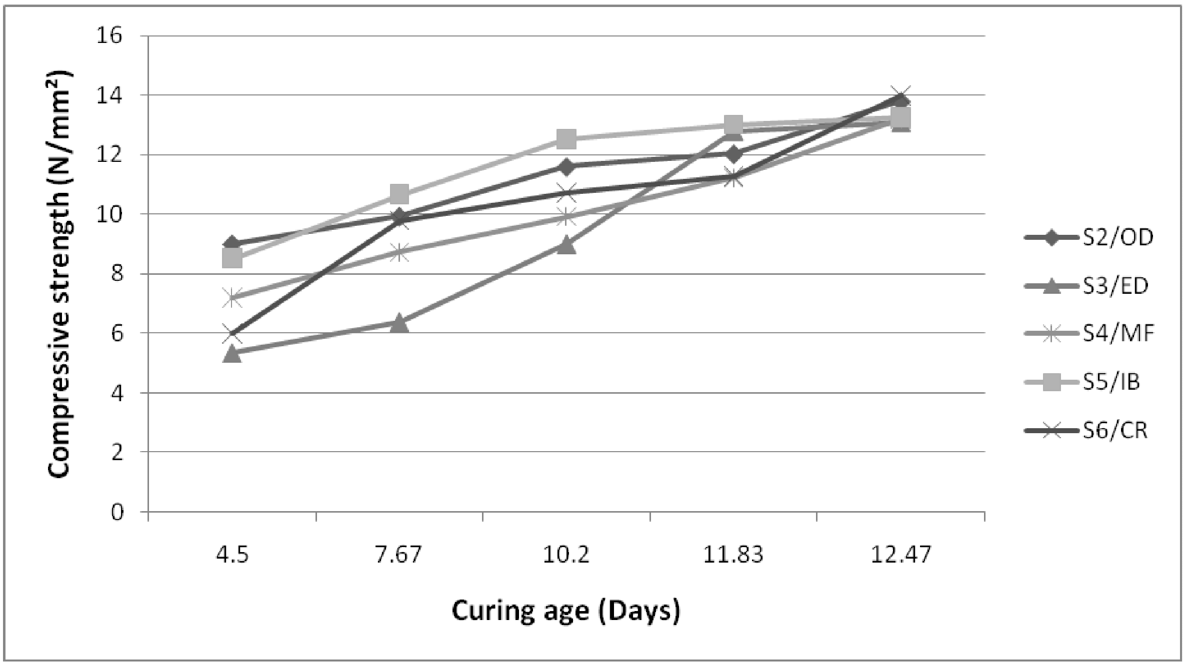

Figure 1: Variation of compressive strength of concrete cubes cast with water from different sources with curing age

The compressive strengths of concrete cast with water from various sources at various curing ages are shown in Figure 1 (also in Table 2). Generally, there is an increase in compressive strength of all concrete cubes cast with mixing water from all the sampled sources with an increase in curing age, though at different rate. In general, when comparing the result of the different water, the sample IB has the highest value of 11.6N/mm^2 which implies that the water from Ibadan Road is most likely to produce concrete with the highest compressive strength when mixing with water from various sources in Ile-Ife environ. What this means is that if we should choose to cast with only one of these water samples, the water from Ibadan Road river will be the best water to be used for mixing concrete. However, the long term performance and durability of concrete made from these water samples have not been ascertained. Also the effects of biological constituents, turbidity and presence of E-coli may not be insignificant on compressive strength of concrete especially on long-term. These are potential grounds for further studies to provide adequate information on the suitability of stream water in Ile-Ife for concreting.

4. Conclusions

This research was carried out to investigate the effect of different types of mixing water on properties of concrete especially compressive strength. The study analyzed the quality of some water samples. Then, tests were conducted on concrete made with the water samples. Particular attention was focused on various river water used for concrete mix in Ile-Ife environ in Osun State, Nigeria. All the river water tested met the ASTM C94 requirements on mixing water for ready-mixed concrete.

Based on the results of this experimental study, the following conclusions may be drawn:

i. Stream water in Ife environ compared favourably with tap water for mixing concrete without any significant reduction in compressive strength. However, its effects on concrete durability need to be established before using in for construction work.
ii. Different water sources have different levels of impurities and these generally have significant impact on the strength of concrete.
iii. Regardless of the mixing water sources; the compressive strength of concrete increases with increase in curing age.

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