Interdependence between Structural Engineering and Construction Management
Edited by Ozevin, D., Ataei, H., Modares, M., Gurgun, A., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-6-2

EFFECTS OF DIFFERENT SOURCES OF WATER ON THE PROPERTIES OF CONCRETE

IGNATIUS OMUH, RAPHEAL OJELABI, ADEDEJI AFOLABI, PATIENCE TUNJI-OLAYENI, CHUKWUMA OBI, and TIMOTHY MOSAKU

Dept of Building Technology, Covenant University, Ota, Nigeria

Water is vital to human existence and life can only be sustained by it. Concrete is a widely used construction material and water is an important part of its composition. Potable water is what is recommended for concrete works, but unfortunately, some places do not have access to this. Places that do not have access to potable water might have access to other water sources that might be used for concrete works. This study was undertaken to investigate the effects of water from different sources on concrete mechanical properties. This study evaluates the characteristics of concrete produced with river water, well water, and potable tap water. Compressive strength and Density, were used to evaluate the characteristics of concrete specimens of mix ratios 1:2:4 and $1{:}1^1/_2{:}3$ produced with water from the different sources. The results showed that concrete specimens produced with tap water had the highest mean compressive strength at 28 days. While well water had the lowest compressive strength, it was concluded that well water was not suitable for concrete works even though it is already being used on some sites that can’t access tap water.

Keywords: Compressive strength, Concrete density, Hard water, Mix ratio, Potable water, Water-cement ration, Turbidity, Acidity.

1 INTRODUCTION

Concrete is a major component of infrastructural facilities in the 21st century because of the versatility in its use. According to the European commission, concrete is the most popularly used construction material (Montero and Laserna 2017). Concrete is a mixture of cement, fine aggregates, coarse aggregates, and water combined in the correct proportions to give a strong, dense, homogeneous material which can be easily molded into desired shapes and is ideally suited for the manufacture of structural components (Ekmekyapar and Orung 2001). Water is essential of concrete practice for both mixing the concrete and curing the hardened concrete (Omuh *et al.* 2018). According to Kulkarni *et al.* (2014), the concrete industry is consuming annually 1 billion tons of mixing water in the world. The water performs two main functions. First, it allows the cement to hydrate, which is the chemical reaction between cement and water which results in the setting of the concrete. Secondly, water is also included in a concrete mix to provide workability to the mix. This enables the constituent’s materials to be mixed together easily, to be placed in the position and compacted properly. The presence of water in any concrete mix is a major factor that controls the strength development and other properties of concrete (Aitcin 2016). However, not every potential concrete site is situated near a water source. For instance, concrete production in some rural areas may compel the use of water from alternative sources such as wells and even rivers. These waters from alternative sources that are readily accessible might or might not be fit for concreting works therefore the purpose of this research. ACI 318M (2015) specifies that water suitable for concrete should be potable, colorless, odorless water fit for drinking. However, ASTM C94 (2016) permits the use of non-potable water for ready mix concrete. Although according to Neville (2000) there is no standard for mixing water in concrete, most other researchers would disagree because it is usually specified that water fit for drinking is most appropriate for concrete.

The most important property of concrete is strength which determines the quality of the concrete according to Rakesh and Dubey (2014). The compressive strength of concrete is the most common performance measure used by engineers and builders for testing of concrete cubes and cylinders. The compressive strength of concrete can be calculated from the failure load divided by the cross-sectional area resisting the load.

2 MATERIALS AND METHODS

2.1 Materials

2.1.1 *Ordinary Portland cement*

Portland cement was used in the production of the concrete; cement acts as a binder for the rest of the materials, specifically Dangote Cement, which was obtained from a local dealer of cement at Ota, Ogun State. The grade to be employed is 42.5R.

2.1.2 *Aggregates*

The fine aggregate used for the study was bought from a local source at Ota, Ogun State. The fine aggregate is sharp river sand with sizes not greater than 5mm diameter. The aggregates conform to the ASTM C136 (2006).

The coarse aggregate used for this experiment is granite from crushed quarried rocks. The size of the granite is not greater than 19 mm and it was bought from local granite seller at Ota, Ogun State. This also conforms to the ASTM C136 (2006) (Method for sieve analysis of fine and coarse aggregates).

2.1.3 *Water*

The water samples were obtained from three sources. The sources of the water are listed:

1. River water which was obtained from the Atuara River, Ota Ogun State.
2. Open well water which was obtained from a residence in ilogbo, Ota Ogun State.
3. Tap water which was obtained from Building Technology's Concrete Laboratory, Covenant University, Ota, Ogun State.

The water used in this study was analyzed in the Chemistry Laboratory of Covenant University, Ota, Ogun State.

The properties that were analyzed were the physical and chemical properties of the water. The physical properties determined included color, odor, pH at 20^{o} C, turbidity and conductivity. The chemical properties determined includes acidity, alkalinity, total hardness, chloride, sulphite, sulphate, nitrite, ammonia, and silica.

2.1.4 *Preparation of concrete cube specimens*

A total of 54 cubes were cast for concrete of mix ratio 1:2:4 and $1{:}1^{1}/_{2}{:}3$. The concrete cubes were of size 150 mm x 150 mmx 150 mm. the design for the experiment had three samples for each mix and three hydration periods as shown in Table 1. Steel molds were used for casting the cubes. The materials will be mixed to produce a total of 54 concrete cubes with the specifications:

a. The grade of concrete to be achieved are of characteristic strength 25 MPa, and 30 MPa respectively with their respective mix ratio's 1:2:4 and $1{:}1^{1}/_{2}{:}3$
b. The mixing method was the same for all the concrete samples with different water sources. Manual mixing was employed because of the small volume of the concrete to be mixed.
c. The curing method employed was ponding for 7 days, 21 days and 28 days.

2.1.5 *Mix Ratio*

For each water sample used, there were two mix ratios. The cube samples were marked to differentiate the test conditions (A1, A2, A3), (B1, B2, B3), (C1, C2, C3), (D1, D2, D3,), (E1, E2, E3), (F1, F2, F3). Table 1 represents the sample identification and Table 2 shows details about concrete cube samples.

Table 1. Concrete specimen identification.

S/N	Source of water	Mix Ratio	Symbol
1	River water	1:2:4	**A**
2	River water	$1{:}1^{1}/2{:}3$	**B**
3	Well water	1:2:4	**C**
4	Well water	$1{:}1^{1}/2{:}3$	**D**
5	Tap water	1:2:4	**E**
6	Tap water	$1{:}1^{1}/2{:}3$	**F**

Table 2. Batching summary for concrete cubes samples.

Sample	Cement (Kg)	Sand (Kg)	Granite (Kg)	Water (Kg)	Water/ Cement Ratio
A	13	26	52	8.5	0.60
B	17	25.5	51	11.1	0.65
C	13	26	52	8.5	0.60
D	17	25.5	51	11.1	0.65
E	13	26	52	8.5	0.60
F	17	25.5	51	11.1	0.65

The concrete cubes were removed from the molds after 24 hours and placed into the curing tanks. There were three hydration periods within which samples were tested for the compressive test to examine the strength development of the concrete samples.

3 FINDINGS AND DISCUSSION

From Table 3, River water tested showed a slightly clear appearance, pale yellow in color. The odor was objectionable, which may indicate the presence of organic matters, and a pH of 6.46 which is acidic. For the Well Water tested, it showed a clear sample, colorless and odorless, and a pH of 5.91 which is acidic. For Tap Water, the water was clear in appearance, odorless, and a pH of 5.23 indicating acidity. The WHO standard for water states: clear, odorless, and has a pH ranging from 6.50 - 9.20. The pH value of River Water did not satisfy the WHO and Nigerian Industrial Standards (NIS) standard for drinking water but fails to satisfy the conductivity standard. The pH of Tap Water and Well Water used does not satisfy the WHO and NIS standard at 5.23.

Table 3. Physical characteristics of the water samples.

S/No	**Parameter**	**River water**	**Well water**	**Tap water**	**WHO Standard for Drinking water**		**NIS Standard for Drinking Water**
					Minimum acceptable	**Maximum acceptable**	**Maximum acceptable**
1	**Appearance**	Slightly Clear	Clear	Clear	Clear	Clear	Clear
2	**Color**	Pale Yellow	-	-	-	-	-
3	**Odor**	Objectionable	Odorless	Odorless	Odorless	Odorless	Odorless
4	**pH at 28°C**	6.46	5.91	5.23	6.5	9.2	6.5-8.5
5	**Turbidity (mg/l)**	<50	<50	<50	5	50	5
6	**Conductivity (μScm-1)**	192.6	132.6	30	0.9×10^{-4}	1.20×10^{-1}	1000

Table 4. Chemical characteristics of water sample.

S/No	**Parameter**	**River water**	**Well water**	**Tap water**	**WHO Standard for Drinking water**		**NIS Standard for Drinking Water**
					Minimum acceptable	**Maximum acceptable**	**Maximum permitted**
1	**Acidity-P (mg/l $CaCaO_3$)**	40	20	20	Nil	Nil	Nil
2	**Alkalinity-M (mg/l $CaCaO_3$)**	70	40	40	30	500	Nil
3	**Total Hardness (mg/l $CaCaO_3$)**	60	30	20	30	200	150
4	**Chloride, Cl^- (mg/l)**	3.55	1.78	1.78	200	600	250
5	**Sulphate,SO_2^{-4} (mg/l)**	<50	<50	<50	200	400	200
6	**Silica, SiO_2 (mg/l)**	ND	ND	ND	-	-	-

Note: ND= Not Detected

From Table 4, River Water tested showed chlorine content of 3.55 mg/l, total hardness of 60 mg/l $CaCO_3$ and sulphate was less than 50 mg/l. For Well Water tested, it showed a total hardness of 30 mg/l $CaCO_3$, chloride content of 1.78 and sulphate was less than 50 mg/l. For Tap Water, the water showed total hardness of 20 mg/l $CaCO_3$, chloride content of 1.78 mg/l and sulphate was less than 50 mg/l. The WHO standard for water states a total hardness of 30 – 200 mg/l $CaCO_3$, chloride content of 200 – 600 mg/l and a sulphate content of 200 – 400 mg/l. The total hardness and the chlorine content of River Water fails to satisfy the WHO and NIS standard for drinking water. The Tap Water, Well Water and River Water used fail to satisfy the WHO and NIS standard in terms of acidity with an acidity of 20 mg/l $CaCO_3$ as compared to the standard which is Nil. All three water samples fall below W.H.O‘s minimum standard for chloride. The total hardness of Tap Water falls below W.H.O‘s minimum standard for total hardness. Figure 1 shows the compressive strength of 1:2:4 concrete mixed with water from different sources. It shows that the concrete that was mixed with river water possessed the lowest compressive strength at 28 days of 17.8 MPa.

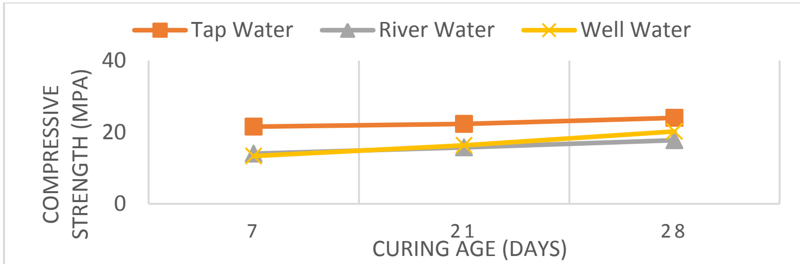

Figure 1. Compressive strength development for concrete with different mixing water types (1:2:4).

This could be because the water possessed impurities that may have been detrimental to the concrete strength development. The concrete mixed with well water yielded concrete of compressive strength of 20.24 MPa while the concrete mixed with tap water (which is supposed to be potable water) yielded the highest compressive strength of 24.01 MPa. It was also noted that the concrete mixed with well water possessed a lower 7-day strength than the concrete mixed with river water. The cube sample yielded a compressive strength at 28 days that was higher than the compressive strength of the samples mixed with river water.

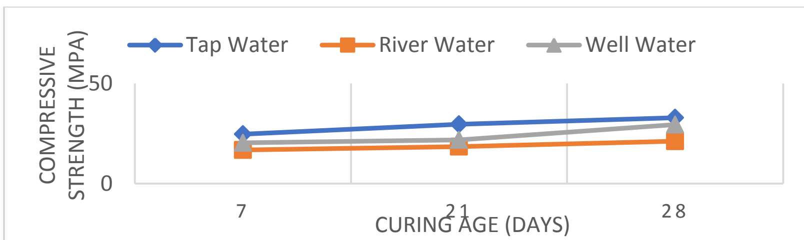

Figure 2. Compressive strength development for concrete with different mixing water types (1:1$^1/_2$:3).

Figure 2 shows the compressive strength of 1:1$^1/_2$:3 concrete mixed with water from different sources. The trend of the results is like that for concrete of mix ratio 1:2:4. The expected strength of mix 1:$^1/_2$:3 concrete is 30 MPa but both the concrete mixed with river water and well water respectively did not attain the 28-day strength of 30 MPa.

The Tap Water produced the highest compressive strength. The Well Water produced lower compressive strength while the river water used produced the lowest compressive strength, with slow strength development as observed from the Figures 1 and 2. This can be attributed to the organic nature of the water which can be deduced from the physical properties of been pungent in odor and pale color and the acidity of the water can be attributed for low strength recorded. It was determined by De Melo *et al.* (2016), that River Eater possessed some form of humic acid that is harmful to concrete (Kucche *et al.* 2015). This may have been responsible for the low compressive strength obtained.

4 CONCLUSIONS AND RECOMMENDATIONS

The Tap and Well Water samples tested did not meet the WHO and NIS standards for acidity but were within the standards for all the other parameters. The River Water was within the limits for acidity/pH value but possessed color while both the WHO and NIS standards specify that it must be clear. The findings also showed that Tap Water, which is the most potable to drink, is the most suitable for concrete works which agrees with what was indicated from literature (Shetty

2000, Neville and Brooks 2010). While the use of potable water is generally safe, water not fit for drinking may also be satisfactorily used in making concrete. As a rule, any water with pH of 6.0 to 8.0 which does not taste saline or brackish is suitable for use (Kucche *et al.* 2015). Color and odor do not indicate that deleterious substances are present in water. Natural waters that are slightly acidic are harmless, but water containing humic or other organic acids may adversely affect the strength of concrete. The Well Water used was tested to be acidic therefore not complying with W.H.O and NIS standard for drinking water in terms of the pH value. Concrete specimens produced with Well water had densities. Tap Water (or potable water) is the most appropriate for concrete works but in the circumstance where it is not available, Well Water can still be used. It should be noted that the strength might be reduced but not significantly. It is also recommended that River Water should be avoided by all means in concrete works.

Acknowledgments

The researchers wish to acknowledge the Covenant University Centre for Research, Innovation and Discovery (CUCRID) for their support in this study.

References

ACI 318M, Building Code Requirements for Structural Concrete (ACI 318M-14): an ACI Standard: Commentary on Building Code Requirements for Structural Concrete (ACI 318M-14), ACI Committee. *Farmington Hills, MI: American Concrete Institute*, 2015.

Aitcin, P. C., Water and its Role on Concrete Performance, *Science and Technology of Concrete Admixtures*, 75-86, 2016.

ASTM, C136, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, American Society for Testing and Materials, West Conshohocken, USA, 2006.

ASTM, C94, Standard Specification for Ready Mixed Concrete, American Society for Testing and Materials, West Conshohocken, USA, 2016.

De Melo, B. A. G., Motta, F. L., and Santana, M. H. A., Humic Acids: Structural Properties and Multiple Functionalities for Novel Technological Developments, *Materials Science and Engineering: C*, 62, 967-974, 2016.

Ekmekyapar, T., and Orung, I., Buildings Materials, *Ataturk Univ. Agricultural Faculty Publication*, 145, 70-135, 2001.

Kucche, M. K., Jamkar, S. S., and Sadgir, P. A., Quality of Water for Making Concrete: A Review of Literature, 2015.

Kulkarni, V., Patil, S. G., Shivasharanappa, Study on Compressive Strength of Concrete by using Treated Domestic Waste Water as Mixing and Curing of Concrete, *International Journal of Research in Engineering and Technology,* 03(12), 152-156, 2014. Retrieved from https://ijret.org/volumes/2014v03/i12/IJRET20140312021.pdf on June 22, 2018.

Montero, J., and Laserna, S., Influence of Effective Mixing Water in Recycled Concrete, *Construction and Building Materials*, *132*, 343-352, 2017.

Neville, A., Water Cinderella Ingredient of Concrete, *Concrete International*, *22*(9), 66-71, 2000.

Neville, A. M., and Brooks, J. J., *Concrete Technology.* Second edition, Prenticehall, 269, 276, 2010.

Omuh, I. O., Mosaku, T. O., Joshua, O., Ojelabi, R. A., Amusan, L. M., Afolabi, A. O., and Arowolo, A. O., Data on Mixing and Curing Methods Effects on the Compressive Strength of Concrete, *Data in Brief*, 18, 877-881, 2018.

Rakesh, A. M., and Dubey, S. K., Effects of Different Types of Water on Compressive Strength of Concrete, *International Journal of Emerging Technologies,* 5(2), 40-50, 2014.

Shetty, M. S., *Concrete Technology,* S. Chand and Company Ltd., New Delhi, India, 2000.