

PAPER 46 – NEED FOR EFFECTIVE EVALUATION OF WATER RESOURCES QUALITIES FOR SUSTENANCE AND ATTAINMENT OF CONSTRUCTION (ENGINEERING) DEVELOPMENT GOALS

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ABSTRACT

Water that is good for drinking is also good for construction purposes. Consequently, this study aims to evaluate the physicochemical qualities of water resources and to access their impact on the selected mechanical properties of concrete for sustainability and attainment of construction development goals. The water resource of interest here is the groundwater whose samples were collected in five locations in Owerri town of Imo state, Nigeria. The physicochemical parameters of the collected samples were analyzed in accordance with guidelines under the World Health Organization (WHO) standard. Thereafter, the analysed water samples were used to mix concrete where the compressive strength, flexural strength and split tensile strength were determined. The results from the quality analyses showed that the concentrations of the groundwater sampling fall within the WHO recommended standard. Similarly, the results of the compressive strength, flexural and split tensile strengths showed that analyzed water samples from the five locations which were used to mix concrete are capable of helping to produce concrete of excellent properties. Stakeholders are therefore advised to maintain the use of water resources that meet drinking standards as part of concrete ingredients to ensure sustenance of safety in the construction industry.

Keywords: Water Resources, Concrete, Compressive Strength, Flexural Strength and Split Tensile Strength

1. INTRODUCTION

Water resources is a term used to describe natural resources (bodies) of water that are potentially useful as a source of water supply. There are indeed three necessities of life which include water, food and shelter. That proves to a large extent the reason why water resources as natural elements are very essential and precious to life's existence. Two main classes of water resources can be identified as Groundwater and Surface water, but this recent work focuses on groundwater. Groundwater, according to Akpobori and Nfor (2007) has been the cornerstone of all rural and urban water supply development in Nigeria. As opined by Agunwamba (2000), two major sources of groundwater can be identified. Some are formed by rainwater which permeates into the ground through the pores of rock formation and finally reached the underground water table. There is the water from streams, lakes, and reservoirs which percolate through the soil to the underground water table. Thus, depending on the groundwater source, we can have Shallow well, Deep well and Boreholes as major sources of groundwater.

It is also important to note that water plays a crucial role in most human activities as well as the socio-economic development of any country, state, town or community. Its importance to mankind cannot be overemphasized. It is used for domestic purposes. The majority of city dwellers in Nigeria depend on groundwater as their source of water supplies. In the field of agriculture, water is used for irrigation and in the construction industry; it is a widely used raw material, especially as an ingredient in the concrete mixture for better workability. In a nutshell, it is those water samples whose physicochemical parameters meet the WHO recommended limits are eligible to be used in the construction works. This is one of the reasons why most of the specifications recommend the use of potable (treated) water for making concrete so that good mechanical properties of concrete can be sustained.

Owerri is the capital city of Imo State, Nigeria. Although, it consists of three local government areas which include Owerri Municipal, Owerri West and Owerri North, Owerri Municipal, which is the choice of our study in this present work constitute the majority of the state capital. With the presence of the majority of government activities, workers' activities, government facilities, federal and state institutions like Imo state university, Owerri, Alvan Ikoku Federal College of Education, state and federal agencies, notable establishment, industries and churches, the area has been one of the fastest developing LGA of the state. This means that there is always an increase in economic activities prompting an increase in water demand for any purpose. Sometimes, urbanisation might come with an acute shortage of water which might trigger many challenges like health-related issues or even building collapse. Though many factors may be responsible for building failures and collapse, the impact of poor water cannot be ruled out. According to Saravanakumar and Dhinakaran (2010), the use of poor-quality water in concrete leads to corrosion and ultimately causes failure in concrete, while the use of saline water in

2.2. COLLECTION OF GROUNDWATER DATA AND SAMPLING

The primary sources of data (physicochemical data) in this study were obtained through laboratory analysis of the groundwater from the five selected sample locations in Owerri Municipal L.G.A. of Imo state. The physicochemical data include the following: Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Nitrite (NO₃), Bicarbonate (HCO₃), Sulphate (SO₄) Total Hardness (TH), Total Alkalinity (TA), Total Dissolved Solids (TDS) and pH. On the hand, the secondary data were obtained from extracts from WHO (World Health Organization) where the recommended limits for each groundwater resource for a particular purpose were selected. For the physicochemical parameters analysis, two 2-litre polyethene bottles were used to fetch two samples of water from the groundwater (borehole) in the five selected locations. The samples were then stored in a refrigerator at a temperature below 20 °C to prevent changes in the water sample between the time of collection and analysis. For assessment of the performance of the groundwater water in concrete production, two samples of groundwater per location were obtained for use in the mixing of concrete

2.3. PROCEDURE / METHOD OF LABORATORY ANALYSIS

In the first place, to assess the suitability of the groundwater qualities for drinking purposes, physicochemical analyses are carried out on the collected water samples. They are pH, Sodium (Na⁺), Potassium (K⁺), Calcium (Ca²⁺), Magnesium (Mg²⁺), Chloride (Cl⁻), Sulphate (SO₄²⁻), Nitrite (NO₃⁻), HCO₃, Total Hardness (TH), Total Alkalinity(TA), and Total Dissolve Solids (TDS). Analyses of the majority of the parameters were done using the various standard methods for water analysis and in accordance with APHA (American Public Health Association), AWWA (American Water Works Association) and WPCF (Water Pollution Control Federation) (2005) guidelines. Specifically, the pH was determined using a pH meter. The cation concentrations were determined using atomic absorption spectrophotometer. Nitrate and sulphate concentrations were determined turbid metrically using a spectro-photometer at wavelengths of 410nm and 420nm, respectively. To ensure the correctness of chemical analysis of these water resources parameters, one must ascertain that the equality of the sum of the cations and anions expressed in terms of milliequivalents per litre satisfies the principle of electroneutrality. See the works of Nwachukwu and others (2022) for the steps involved.

Subsequently, the groundwater sample is assessed for its performance in the concrete mixture. In this section, the materials under investigation are a mixture of cement, fine and coarse aggregate and analysed water from the groundwater which was used in accordance with ASTM C1602/C1602M-22 (2022). Our attention here is to determine the compressive strength, flexural strength and split tensile strength of concrete cubes and cylinders. A total of thirty (30) cubes were prepared for compressive strength, flexural strength and split tensile strength. The procedure for compressive strength testing was done in accordance with BS 1881 – part 116 (1983) - Method of determination of compressive strength of concrete cube. Two samples were crushed for each mixture with groundwater per location. In each case, the compressive strength was calculated using Eqn. (1)

$$\text{Compressive Strength} = \frac{\text{Average failure Load (N)}}{\text{Cross-sectional Area (mm}^2\text{)}} = \frac{P}{A} \quad (1)$$

Flexural strength testing was done in accordance with BS 1881 – part 118 (1983) - Method of determination of Flexural Strength, ASTM C78/C78M-22 (2022) and ACI (1989) guideline. In this present study, two samples were crushed for each concrete cube. In each case, the Flexural Strength which is expressed as the Modulus of Rupture (MOR) was then calculated to the nearest 0.05 MPa using Equation 2.

$$\text{MOR} = \frac{PL}{bd^2} \quad (2)$$

Where b = measured width in cm of the specimen, d = measured depth in cm of the specimen at the point of failure, where L = Length in cm of the span on which the specimen was supported and P = maximum load in kg applied to the specimen.

The cylindrical split tensile test was done using the universal testing machine in accordance with BS EN 12390-6:2009 and ASTM C 496/ C 496 M-17 (2017). Two samples were crushed for each concrete cylinder and in each case, the Split Tensile Strength was then calculated using Eqn. (3)

$$F_t = \frac{2P}{\pi DL} \quad (3)$$

Where, F_t = Split Tensile Strength, MPa, P = maximum applied load (that is Load at failure, N) ; D = diameter of the cylindrical specimen (Diameter of cylinder, mm); and L = Length of the specimen (Length of the cylinder, mm),

3. RESULTS AND DISCUSSION

3.1 PRESENTATION OF RESULTS

The result of the physicochemical analysis obtained for the five selected locations (A - E) in Owerri Municipal L.G.A of Imo state for groundwater sampling as well as the result of the compressive strength (CS), flexural strength (FS) and Split tensile strength (STS) are presented in Tables 1 and 2.

Table 1. Presentation of Results of Physico-Chemical Analysis of The Groundwater Samples.

S/NO	LOC ATIO N	Exp. No.	Ca ²⁺ Mg/L (NA/*100-300)	Mg ²⁺ (50)	N ⁺ (NA/*200)	K ⁺ (NA)	HCO ₃ ⁻ (<600)	Cl ⁻ (250)	NO ₃ ⁻ (50)	SO ₄ ²⁻ (NA/*250)
1.	A	1A	34.7	8.9	24.9	0.40	35.0	65.8	9.4	57.2
		1B	35.5	9.0	25.5	0.42	36.5	65.9	9.5	60.0
		AV.	35.1	9.0	25.2	0.41	35.8	65.9	9.5	58.6
2.	B	2A	27.8	8.3	25.3	0.33	48.2	72.3	7.8	64.3
		2B	28.2	8.8	25.2	0.32	49.5	74.6	7.5	65.2
		AV.	28.0	8.6	25.3	0.33	48.9	73.5	76.5	64.75
3.	C	3A	34.6	9.3	39.8	0.24	50.0	75.0	8.3	70.8
		3B	35.8	9.5	39.1	0.28	50.3	75.9	8.4	72.7
		AV.	35.2	9.4	39.5	0.26	50.2	75.5	8.4	71.8
4.	D	4A	36.7	8.7	34.6	0.31	56.3	67.7	7.8	68.3
		4B	37.2	7.8	37.2	0.34	54.3	72.2	8.2	70.3
		AV.	37.0	8.3	35.9	0.33	55.3	70.0	8.0	69.3
5.	E	5A	29.6	7.5	40.3	0.40	48.9	75.0	7.6	81.2
		5B	30.5	7.6	39.3	0.34	48.2	80.0	8.5	79.4
		AV.	30.1	7.6	39.8	0.37	48.6	77.5	8.1	80.3

Table 2. Presentation Of Results Of Physico-Chemical Analysis (Contd), Compressive Strength (CS), Flexural Strength (FS) And Split Tensile Strength (STS) Of The Groundwater Samples.

S/NO	LOCA TION	Expt. No.	TA Mg/CaCo ₃ (200)	TH Mg/L CaCo ₃ (NA/*100-500)	TDS Mg/L CaCo ₃ (500)	pH (6.5 - 8.5)	CS (MPa) (20 -35)	FS (MPa)	STS (MPa)
1.	A	1A	54.32	98.76	267.9	7.1	27.13	8.48	5.03
		1B	54.76	97.89	271.0	7.3	28.03	8.52	5.05
		AV.	54.54	98.33	269.5	7.2	27.58	8.50	5.04
2.	B	2A	51.19	87.35	280.2	7.1	24.54	7.76	4.59
		2B	52.82	89.04	284.7	7.5	25.14	7.82	4.61
		AV.	52.01	88.20	282.5	7.3	24.84	7.79	4.60
3.	C	3A	52.43	88.65	273.2	7.2	26.37	6.77	5.05
		3B	53.12	89.23	269.9	7.4	25.83	6.96	5.09
		AV.	52.78	88.9	271.6	7.3	26.10	6.88	5.07
4.	D	4A	49.23	90.68	272.8	7.2	22.34	7.00	4.76
		4B	51.46	94.34	281.5	7.2	23.27	7.04	4.82

		AV.	50.35	92.51	271.2	7.2	7.02	4.79
		5A	50.09	89.03	255.8	6.5	22.81	
		5B	50.21	88.28	261.0	6.5	24.28	7.65
5.	E	AV.	50.15	88.63	258.4	6.5	25.18	5.88
							7.68	5.89
							24.73	

The following items describe the content in Tables 1 and 2: **i.** The procedures for checking the accuracy of the analysis and calculating the values of Total Alkalinity (**TA**), Total Hardness (**TH**) and Total Dissolved Solids (**TDS**) have been demonstrated by the works of Nwachukwu and others (2022). **ii.** The values in the bracket represent WHO Standards. **iii.** NA implies that no health-based guideline value has been derived. **iv.** * indicate the taste threshold values.

3.2. DISCUSSION OF RESULTS

From the results of the physicochemical analyses for groundwater samples shown in Tables 1 and 2, the pH values of locations A to D indicate a neutral value which makes them fit for consumption. Of location, E shows a slightly acidic situation but somehow compares favourably with the WHO stipulated standards. The TDS values are also within the WHO recommended limit. For the anions, chloride concentration, nitrate ((NO₃)), Sulphate (SO₄), and HCO₃ levels are generally lower than the prescribed threshold level recommended by the WHO standard and therefore accepted. Similarly for the cations, Ca²⁺.Mg²⁺, Na⁺ and K⁺, the values also fall within the WHO stipulated standards. Although the values of TH in all selected locations fall within the WHO Taste Threshold stipulated standard, there is still the presence of hardness in these water sources, even though consumers can tolerate hardness up to 500 mg/L. However, their uses in the construction industries are guaranteed. Again, the result of the compressive strength for the groundwater in all selected locations shows that the values meet the minimum ACI (American Concrete Institute) standard (of 20MPa) for good concrete. Other design strengths conducted are also in good agreement with the production of concrete for sustainable construction development. Thus, water from the groundwater sources in these areas that satisfy the WHO standard, when used to mix concrete can positively impact the general strength of concrete cubes.

4. CONCLUSION

So far, the physicochemical analyses of samples of groundwater resources from the selected locations in Owerri Municipal L.G.A of Imo state, Nigeria have been presented. Also presented are the evaluation of the compressive strength, the flexural strength and the split tensile strength of the concrete mixed with samples of water from the selected locations. Both the cation and anion concentrations for the groundwater fall within the WHO recommended standard. Again, the total dissolved solids (TDS), fall within the WHO recommended standard. From the mechanical properties investigation, the compressive strength of concrete cubes mixed with water from the groundwater sources meets up with the minimum requirement of 20 MPa stipulated by ACI. Thus, to ensure the sustainability of good mechanical properties of concrete, there is a need for a prior physicochemical assessment of these water resources.

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