

# **EFFECT OF WATER QUALITY ON THE COMPRESSIVE STRENGTH OF CONCRETE (A case study of well, stream and tap water in Kaduna State)**

**J.O. AFOLAYAN**

**Department of Civil Engineering,  
Faculty of Engineering,  
Nigerian Defence Academy, Kaduna.**

## **ABSTRACT**

*Water forms the basic constituents in concrete work. It is the principal hydrating agent that initiates the chemical reaction; other constituent materials are cement, fine and coarse aggregates. Water is the most important and least expensive ingredient of concrete as it actively participates in the chemical reaction with the content. A part of mixing water is utilized in the hydration of cement to form the binding matrix in which the inert aggregate are held in suspension until the matrix has hardening. The remaining water serves as a lubricant between the fine and coarse aggregate and makes concrete workable. The quality of water used in mixing concrete plays an important role in the resulting compressive strength of the concrete. The water used for the mixing and curing of concrete should be free from injurious amounts of deleterious materials. Hence the need to investigate the effect of water quality on the compressive strength of concrete is of paramount importance. A visit to most construction sites in Northern Nigeria shows that the common sources of water used are well, stream/river and treated water from the public system which is seldomly available due to epileptic supply. A close examination of these water show different shades of colours and impurities. This paper presents the results of water samples obtained from the various sources mentioned above and their suitability for concrete production. The water samples were analyzed to determine the level of impurities in terms of solid suspension/dissolved and their corresponding pH values. Compressive strength tests were carried out on concrete cubes cured at 28days. In addition the fresh concrete was subjected to relevant tests in order to establish their conformity with established standards as in BS 1881part 102 to 104, 1983.*

**KEY WORDS:** Water quality, pH value, compressive strength.

## **INTRODUCTION CONCRETE**

Concrete is the most widely used man-made construction material in the world and is second only to water as the most utilized substance on the planet [8,12]. Concrete is like stone when dry and pasty in wet condition. It is an important material commonly used in almost all modern buildings and structures [12]. Concrete can also be described as a product or mass made by the use of hydration product. It is obtained from a correctly designed mix made up of cement, water, aggregate and admixture if necessary [7]. Concrete mix design is the procedure by which, for any given set of condition, the proportions of the constituent materials are chosen so as to produce a concrete with all the required properties at the minimum cost. Production of concrete takes place by mixing the constituent material that is cement, water and aggregate. This ensures homogeneity of the product after mixing the constituent material in simple proportions by volume or weight. The mixing could also be done manually by the use of the shovels.

## **WATER**

Water is the most important and least expensive ingredient of concrete as it actively participates in the chemical reaction with the content [6]. A part of mixing water is utilized in the hydration of cement to form the binding matrix in which the inert aggregate are held in suspension until the matrix has hardened. The remaining water serves as a lubricant

between the fine and coarse aggregate and makes concrete workable [6,12]. Generally, cement requires about three-tenth of its weight of water for hydration [6]. Hence the minimum water, cement ratio required is 0.30 [6]. But it has been noted that the concrete containing water in this proportion will be very hash and difficult to place. Additional water is required to lubricate the acid, which makes the concrete workable. This additional water must be kept to minimum, since too much water reduces the strength of concrete [9]. The water-cement ratio is influenced by the grade of concrete, nature and type of aggregate, the workability and durability [8]. If too much water is added to concrete the excess water along with cement comes to the surface by capillary action and this cement water mixture forms a scum, or a layer of chalky material known as contance [6]. This contance prevents bond formation between the successive layers of concrete and forms a plane of weakness. Excess water may also leak through the joints of the formwork and make the concrete honey combed.

### QUALITY OF WATER

The water used for the mixing and curing of concrete should be free from injurious amounts of deleterious materials. The unwanted situations leading to the distress of concrete have been found to be a result of the mixing and curing water being of inadequate quality. Portable water is generally considered satisfactory for mixing concrete. In the case of doubt about the suitability of water particularly in waste acid or where water is derived from sources that are not normally utilized for domestic purposes the water should be tested [6,9,12].

### EFFECTS OF IMPURITIES IN WATER ON PROPERTIES OF CONCRETE

The strength and durability of concrete is reduced due to the presence of impurities in the mixing water. The effects can be expressed mainly in terms of differences in the setting times of Portland cement mixes containing proposed mixing water as compared to distilled water, and concrete strengths compared with those of control specimens prepared with distilled water. The effluents from sewerage works, gas works, and from paint, textile, sugar and fertilizer industries are harmful for concrete. The test show that water containing excessive amounts of dissolved salts reduces compressive strength by 10 to 30 per cent of that obtained using potable water. In addition, water containing large quantities of chlorides tends to cause persistent dampness, surface efflorescence and increases the corrosion of the reinforcing steel [5,6,9,12]. The adverse effects on compressive strength of concrete due to various dissolved salts are given in table 1

**Table 1: Effect of dissolved salt on compressive strength of concrete [6]**

Percentage of salt in water	Percentage reduction in compressive strength
0.05 SO <sub>4</sub>	4
1.0 SO <sub>4</sub>	10
5.0 NaCl	30
CO <sub>2</sub>	20

### SUSPENDED PARTICLES

The presence of suspended particles of clay and silt in the mixing water up to 0.02 percent by weight of water does not affect the properties of concrete [6]. Even higher percentage can be tolerated so far as strength is concerned, but other properties of concrete are affected [5,6].

## **MISCELLANEOUS INORGANIC SALTS**

The presence of salt and manganese, tin, zinc, copper and lead in water causes reduction in the strength of concrete [6]. The zinc chloride retards the setting of concrete to such an extent that no strength tests are possible at 2 and 3 days. The effect of lead nitrate is completely destructive [12]. Some salts like sodium iodate, sodium phosphate, sodium arsenate and sodium borate reduce the initial strength of concrete to a very low degree [6]. The carbonates of sodium and potassium may cause extremely rapid setting and in large concentrations, reduce the concrete strength. On the other hand, the presence of calcium chloride is restricted to 1.5 per cent by weight of cement [6,9,10,12].

## **SALTS IN SEAWATER**

Seawater generally contains 3.5 per cent of dissolved salts. The salt chemical composition of seawater throughout the world is remarkably uniform and all the chloride is associated with the sodium except for a very small amount with potassium and all the sulphate is associated with magnesium. The approximate percentages of various ions due to salts in seawater are: chloride, 1.3; sulphate, 7.2; sodium, 28.5; magnesium, 3.6; calcium, 1.3; potassium, 1.0. However, the total amount of any ion varies widely. For a given mass of seawater the ingress into the concrete of any given ion is proportional to the salinity of that seawater. From the standpoint of chemical effects of seawater on plain or unreinforced concrete, it is the sulphate content which is problematic, hence, the need for sulphate-resisting cement. However, this need is greatly reduced by employing concrete of lower water-cement ratio. The salts present in seawater reduce the ultimate strength of concrete. The reduction in strength of concrete may be of the order of 10 to 20 per cent. However, the major concern is the risk of corrosion of reinforcing steel due to chlorides. In general, the risk of corrosion of steel is more when the reinforced concrete member is exposed to air than when it is continuously submerged under water. The presence of chlorides in water is also responsible for efflorescence. It is advantageous to use cement with as much C<sub>3</sub>A as can be tolerated without incurring sulphate attack in concrete containing corrodible metal. The more is the C<sub>3</sub>A in the cement, the more chloride ion will be intercepted by aluminate (precipitated as non-detrimental calcium chloroaluminate), taking longer for the ion to build up at the surface of the steel [6,7,8,9,12].

## **ACIDS AND ALKALIES**

The industrial waste water containing acids or alkalies is usually unsuitable for concrete construction. With reference to acidity the water having pH value higher than 6 can be used. However, the pH may not be as satisfactory a measure of the amount of acid. The effect of acidity in water is best gauged on the basis of total acidity, the extent of which should satisfy the following requirement [6]. The amount of 0.02 normal NaOH required to neutralize 100 ml sample of water using phenolphthalein as indicator should not be more than 5 ml. This acidity is equivalent to 49 ppm of H<sub>2</sub>SO<sub>4</sub> or 36 ppm HCl.

## **ALGAE**

Algae may be present in mixing water or on the surface of aggregate particles. It combines with cement and reduces the bond between aggregate and cement paste. The water containing algae has the effect of entraining large quantities of air in concrete and thus lowering the strength of concrete [9].

## **SUGAR**

If the amount of sugar present in the mixing water is less than 0.05 per cent by weight of water there is no adverse effect on the strength of concrete. Small amounts of sugar up to 0.15 per cent by weight of cement retard the setting of cement and the early strengths may be reduced whereas the 28-day strength may be improved. When the quantity of sugar is increased to 0.20 per cent by weight of cement, setting is accelerated. When quantity is further increased, rapid setting may result and 28-day strength is reduced [6].

## **OIL CONTAMINATION**

Mineral oils not mixed with animal or vegetable oils have no reverse effect on the strength of concrete. If the concentration of mineral oil is up to 2 per cent by weight of cement, a significant increase in strength has been noticed. For a percentage of mineral oil (more than 8 per cent), the strength is slightly reduced. The vegetable oils have detrimental effect on the strength of concrete, particularly at later ages [6,9,12].

## **TESTS AND METHOD**

### **SUSPENDED SOLID TEST**

The suspended solid test was conducted in the laboratory on the samples of water from well and stream/river with the aid of a funnel shaped filter paper, oven. Funnel and a desiccators, care was taken to achieve results with a high degree of accuracy. Total suspended solids represents in mg/l the portion of the total solid retained by filtering water containing suspended solids. The filter paper was dried at 100<sup>0</sup>C for 20 minutes in the oven, and then it was removed and cooled in the desiccators for 20 minutes and then weighed. The value obtained was the initial reading [W<sub>1</sub>]. The filter paper was folded to funnel shape and put in a funnel., 50ml of the sample was filtered and the filter paper was taken to the oven for drying at 100<sup>0</sup>C for 20 minutes. After drying the filter paper, it was then removed and cooled in the desiccators for 20 minutes. The filter paper was then weighed and value obtained as final reading [W<sub>2</sub>]. Suspended solid = W<sub>2</sub> – W<sub>1</sub> (suspended solids values in g/50ml).

### **TOTAL SOLID TEST**

The total solid test was conducted immediately after the suspended solid test on the three samples. It was conducted using evaporating dish, oven and desiccators. Care was taken to achieve a high degree of accuracy. Total solids reported in mg/l is the amount of the residue left in the evaporating dish after evaporation of the sample and its subsequent drying in an oven at a specified temperature. The evaporating dish was cleaned and dried in the oven at 100<sup>0</sup>C for 20 minutes. The dish was removed and cooled in the desiccators for 20 minutes, after cooling the evaporation dish was weighted and recorded as W<sub>1</sub>. 50ml of the sample was poured on the evaporating dish and heated until all the water dried up. It was removed and cooled in the desiccators or 20 minutes and then weighed to obtain W<sub>2</sub>. Total solid = W<sub>2</sub> – W<sub>1</sub> (total solid value in g/50ml)

### **DISSOLVED SOLID TEST**

This test was conducted by evaluating the values obtained from the suspended solid test and the total solid test.

Dissolved solid reported in mg/l is the amount of solid from the subtraction of suspended solid from total solid.

Dissolved solid = total solid – suspended solid

### **pH TEST**

This test was conducted in the laboratory using the pH meter. Measurement of pH is one of the most important of frequently used test in water chemistry. At a given temperature, pH indicates the intensity of acidic or basic character of a solution. It is done by instrumental analysis. The pH meter was dipped into the different water sample and their pH values were directly read. The pH values obtained for the various water samples is shown in table 7.

### **SLUMP TEST**

The slump test was conducted using the concrete of mix ratio 1:2:4 and 1:3:6.

The importance of slump test is to control the water content and to detect the variation in the uniformity of a mix of a given nominal proportion. The procedure as prescribed by BS 1881 part 102 was adopted and concrete cube prepared under standard condition. The slump test results are presented in tables 8 and 9.

### **COMPACTING FACTOR TEST**

This test was conducted after the slump test using the same paste. It was conducted using the compacting factor apparatus. This test measures the degree of compaction achieved by a standard amount of work. The degree of compaction called compacting factor is a density ratio. That is the ratio of the density actually achieved in the test (partially compacted) to the density of the same concrete when fully compacted.

Weight of the concrete falling from hoppers in cylinder + weight of cylinder =  $W_1$

Weight of fully compacted concrete + cylinder =  $W_2$

Weight of empty cylinder =  $W_3$

$$\text{Compacting factor} = \frac{W_1 - W_3}{W_2 - W_3}$$

Note that a compacting factor of 0.85 represents a mix of poor workability, 0.92 represents medium workability and 0.95 for good workability. Tables 10 and 11 shows the compacting factors for the mix ratios adopted.

### **COMPRESSIVE STRENGTH TEST**

This test was conducted using the crushing machine. It was done after curing the cubes for 28 days. The type of fracture was observed and noted. The compressive strength of concrete is a measure of its resistance to compressive force, it is influenced principally by the mix proportion, water cement ratio, effectiveness of curing and age of the concrete. This is perhaps the most important property of concrete since concrete resist compressive force better than any other type of stress, hence it forms the basis of this study. The compressive strength is often determined using concrete cube specimens of 150x150x150mm.

## **RESULTS AND DISCUSSIONS**

### **SUSPENDED SOLID TEST**

The suspended solid test indicates that stream water have the highest weight of suspended solid of 0.0037g compared with that of well and tap water. This is obvious because of discharge of solid waste into the streams/rivers.

### **TOTAL SOLID TEST**

The well water exhibited the highest content of total solid of 0.0067 Kg, closely followed by tap water. Table 3 in the appendix shows the detailed results obtained in this test. The total solid in the respective water samples are within tolerable limit of 0.02 percent by weight of mixing water [5,6]. This percentage will not have adverse effect on the properties of concrete.

### **pH VALUE TEST**

The acceptable maximum pH value of mixing water appropriate for concrete production lies between 6.5-9.2 [5,6]. The samples tested fell within this range. This means that all the water samples obtained from the sources are adequate for concrete casting. Table 5 in the appendix gives details of the results.

### **SLUMP TEST**

The slump tests indicates that well water produces concrete samples that exhibits true slump from both mix ratios. While the samples produced from stream and public water system gave shear slump and true slump for mix ratios 1:2:4 and 1:3:6 respectively. The results of the slump test is presented in table 6 of appendix.

### **COMPRESSIVE STRENGTH**

The compressive strength test results for concrete cubes produced from well water gives an average compressive strength of 34.22N/mm<sup>2</sup> and 16.30 N/mm<sup>2</sup> respectively for mix ratio 1:2:4 and 1:3:6 after 28days of curing. While that of samples produced from stream water shows an average compressive strength of 30.97N/mm<sup>2</sup> and 12.21N/mm<sup>2</sup> for the mix 1:2:4 and 1:3:6. The samples cast from the public water system gave an average compressive strength of 34.07N/mm<sup>2</sup> and 20.00N/mm<sup>2</sup> for the two mix ratio under consideration.

### **CONCLUSION**

The following conclusions have been drawn from this investigation. It was noted that the slump test conducted on the three samples using a mix ratio of 1:2:4 exhibited true slump for well water and shear slump for both stream and tap water. This showed that workability was low for well water while for stream water and tap water it was medium. The samples from well water are suitable for road, mass concrete foundation without or lightly reinforced sections with vibration or without vibration and samples from the stream and tap water are suitable for normal reinforced concrete manually compacted and heavily reinforced section with vibration. It was also noted that the slump test conducted on the three samples using a mix ratio of 1:3:6 exhibited no slump which showed that they all had a very low workability. The samples are suitable for roads with vibration. For the mix ratio of 1:2:4 well water had a slump of 47mm, stream water 75mm and tap water 92mm, while for the mix ratio 1:3:6 all the water samples had a zero slump.

From the experiment conducted, using the 1:2:4 mix ratio, the compacting factor of concrete form well water was 0.91, stream water 0.93 and tap water was 0.94. The compacting factor values are required for concrete road construction with vibration and it can be said to have low degree of workability for well water medium degree of workability for stream and tap water. From the four water quality test that were conducted viz: suspended solid test, total solid test, dissolved solid test, and pH test, it was noted that from BS 3145:1980 which suggest a tolerance of 10 percent to allow for chance variation in strength, that the water samples were adequate and good enough to use for concrete casting. From the result of the crushing of the concrete cubes cured for 28 days, it was seen from

using a mix ratio of 1:2:4, the variation of strength between the concrete cast with tap water and concrete cubes cast with well water had slight differences which was tolerable compared to concrete cast using steam water. Using a mix ratio of 1:3:6 also gives a similar result, so either well water or tap is good enough. It should be noted that water from different wells and streams would not have the same properties. The properties will be dependant on where the well or the stream is located, the type of rock and soil found in the area.

## RECOMMENDATIONS

The following recommendations are hereby made

1. For mixing concrete, a suitable mix ratio should be prepared with adequate workability test. This is to achieve the best workability to suit the required job the concrete is to be used for. The workability can be achieved through a slump test and compacting factor test as was done in this project.
2. On the best source of water among the three, the well water is highly recommended for use in the absence of portable drinking water.
3. The choice of any water and it's suitability should be determined using the tests outlined here in if the quality is doubtful.
4. The findings here in is applicable to Kaduna environ since ground water is dependent on the rock and soil type of the locality. This also varies from place to place.

## REFERENCES

1. Brady G. S., 1986 *Materials Hand Book*, McGraw-Hill, London, p. 126.
2. British Standards Institution, *Sampling and Testing of Mineral Aggregates, Sands and Fillers*, BS 812, London, 1975.
3. British Standards Institution, 1983: *Methods of Determination of Slump*, BS 1881, Part 102, London.
4. British Standards Institution, 1983 *Method for Determination of Compressive Strength of Concrete Cubes*, BS 1881, Part 116, London.
5. Gambir, M.L (2005); *Concrete Technology*, Tata McGrawHill publishing Co. Ltd.
6. Gambir M.L (1992) ; *Concrete Manual, Laboratory testing for quality control of concrete* 4<sup>th</sup> ed; Dhanpat Rai and Sons, Delhi.
7. Jackson N. (1991) *Civil Engineering Materials*, Macmillan Education Ltd, Hong Kong
8. Neville A. M.,(1995) *Cementitious Materials of Different Types*, Pearson Education Asia Pte. Ltd..
9. Neville A. M., (1996) *Properties of Concrete*, 4<sup>th</sup> ed., Pitman Publishing Company.
10. Neville A. M., (1999) "How useful is the Water Cement Ratio?" *Concrete international*, vol21, No 9, pp. 69-70.
11. Portland Cement Association. *Design and Control of concrete Mixtures*. Illinois: Shokie 1979.
12. Shetty M.S (2006). *Concrete Technology (Theory and practice)*, First Multi colour illustrative revised Edition 2005: Rajendra Ravindra Printers Ltd.
13. Taylor, W.H., (1977) *Concrete technology and Practice*, McGraw-Hill, Sydney.

**APPENDIX**

Table 2 : Suspended Solid Test Result

	Well Water	Stream Water	Tap Water
Initial Reading (g)	0.3483	0.3429	0.3400
Final Reading (g)	0.3622	0.3795	0.3400
Suspended Solid (g)	0.0139	0.0366	0.0000

Table 3: Total Solid Test Result

	Well Water	Stream Water	Tap Water
Initial Reading (g)	50.1161	52.1685	52.1728
Final Reading (g)	50.1228	52.1703	52.1734
Total Solid (g)	0.0067	0.0018	0.006

Table 4: Dissolved Solid Test Results

	Well Water	Stream Water	Tap Water
Total Solid (g)	0.0067	0.0018	0.0006
Suspended Solid (g)	0.0139	0.0366	0.0000
Dissolved Solid (g)	-0.0072	-0.0348	0.0006

Table 5: pH Test Result

PH	Well Water	Stream Water	Tap Water	Max Value
	5.4	7.8	7.2	6.5 – 9.2

**SLUMP TEST RESULT**

Table 6 : Slump test result for Mix Ratio 1:2:4 with water/ cement Ratio 0.65

	Well Water	Stream Water	Tap Water
Initial Height [mm]	300	300	300
Final Height [mm]	253	225	208
Slump [mm]	47	75	92
Type of Slump	True Slump	Shear Slump	Shear Slump
Workability	Low	Medium	Medium

Table 7 : Slump test result for Mix Ratio 1:3:6 with water/ cement Ratio 0.70

	Well Water	Stream Water	Tap Water
Initial Height [mm]	300	300	300
Final Height [mm]	300	300	300
Slump [mm]	0	0	0
Type of Slump	True Slump	True Slump	True Slump
Workability	Very low	Very low	Very low

### COMPACTING FACTOR TEST RESULT

Table 8: Compacting factor test result for Mix Ratio 1:2:4 with water/ cement Ratio 0.65

	Well Water	Stream Water	Tap Water
Weight of partially compacted concrete to fill cylinder [kg]	15.438	15.855	0.3400
Weight of compacted concrete to fill cylinder [kg]	17.028	17.041	17.040
Compacted factor	0.91	0.93	0.94
Workability	Low	Medium	Medium

Table 9: Compacting factor test result for Mix Ratio 1:3:6 with water/ cement Ratio 0.70

	Well Water	Stream Water	Tap Water
Weight of partially compacted concrete to fill cylinder [kg]	13.879	13.836	14.031
Weight of compacted concrete to fill cylinder [kg]	16.174	16.247	16.214
Compacted factor	0.86	0.85	0.87
Workability	Low	Low	Low

Table 10 : Compressive strength test result at 28 day (well water)

Cube Number	Mix Ratio	Mass of cube (g)	Density of cube [g/cm <sup>3</sup> ]	Load at Failure [KN]	Compressive Strength [Load] [Area] [N/MM <sup>2</sup> ]	Average Compressive strength [N/MM <sup>2</sup> ]
Z1	1:2:4	8200	2.43	760	33.78	34.22
Z2	1:2:4	8400	2.49	820	36.44	
Z3	1:2:4	8358	2.48	730	32.44	
U1	1:3:6	7842	2.32	200	11.56	16.30
U2	1:3:6	7896	2.34	220	12.44	
U3	1:3:6	7810	2.31	560	24.89	

Table 11 : Compressive strength test result at 28 day (stream water)

Cube Number	Mix Ratio	Mass of cube (g)	Density of cube [g/cm <sup>3</sup> ]	Load at Failure [KN]	Compressive Strength [Load] [Area] [N/MM <sup>2</sup> ]	Average Compressive strength [N/MM <sup>2</sup> ]
Y1	1:2:4	8375	2.48	690	30.67	30.97
Y2	1:2:4	7852	2.33	620	27.56	
Y3	1:2:4	8228	2.44	780	34.67	
V1	1:3:6	7875	2.33	260	11.56	12.21
V2	1:3:6	7733	2.29	280	12.44	
V3	1:3:6	7952	2.36	560	12.62	

Table 12 : Compressive strength test result at 28 day (Tap water)

Cube Number	Mix Ratio	Mass of cube (g)	Density of cube [g/cm <sup>3</sup> ]	Load at Failure [KN]	Compressive Strength [Load] [Area] [N/MM <sup>2</sup> ]	Average Compressive strength [N/MM <sup>2</sup> ]
W1	1:2:4	7500	2.22	590	26.22	34.07
W2	1:2:4	7547	2.24	600	26.67	
W3	1:2:4	7385	2.19	1110	49.33	
T1	1:3:6	7977	2.36	300	13.33	20.00
T2	1:3:6	7965	2.36	450	20.00	
T3	1:3:6	7925	2.35	600	26.67	