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Production of Concrete Using Contaminated Water and Its Effects on Compressive Strength of Concrete

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Abstract

In saline environment and places where there is no access to clean water for concrete work, contaminated water is often used for mixing and preparation of concrete for different structural members of buildings and this practice is in complete violation of most approved standard codes for concrete production. This study is aimed at determining effects of the use of salt contaminated water on compressive strength of concrete with a view to providing mitigating measures. 150 mm cube samples were cast with these water samples. Compressive strength test was carried out on the cubes. Findings revealed that for potable water, the initial strength was retarded in the first 7 days, uniformly progresses through 14 days, 21 days until the 28 days. In the case of contamination of 1000 mg/litre, concrete strength follows the same trend as the control. As the quantity of contaminated salt increases after this stage, the compressive strength generally decreases. It was further observed that the contamination effects were not pronounced on the strength within the first 7 days. According to the 28 day compressive strength ranged from 23.26 to 15.78 N/mm^2 as the concentration of contaminant (NaCl) in concrete mixing water ranged from 0 to 5000 mg/l. The study therefore concludes that the salt contaminated water have adverse effect on the properties of concrete. The use of salt contaminated water for concrete mixing is seen to favorable for strength development only at 4000 and 5000 mg dosages at early ages and reduction in long term strength.

Keywords: chloride, compressive strength, concrete, contaminated water, salt solution

Introduction

Concrete is one of the major building materials use in modern day construction. It is a composite construction material composed of 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 (Akinkurolere *et al.*, 2007; Ajamu *et al.*, 2018; Olaoye *et al.*, 2018). Concrete is used for numerous purposes in construction such as construction of buildings, dams, foundations, highways, parking structures, pipes, poles among others (Matthias, 2010). According to Olugbenga (2014), 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 cementitious 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 the structural element (Olugbenga, 2014).

Cement play a crucial role in concrete mixtures. Other ingredients namely, water and aggregate are natural materials and can vary to any extent in many of their properties (Rakesh and Dubey, 2014). The depth and range of studies that are required to be made in respect of aggregates to understand their widely varying effects and influence on the properties of concrete cannot be underrated. Cement is an extremely ground material having adhesive and cohesive properties which provide a binding medium for the discrete ingredients. Cement generally represent 12-14% of concrete weight and it plays an active part in the mixture (Rakesh and Dubey, 2014). During the hardening process, it generates shrinkage and heat dissipation phenomena which lead to material cracking (Rakesh and Dubey, 2014).

Rakesh *et al.* (2014) showed that water is a vital ingredient of concrete as it actively participates in the chemical reaction with cement, it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. 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). Seawater is water gotten from sea, which is salty in taste. Sea water can be said to have a solution containing a great number of elements in different proportions. Primarily sea water contains some chemical constituent such as ions of chloride, magnesium, calcium and potassium (Akinkurolere *et al.*, 2007; Gopal, 2010). Compressive strength of concrete is influenced by age, type of material, and the process of curing, water cement ratio, size of aggregate, type of aggregate, and some other parameters (Abdullahi, 2012; Bamigboye *et al.*, 2015). Emphasis is given to the parameters of the coarse aggregate size and its impact on the strength and workability of concrete.

A difference of compressive strength is measured on 28th day of curing. Up to 10% of the controlled test is adequate to measure the quality of the mixing water. According to IS: 456-2000, a difference in the initial setting time by a value +/-30 minutes, given that the initial setting time is not less than 30 minutes is prescribed. Concrete is affected by the effluents that are expelled out from the sewerage works, sugar and the fertilizer industry, paint, gas works, and textile industries. Various tests have shown that the usage of water or structure that are constructed near to a water body with the excessive amount of salts (dissolved salts) tend to decrease the compressive strength of the concrete by an amount of 10 to 30%. This decrease is the strength of concrete compared with that obtained by the concrete using distilled water. The high content of chlorides in water tends to show surface efflorescence, dampness persistently and makes the reinforcement steel prone to corrosion. This problem in concrete structures due to water quality problems is more severe in the tropical regions, mostly in that mix that is lean (Mandar and Deshmukh, 2019). This study is aimed at determining effects of the use of salt contaminated water on compressive strength of concrete with a view to providing mitigating measures.

Materials and Method

The methods adopted in this research were field work and laboratory tests. The field work comprised of major processes in the preparation of concrete while the laboratory tests were conducted on the concrete materials and the hardened concrete.

i. Cement: Ordinary Portland cement, Lafarge (Elephant) cement brand was obtained in bags of 50kg sizes.

ii. Fine aggregate: sand of medium size and was obtained in tons from Julius Berger -dredged sand at Lekki, Lagos.
iii. Coarse aggregate: crushed stone of one inch sizes obtained from the RCC Quarry along Lagos-Ibadan Express Way.
iv. Water: distilled water that has no taste (palatable), colour, odour or any impurity on one part for the control experiment; and the other part was chloride-contaminated.
v. Contaminants: The contaminants were Sodium Chloride (NaCl) salt. This was in various concentrations of 0, 1000, 2000, 3000, 4000 and 5000mg/l of water.

The Equipment used for the research include weighing balance, measuring tape, set of British Standard sieves, lubricating oil, head pans, shovels, hand trowels, 150mm x 150mm x 150mm steel moulds, tapping rods, curing tank and the Compressive Strength Machine.

Physico-chemical analysis of water

The physico-chemical analysis was performed on tap water from the structural laboratory LAUTECH and salt contaminated water in order to determine their physical properties and chemical constituents.

Laboratory test on the concrete materials

The Particle size distribution analysis test was carried out in accordance to BS 4110:1986, to determine the particle size distribution of the aggregate sample. The sets of sieves to be arranged in descending order of sieve sizes mounted on a sieve shaker which to be operated by electrical power (Figure 1). The percentages of soil sample passing through and retained each sieve were calculated using the expression in Equation 1 and 2, respectively.

$$\% \text{ passing} = \frac{\text{Total weight} - \text{weight retained}}{\text{Total weight}} \text{ x } 100\% \qquad (1)$$

$$\% \text{ retained} = \frac{\text{weight retained}}{\text{Total weight}} \text{ x } 100\% \qquad (2)$$

Further analysis of cumulative percentage passing, coefficient of uniformity and coefficient of curvature were calculated and the result to be used to classify the soil.

Concrete mix proportion and specimens preparation

Batching of concrete constituents was done by volume because of the small quantity of concrete operation that will be involved. The mix ratio was 1:2:4 to achieve a grade 20 concrete. That is, 1 head pan of cement, 2 head pans of fine aggregate (sharp sand), and 4 head pans of crushed stones (25 mm size). Weighing was carried out during sieve analysis to weighed the both fine and coarse aggregates and for compressive strength test to determine the weight for the concrete cubes after removed from the water tank which were carried out with the aid of weighing Balance (as shown in Figure 2). Mixing was done manually as high efficiency could be achieved due to the small volume of concrete under consideration. The sand and cement were thoroughly dry-mixed before adding the granite.

Figure 1: The set of Sieves employed in Particle Size Distribution Analysis

The mixing was in six different parts though with same mix ratio. Lubricating oil was applied on the inner surfaces of the moulds in order to ensure smooth surfaced concrete cubes. The first part of the mix was mixed with distilled water (devoid of any impurity), to serve as the control. The other five (5) parts were mixed with water contaminated with NaCl in the following respective proportions of 1000, 2000, 3000, 4000 and 5000 mg of salt per litre of water. Each of the parts was transported and placed into their respective moulds with hand-trowel (Figure 3). Since the distance from mixing point was closer and the volume of concrete was equally not much. The moulds were placed on paved area to avoid contact with soil or ground. Adequate water was applied to ensure workability of the concrete. Three (3) cubes each were cast from each of the six (6) parts, making a total of seventy-two (72) cubes. Compaction was carried out manually by gentle tapping with rod to allow even settlement of the fresh concrete in the moulds (Figure 4).

Plate 2: Weighing balance

Figure 3: Casting of the concrete cubes

Figure 4: Compaction of fresh concrete with tapping rod

Laboratory tests on the concrete the hardened concrete

Compressive Strength test was carried out by crushing of the concrete cubes. Three (3) concretes from each contaminated water samples was carried out with the Compression Machine (Figure 5) in the laboratory at 7 days, 14 days, 21 days and 28 days respectively after casting. This was be check the strength of concrete under the application of axial load. The parameters measured and recorded at every crushing day include cross sectional areas of the reinforced concrete, volume of the concrete, mass of the concrete and maximum crushing load (kN) from the machine. Compressive strength (N/mm²) was then calculated for each of the reinforced concrete. Separate results for each day of crushing to be recorded for the control and the respective salt Concentrations.

Figure 5: The Compressive Strength Machine

Results and Discussion

Physico-chemical properties of water

The physio-chemical properties of the contaminated water samples used in the research study are presented in Table 1. Physio-chemical analysis results showed that although the chemical compositions (chloride, nitrate, total suspended solid and sulphate) of contaminated water were much higher than those parameters found in tap water, the contaminated water compositions were within the ASTM and IS standard limits for all substance indicating that the salt contaminated water produced can be used satisfactorily in concrete mixtures.

Particle size distribution

The particle size distribution curves for fine aggregate and coarse aggregate are shown in Figure 6 and 7 respectively. The Figure shows the percentage of the sample passing through different sieve sizes in dry sample. For the fine aggregate, the co-efficient of uniformity (C_u) and co-efficient of curvature (Cc) are 4.11 and 1.09 respectively. For the coarse aggregate, the C_u and C_c are 4.10 and 1.01 respectively.

Table 1: Physio-chemical properties of contaminated water samples

Parameters	Contaminant's concentration (mg/l of water)						ASTM
	0mg/l	1000mg/l	2000mg/l	3000mgl	4000mg/l	5000mg/l	
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	-
TDS (mg/l)	0.95	1.84	6.52	1.00	1.00	1.00	-
EC (mg/l)	0.13	1.53	2.96	4.22	5.42	5.64	-
Salinity (mg/l)	0.00013	0.00153	0.00296	0.00422	0.00542	0.00564	-
Hardness (mg/l)	125	110	70	105	102	141	-
Chloride (mg/100ml)	34.33	36.00	36.03	38.78	52.86	53.47	1000
Nitrate (mg/100ml)	0.120	0.154	0.170	0.187	0.220	0.237	-
Calcium (mg/100ml)	62.50	54.80	34.10	52.45	50.29	69.70	-
Magnesium (mg/100ml)	61.90	55.10	34.58	52.54	51.01	70.51	-
Iron (mg/100ml)	1.750	1.907	0.510	1.130	0.820	0.975	-
Sulphate (mg/100ml)	0.095	0.227	0.195	0.160	0.183	0.175	3000
Potassium (mg/100ml)	1.711	1.641	1.616	1.605	1.271	1.318	-
Phosphate (mg/100ml)	0.347	0.367	0.363	0.362	0.353	0.355	-
TSS (mg/l)	0.11	0.21	0.42	0.24	0.14	0.15	50000
Acidity (mg/l)	325	170	90	125	260	180	-
Alkalinity (mg/l)	15	20	25	20	15	20	600

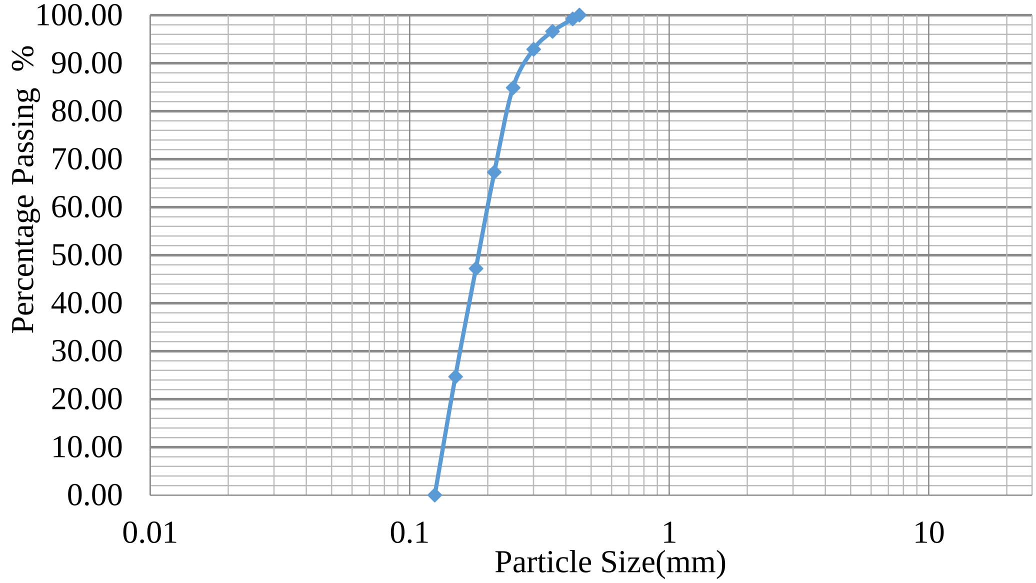

Figure 6: Sieve Analysis Graph of Fine Aggregate

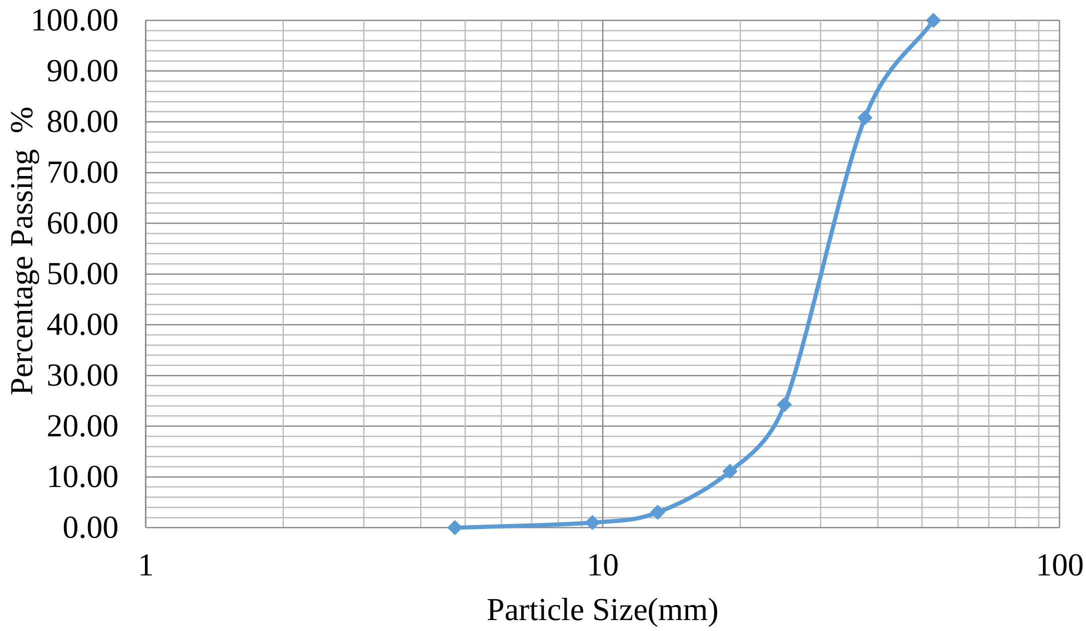

Figure 7: Sieve Analysis Graph of Coarse Aggregate

Compressive strength

The compressive strength results of the concrete with varying addition of contaminant (NaCl) at 7, 14, 21 and 28 days are presented in Figure 8. Compressive strength tests were carried out had varying indicative result as the salt concentration varies respectively. Compressive strength results as summarized on figure 8 shows that the chloride salt does not have appreciable effect on the concrete in the earlier age (up to 21 days), its negative effects were noticeable for 5000 mg dosage in the 28 days strength when there is a sharp decline from 21.85 to 15.78 N/mm^2. The result showed in Figure 8 corroborates this fact as well giving the

28 days strength of the strongest contamination as the weakest. It was generally observed that the higher the concentration of the contaminant (especially 4000 and 5000mg dosage) and with increase in age the lower the compressive strengths recorded. Because the high concentrations of some substances (chlorides) in the water.

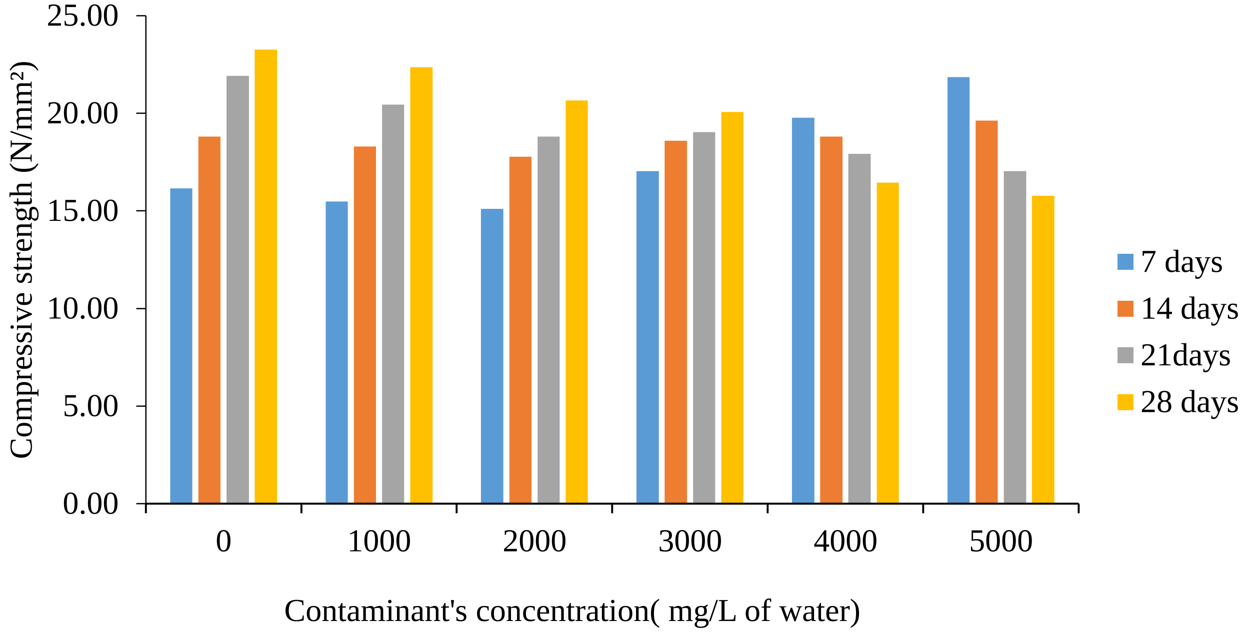

Figure 8: Cube compressive strength for high strength concrete at specified days curing

Conclusion and Recommendation

The following conclusions are drawn from this study:

i. The physio-chemical properties of the salt contaminated water of different concentrations (1000mg/l, to 5000mg/l) which are Chloride (36.00, 36.03, 38.78, 52.86, 53.47mg/100ml), Sulphate (0.227, 0.195, 0.160, 0.183, 0.175mg/100ml), Phosphate (0.367, 0.363, 0.362, 0.353, 0.355 mg/100ml), magnesium (55.10, 34.58, 52.54, 51.01, 70.51 mg/100ml), Nitrate (0.154, 0.170, 0.187, 0.220, 0.237 mg/100ml) etc. is generally higher than potable water such as chloride (34.33), sulphate (0.095), phosphate (0.347), magnesium (61.90), nitrate (0.120) etc., but fall within the standard limits specified in ASTM and IS. The high concentrations of some substances (chlorides) could tends to accelerate the setting of cement and to improve the strength of concrete in early stages.

ii. As the curing period increase the effects of contaminated water samples used on the compressive strength of concrete worsened. All the contaminated water may not have adverse effect on the properties of concrete. The use of salt contaminated water for concrete mixing is seen to favorable for strength development only at 4000 and 5000mg dosages at early ages and reduction in long term strength.

iii. It is recommended that the use of clean water is highly necessary for concrete mixes. Nevertheless, the source of water to be used in making concrete should be examined and approved by required authority prior to casting.

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