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The Influence of Salt Water on the Compressive Strength of Concrete

[1,2]O.O. Akinkurolere, [1]Cangru Jiang and [2]O.M. Shobola
[1]School of Civil Engineering and Architecture, Wuhan University of Technology, No. 205 Luoshi Road Wuchang, Wuhan 430070, Hubei, People Republic China
[2]Department of Civil Engineering, University of Ado-Ekiti, P.M.B. 5363, Ado-Ekiti, Ekiti State, Nigeria, West Africa

Abstract: This syudy is aimed at investigating the effect of sea water as mixing or curing water on concrete compressive strength. This paper therefore presents the result and findings of an experimental research on the influence of salt water from Lagos lagoon, in Nigeria on concrete compressive strength. In the research, concrete cubes were cast with fresh and salt water using a 150×150×150 mm mould and a mix ratio of 1:2:4 by weight of concrete 0.6 water-cement ratio were used. A total of 132 concrete cubes were made. Half of the cubes were made using fresh water and remaining half were made using salt water. They were cured in fresh and seawater respectively. The concrete cubes were tested for compressive strength at 7, 14, 21and 28 days. The compressive strength of concrete is shown to be increased by the presence of salt or ocean salt in the mixing and curing water. The rate of strength gain is also affected when the concrete is cast with fresh water and cured with salt water and vice-visa. Mixing concrete with salt water and curing with salt-water increases the compressive strength rapidly and the strength was still increasing at 28 days.

Key words: Sea water, comprehensive strength, concrete

INTRODUCTION

Concrete is one of the major building materials in all branches of modern construction. Concrete as a building and structural material is composed of three constituents namely; cement, water and aggregate, some times additional material, known as an admixture, is sometime added to modify certain of its properties which includes workability, consistency, uniformity etc. These constituent materials are a hardened binding medium or matrix formed by a chemical reaction between cement and water and the aggregates to which the hardened cement adheres to greater or lesser degree (Murdock and Brook, 1979). Cement is the chemically active constituent but its reactivity is only brought into effect on mixing with water. The cement generally used is hydraulic cement and usually Portland cements.

For this study we shall therefore focus on Portland cement. The compressive strength of concrete depends to a considerable extent upon the water content of the original mix. The strength is also affected by the water/cement ratio, aggregate properties and cement types. It also varies with other factors among which are age, condition of curing, and quality of materials. If concrete is kept moist its strength increases almost indefinitely, although the rate of increase is very slow after the first few weeks.

When planning and erecting concrete structures, one of the factors to be considered is the attack on the concrete by chemical substances (Grube and Rechenbey 1989). The durability of concrete is generally regarded as its ability to resist the effects and influences of the environment while performing its desired function (Hoff, 1991).

Salt water is the product of the sea. The primary chemical constituents of seawater are the ions of chloride, sodium, magnesium, calcium and potassium. The concentration of major salt constituents of seawater we are given in weight % of salt as: 78% NaCl, 10.5% $MgCl_2$, 5% $MgSO_4$, 3.9% $CaSO_4$, 2.3% K_2SO_4, 0.3% KBr. It evident from above that sodium chloride is by far the predominant salt component of seawater. NaCl and $MgCl_2$ total 88.5% of the entire salt content (Bela, 1989). Although, there are considerable differences in the salt concentration of seawater of different sources the relative abundance of the major constituents of seawater is about the same everywhere. Seawater is an adequate electrolyte and plays a major function in any electrolytic action between dissimilar metals and between salt concentration and steel (Bela, 1989). The pH of seawater varies between 7.4 and

Corresponding Author: O.O.Akinkurolere, School of Civil Engineering and Architecture, Wuhan University of Technology, No. 205 Luoshi Road Wuchang, Wuhan 430070, Hubei, People Republic China

Fig. 1: Diagrammatic representation of a reinforced concrete cylinder exposed to seawater (Mehta, 1980)

8.4. Corrosion of reinforcing steel occurs below a pH of 11, so the cement must supply alkalinity.

The effect on salt water on concrete has been a major problem associated with structures either built in salty water or cast using salt as mixing or curing water. The presence in sodium chloride in soft water accelerates the attack on other compounds on the concrete (Gani, 1997). Moreover in the early century it was realized that, although normally a very durable material concrete could deteriorate with frost and seawater been considered the principal agent causing deterioration of concrete structures. Cases of concrete that could not be attributed to one or other of these cases where left unexplained.

The chemical action of seawater on concrete is mainly due to attack by magnesium sulphate (MgSO4). The mode of the attack is crystallization. Potassium and magnesium sulphates K_2SO_4, $MgSO_4$ present in salt water can cause sulphate attack in concrete because they can initially react with calcium hydroxide ($Ca(OH)_2$) which is present in the set cement formed by the hydration of C_3S and C_2S as shown below.

$$K_2SO4.10H_2O + Ca(OH)_2 \rightarrow CaSO_4.2H_2O + 8H_2O + 2KOH$$
$$MgSO_4.10H_2O + Ca(OH)_2 \rightarrow CaSO_4.2H_20 + Mg(OH)_2 + 8H_20$$

The attack by magnesium sulphate is particularly damaging forming sparing soluble magnesium hydroxide which forces the above reaction to the right to form gypsum. MgSO4 will also react with the calcium sulphate (CSH) gel present in the set cement to form more gypsum (Swarmy, 1992).

Under certain environmental conditions, for example when one side of a retaining wall or slab of a permeable solid is in contact with a salt solution and other sides are subject to loss of moisture by evaporation, the material can deteriorate by stresses caused by crystallization of salts in the pores (Kumar Mehta and Monteiro, 2006). From investigation of masonry damage due to salt crystallization, Binda and Baronio (Bindal and Baronio, 1994) discussed the microclimatic conditions that influence whether or not any serious damage could occur. According to the authors, the extent of damage depends on the site of the salt crystallization, which is determined by a dynamic balance between the rate of evaporation of water from the exposed surface of the material and the rate of supply of salt solution to that site.

However, there is controversy over the use of seawater as mixing water. It increases the risk of corrosion of embedded reinforcing steel if the structure is to be exposed to air in service. The most damaging effect of seawater on concrete structures arises from the action of chlorides on the steel reinforcement and the build-up of salts. Sea water has been used on installation in Pacific Island where fresh water was unavailable. Under particular circumstances, for instance in the construction of unreinforced concrete bulkheads in a mine, highly contaminated water can be used. The risk of corrosion of steel limits the use of seawater in reinforces concrete and may prohibit its use in prestressed concrete. As illustrated by the diagrammatic representation of a reinforced concrete cylinder exposed to seawater in Fig. 1 below, the section that always remains above high the high-tide lines will be vulnerable to cracking and spalling, not only from frost action and steel corrosion but also from wet-dry cycles (Mehta, 1980). Where seawater has to be used in reinforced concrete structure, prior coating of the reinforcement with cement slurry made with fresh water provides greatly improved protection against corrosion. There are reports of cases where the structure was permanently submerged, but corrosion did not occur owing to the uniform salt content.

MATERIALS AND METHODS

Casting of concrete: Due to the controversy over the use of seawater as mixing water and the importance of proper mixing and curing of concrete the research will be carried in the following perspectives aimed at arriving at the single objective, which is to determine the influence of salt of sea water on the compressive strength of concrete. The four approaches are,

- Casting and curing the concrete using salt water.
- Casting and curing concrete using fresh water
- Casting with fresh water and curing with salt water
- Casting with salt water and curing with fresh water

Attention will be limited to two mixes of concrete i.e. casting a set of concrete cubes causing fresh water and casting another set of concrete cubes using salt water.

Half of cubes from the fresh water concrete cast will be cured in fresh water and the remaining half cured in salt water for 7, 14, 21, 28 days. Similar curing method will also be applied for the concrete cast with salt water under same curing days and environmental conditions. A total of 128 cubes were used. Table 1 below show the designations used for the concrete batches

RESULTS

Test of concrete compressive properties: After casting and demoulding, the salt water batches has a darker surface than the reference concrete when cured in salt water a deposit of salt formed on a specimens, with whitish appearance at bottom edges. The salt water (SS) batches have the most pronounced salt deposits. The results are presented in Table 2.

Seawater test results: The two properties of seawater tested for are chloride content and pH.

Table 1: Designations of concrete batches

Batch No	Batch Designation	Description	No of Replication
1	FF	Concrete cast with fresh water and cured in fresh water	32
2	SS	Concreter cast with salt water and cured in salt water	32
3	FS	Concrete cast with fresh water and cured in salt water	32
4	SF	Concrete cast with salt water and cured in fresh water	32

Table 2: Compressive strength of concrete cubes

Test conditions	Days of curing	Average weight of cube (Kg)	Average applied load (N x 10^3)	Compressive stress (N mm^{-2})
FF	7	8.45	272.5	12.11
	14	8.58	315	14.00
	21	8.80	354.5	15.76
	28	9.05	449	19.96
FS	7	8.40	289.50	12.87
	14	8.68	325.50	14.47
	21	8.80	294.00	13.07
	28	8.85	420.50	18.69
SS	7	8.60	312	13.86
	14	8.75	403	17.91
	21	9.00	446.5	19.84
	28	9.20	492.5	21.89
SF	7	8.53	315.5	14.02
	14	8.75	360	16.00
	21	8.65	382.5	17.00
	28	8.95	458	20.36

Table 3: Chloride contents

Readings	Sample A	Sample B	Sample C
Final readings	131.50	131.70	131.60
Initial readings	0.00	0.00	0.00
$AgNO_3$ added	131.50	131.70	131.60

Chloride content: The result of the experiment is as shown in Table 3.

Average titre value = (131.50 + 131.70 + 131.60)/3 = 131.60 less blank 0.2

Chloride content in seawater (mg L^{-1})

$$= \frac{\text{Titre value x Molarity of AgNO3 xMolecular weight of Cl x1000}}{\text{mL of sample used}}$$

$$= (131.60 \text{ x } 0.01 \text{ x} 35.5 \text{ x } 1000)\ 5 = 9343.60 \text{ mg L}^{-1}$$

pH result: The result of the pH is as shown below
pH meter reading

First reading	7.46
Second reading	7.54
Third reading	7.26
Average pH meter reading	= (7.06 + 7.04 + 6.59)/3
pH of seawater is	7.42

DISCUSSION

The shown by the results Table 2 above, there was an appreciable increase and early strength gain in the SS, SF and FS batches respectively as compared with the control batches which has a lower strength at the early stage. The rate of the strength gain in control batches is slow, as compared with the SS batches, which at 7 days has attained 64.78% of its final compressive strength.

At 14th day, all the batches still recorded an increase in strength. The rate of the increase in FF, SS, SF batches is higher than that of FS batches. At 21 days the rate of strength gained was still increasing proportionally as compared with the control batches. There is also and appreciable strength gain for the SF batches. There is a slight decrease in strength gain in FS batches due to the failure of one of the test cubes replicas.

At 28 days, the rate of strength gain is still increasing in all the batches. The control batches also recorded its maximum strength at 28 days. Although, the comprehensive strength of the SS batches was higher than that of the control batches (FF) at 28 days.

Another points worth of note are the magnitude of the strength gain in the SS and SF bathes at 28 days and the fact that the strength appear to be still increasing. There are clearly some complex chemical mechanisms involved here. Though the surprise at results was that so many previous investigators have reported the deleterious effect. However, it is very difficult to explain the large increase observed for the use of salt water for curing since this can barely penetrate the concrete in the 28 days period.

CONCLUSION

Concrete cast with salt water and cured with in salt water (SS) increases the 28 days compressive strength dramatically and linearly beyond that obtained in the (FF) control cast. The concrete batches cast with fresh water and cured in freshwater increases in strength in a gradual manner and the results quite agrees with the value of the compressive strength of 1:2:4 mix at 28 days, which as about 20N/mm^2.

Batches cast with salt water and cured in freshwater increases in strength even at 28 days. The fresh-fresh water situations are mainly present in building constructed on interlands and main lands. Fresh-salt water situation are mainly present in building or structures close to lagoon or sea.

The salt-fresh water situation is well pronounced in areas were fresh water is scarce or the available surface water is salty. This case is very rare in practice.

The salt-salt water situation is mostly visible in structures built in the ocean or sea, these types of structures are very common in Lagos, Nigeria because of proximity to lagoon.

The result for SS batches has shown that the strength of concrete cast in salt water and cured in salt water increases in strength which corresponds with previous studies results (Michael and Adam Kuwairi, 1978). The use of salt water for casting and curing mass concrete should not be feared but welcome.

In the case of reinforced concrete, the reinforced bar should be protected by painting or coating it with cement slurry made with fresh water which greatly improve protection against corrosion. Another solution is to double the wall thickness that will give the desired life (Neville, 1987).

Further research is needed to investigate the basic mechanism involved to investigate the strength at different curing stages beyond 28 days and to investigate the effects of salt upon the other important characteristics of concrete such as shrinkages, creep e.t.c.

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