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Effects of Varying Concentrations of Chloride (Sodium Chloride) on the Compressive Strength of Laterized Concrete

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Abstract : Compressive strength, one of the important characteristics of concrete can be influenced by different foreign materials present in the constituents of the concrete. This paper demonstrates the influence of sodium chloride (NaCl) on compressive strength of Laterised Concrete (LATCON). Several studies have established the effect of sea water on concrete strength but none of the study has categorically specified the level of concentration at which the strength is defective. This study bridge the gap by examining the variation of concrete compressive strength at different levels of concentrations of salt in the curing bath. The study used LATCON being a cost effective concrete. 72 concrete cubes were produced using 1:2:4 mix ratio with laterite as a fine aggregate. The cubes were cured in NaCl solution of varying concentrations from 0g/l to 50g/l at 10g/l intervals. The compressive strength of the laterized concretes was determined after 7, 14, 21 and 28 days. The results showed that compressive strength of the concrete increase with increase in curing age. The strength also increases with increase in salt concentration in the curing bath, upto 30g/l salt concentration and then starts to decrease. The study thus reveals that NaCl could have a deteriorative effect on the compressive strength of LATCON at higher concentrations. However, this does not pose a major threat if the concrete would be used as a lightweight concrete.

Keywords: Compressive strength, Concentration, Laterized Concrete (LATCON), Light weight, Salt, Sodium Chloride.

I. INTRODUCTION

Several civil engineering structures' failure can be attributed to failure of concrete portion of the structure. Concrete failure usually occurs when there is a reduction in the compressive strength of concrete with time. This strength can be influenced by foreign materials present in its constituents during mixture [1], [2], [3]. The strength can also fail the test of time if the concrete is attacked by chemicals [4]. Compressive strength is one of the major characteristics to be ascertained before it is considered suitable for any engineering work. Therefore, it has been a major concern in research industry to bring to knowledge those foreign materials that could influence the strength. This study is an effort towards establishing the effect of NaCl on the strength if it is present in curing water. The study was patterned to suite situation where a Laterized Concrete (LATCON) is used in a seawater (saline) environment with a significant concentration of sodium chloride (NaCl) salt [1]. It also establishes the possible effect of varying concentrations of the salt on the compressive strength of the concrete. This is not to replicate what has been done but to establish the variation of concrete compressive strength with respect to different salt concentrations' level in curing water. Many researchers have established that sea water is dominated with sodium chloride and that it has effect on compressive strength of concrete [1], [5]. Falah [5] established in his study on the effects of sea water for mixing and curing on structural concrete that there are increases of strengths of concrete mixed and cured in sea water at early ages and a definite decrease for ages more than 28 days and up to 90 days. According to [6], concrete cast with sea water and cured with sea water increases the 28 days compressive strength drastically and linearly beyond when compared with concrete cast in fresh water and cured in fresh water. Preeti*et al* [7] also supported the work of [6] by establishing that compressive strength of concrete of grade-30 has a marginal increase in the strength of cubes cast and cured in salt water as compared to those cast and cured in fresh water at all ages of curing.It was submitted that salt water does not has any effect on the strength of concrete cast and cured with salt water. Kucche [2] also buttressed this that water from stream, river and sea is suitable for concrete casting peradventure it does not contain brackish matter. Tarek [8] likewise established that seawater-mixed concrete shows earlier strength gain compared to the tap water-mixed concrete. Although, after a long-term of exposure, there seems to be no significant difference in compressive strength. Swati and Ashutosh [1] in their study likewise discovered that there was an increase in the compressive strength of concrete cast and cured in sea

water at early ages as compared to the concrete cubes cast and cured with potable water. The strength increases by 4-6% at 7 days and 9-11% at 14 days. It was further established that the strength decreases by about 1-4% at 28 days. It was noticed that none of these studies account for the exact concentration of the salt that affect the strength of the concrete. This study therefore examines this by varying the concentration of salt present in curing water. The research makes use of potable water for casting and salt water for curing.

Laterite was considered as fine aggregate being locally available and an environmentally active material that is under investigation as a viable material in the production of low-cost construction material [9], [10], [11], [12], [13]. Also, the unique nature of laterite, vis-a-vis its varying engineering behaviour in different environment, and the consideration of an increasing attention being given to the use of LATCON for construction works especially road (interlocking stone pavement). The study therefore seeks to determine the effects of sodium chloride on the compressive strength of laterized concrete.

II. MATERIALS AND METHODS

The materials used for this study were cement, laterite (fine aggregate), ¾" granite (coarse aggregate), cement (hydraulic binder) and water.

Lateritic soil sample used for the production of cubes used for this study was obtained from a borrow pit at Ibadan, Lagelu Local Government Area of Oyo State, South Western Nigeria. The granite was obtained from a construction site within the campus (University of Ibadan, Oyo State, South Western, Nigeria). The materials (laterite and granite) were air dried in the laboratory. The coarse aggregate (granite chippings) was passed through sets of sieves, the portion passing through sieve (20mm) and retained on sieve (5mm) was used. The laterite used in the experiments was those passing sieve (2mm) and retained on sieve (150µm). Sample of the laterite soil used for the work was subjected to Atterberg limit test to ascertain the clay content in the sample. The test was carried out according to [14].

Ordinary Portland Cement (OPC) conforming to BS12 was used as hydraulic binder of the fine and coarse aggregates. Dangote (52.5R) brand of ordinary Portland cement sold was used in this research. The cement was ensured protected from dampness to avoid lumps.

Potable water used for casting was obtained directly from the tap in the materials laboratory.

2.1 Specimen Preparation

Seventy two (72) concrete cubes of size 150mm x150mm x150mm were produced using mix ratio 1:2:4.The batching was done by weighing the different constituent materials based on the adopted mix ratio. The process of concrete cube production includes mixing of the concrete constituents together thoroughly, adding of water and subsequent mixing together to produce a workable mixture and filling of the concrete into moulds in approximately 50mm layers with each layer given 35 strokes of the tamping rod. The concrete was trowelled off level with the top of the mould and the specimen stored under damp sacking for 24hours in the laboratory before de-moulding and storing in water for the required curing age.

2.2 Curing and Compressive strength determination

The cubes were cured in curing bath with NaCl solution of concentration ranges from 0g/l-50g/l at interval of 10g/l. Three (3) cubes each were cured for 7, 14, 21 and 28days for compressive strength test respectively. The compressive strength was determined at respective curing age using compression testing machine. Average crushing strength was calculated and the compressive strength was subsequently determined.

III. RESULTS AND DISCUSSION

The results of the geotechnical tests on the lateritic soil and the compressive strength of the concrete cubes are presented and discussed in this section.

3.1 Suitability of Fine Aggregate (Laterite) for Concrete Production

Atterberg limit test was carried out on the lateritic soil sample used for this study to establish its suitability for concrete production. The result of the test comprising liquid limit, plastic limit and plasticity index of the sample is presented in Table 1 and Fig. 1. The test revealed a liquid limit and plasticity index values of 31 % and11% respectively. This shows that the lateritic soil is of intermediate plasticity [15], [16]. The plastic limit (PL) value of 20% obtained classified the laterite sample as A-2-4 soil group material. The value also indicates that the clay content of the sample is within the range considerable for concrete work [17].

Table 1
Result of Atterberg Limit Test

Atterberg Limits	**Value (%)**
Liquid Limit	31
Plastic Limit	20.13
Plasticity Index	10.87

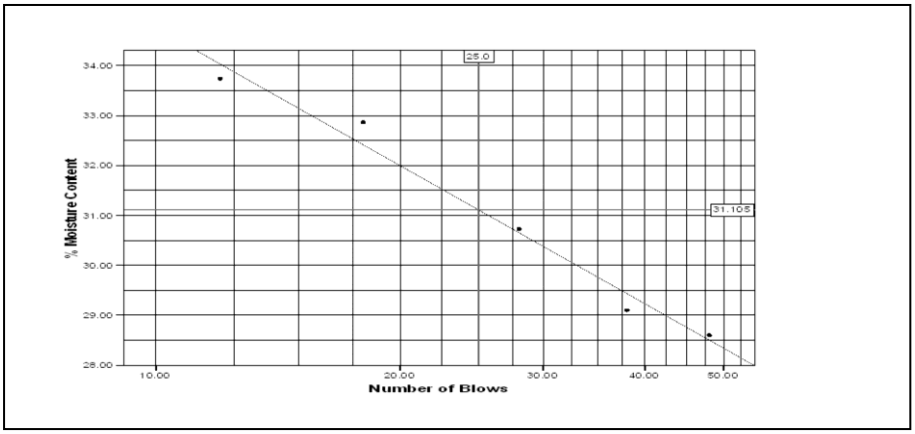

Fig.1:Liquid Limit Chart

3.2 Compressive Strength Test

Table 2 presents the results of compressive strength (N/mm^2) obtained for the 7, 14, 21 and 28 curing days at varying concentrations of NaCl. The compressive strength of the cubes cured in the solution of 0g/lNaCl concentration ranges from 9.78 to 18.47N/mm^2 within 7 to 28days of curing. The strength at 10g/l, 20g/l, and 30g/l salt concentrations range from 10.90 -15.21N/mm^2, 10.22-15.78N/mm^2 and 10.44-16.41N/mm^2 respectively. At concentration of 40g/l and 50g/l, the strength range from 10.00-11.94N/mm^2 and 10.00-11.83N/mm^2 respectively. The result was further represented using graph presented in Fig. 2 and 3. Fig. 2 shows that the strength first dropped between 0g/l and 10g/l with exception to the strength at 7days curing age. The strength picked up again at 20g/l. Fig. 3 indicates that the control (0g/l LATCON) gave the highest compressive strength which is significantly increasing with increase in curing age. This trend is the same for other concentrations. The strength also increases with increase in NaCl concentration in the curing bath up to 30g/l although it is insignificant. It changes at 40g/l concentration when a decrease in the compressive strength began to set in (Fig.2). On the other hand, the rate at which the concrete gained the strength as concentration increases is smaller compared to the strength gained with increase in the curing age.

Table 2
Variation of Compressive Strength of Laterized
Concrete with Sodium Chloride and Curing Age

Concentration of NaCl Solution (g/l)	**Curing Age (Days)/Compressive strength (N/mm^2)**			
	7	**14**	**21**	**28**
0	9.78	12.00	14.03	18.47
10	10.90	11.11	11.48	15.21
20	10.22	11.25	11.67	15.78
30	10.44	12.44	14.67	16.41

40	10.00	10.89	11.78	11.94
50	10.00	10.55	11.63	11.83
Grade 21 Concrete	15.00	18.00	21.00	22.00

The result obtained further indicates a positive linear relationship between the compressive strength of the cubes and the curing age (Fig.3) while the relationship between the strength and concentration of salt in the curing solution is negative linear relationship (Fig. 2). This establishes that the compressive strength of the cubes increases with increase in curing days but decreases with increase in the concentration of the salt in the curing solution. Generally, findings of some researchers ascertained that salt water either in casting or curing concrete increases the compressive strength of concrete [2], [3], [6]. This study established thatthe behavior changed at higher concentration. The strength reduced with increase in concentration of NaCl. This is in support of the finding of [3].

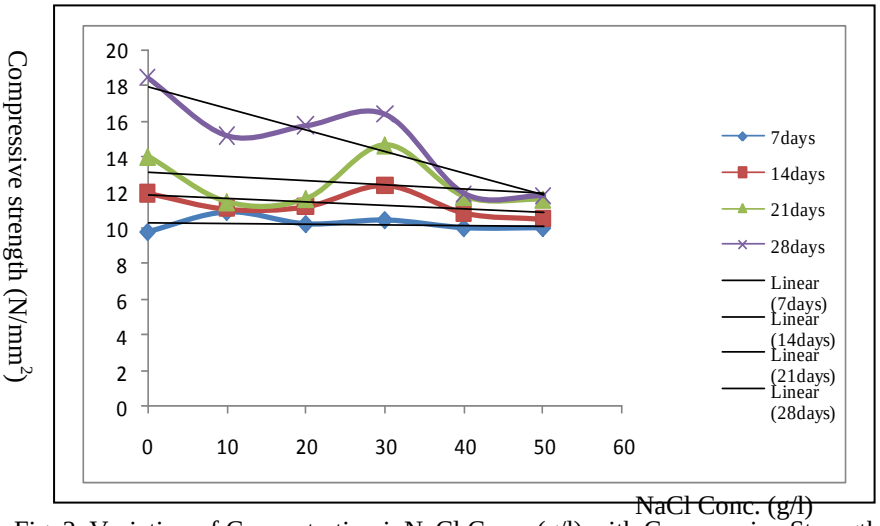

Fig. 2. Variation of Concentration inNaCl Conc. (g/l) with Compressive Strength (N/mm^2)

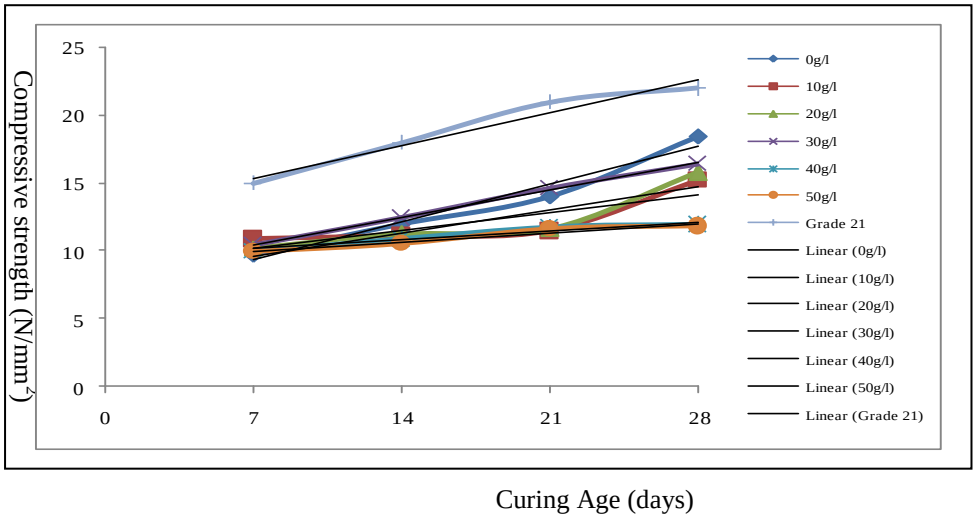

Fig.3: Variation of Compressive Strength (N/mm^2)with Curing age (days)

The figure further shows that change in the compressive strength of LATCON with respect to the length of curing days is in agreement with the findings of [18] who observed an irregularbehaviour of compressive strength of LATCON cured in clean water up to a period of 80 days before a decline was consistently noticed.

The comparison of the strength obtained with conventional grade 21 concrete at 28days (Table 2) shows that LATCON has lower strength than the allowable values of grade 21 concrete but fall within the range of characteristic strength of 7N/mm^2 to 14N/mm^2 as recommended by [19] for lightweight concretes.

IV. CONCLUSION AND RECOMMENDATIONS

In recent times, building collapse has become a thing of concern in our society. These collapses can be attributed to many factors. Among this is inability of concrete portion of the structure to perform the intended role due to the failure of its strength. A concrete starts to fail when the compressive strength of the concrete begins to drop in value. The reduction in this compressive strength can be attributed to many factors. Among these is exposure of concrete to foreign materials which could attack it and subsequently lead to its failure. This research work provides a solution; to identify the effect of varying concentrations of NaCl on the compressive strength of concrete. The following conclusions are drawn from the study:

1. Compressive strength of a concrete cast with potable water and cured in water of varying concentrations of salt increase with curing days but reduce with increase in concentration of salt in the curing water.
2. There is an irregular pattern in the compressive strength in relation to change in NaCl concentration.
3. Sodium Chloride at 10g/l, 20g/l, 30g/l, 40g/l and 50g/l concentrations has a deteriorating effect on the compressive strength of LATCON. The effect increased with increase in the level of concentration.
4. Considering the strength obtained the concrete can nevertheless be used as a lightweight concrete for construction of building structural members.

Based on the findings made in this study it is recommended that:

1. Further study should be conducted to consider concentration within one digit number (1-9g/l) and curing age beyond 28days.
2. Study should be made on component that can be introduced into the concrete to ameliorate or negate the effect of salt at higher concentrations.
3. Further study should also be extended to ascertain concrete strength behavior vis-à-vis concrete (i) cast with salt water and cure in salt water, (ii) cast with salt water and cure in fresh water.

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