STRENGTH ASSESSMENT OF CONCRETE SUBJECTED TO ALKALINE MEDIA

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ABSTRACT

The aim of any structural design is to achieve an acceptable probability that structures being designed will perform satisfactorily during their intended life with an appropriate degree of safety. They should sustain all loads and deformation of normal construction and use, and have adequate durability and resistance to the effect of misuse.

The durability of concrete can be defined as its resistance to deterioration resulting from external and internal causes. The external causes include the effects of environmental and service conditions to which concrete is subjected, such as weathering, chemical actions and wear. The internal causes are the effect of interaction between the constituent materials such as alkali aggregate reaction, volume change, absorption and permeability.

This research work is to assess the structural strength of concrete cubes cured in varying concentration of a number of alkali solutions. Two grades of concrete, 30 and 40 were used. The concrete cubes were cured in aqueous solutions of Sodium hydroxide (NaOH), Potassium hydroxide (KOH) and Calcium hydroxide ($Ca(OH)_2$) of 20, 40, 60 and 80 percent concentrations. Compressive strength test was conducted on the cubes at the end of 7, 14 and 28 days immersion period.

The compressive strength of concrete cubes immersed in water (control cubes) increased steadily from 30.96 N/mm^2 to 35.26 N/mm^2 at the end of 28 days of immersion for grade 30 concrete and from 40.07 N/mm^2 to 42.52 N/mm^2 at the end of 28 days of immersion for grade 40 concrete Generally, the compressive strength increased steadily for cubes in 0 percent concentration of alkali solution up to 40 percent concentration of alkali solution beyond which it started falling, irrespective of the immersion periods for the two grades of concrete.

The influence of alkaline media on concrete is such that the higher the grade of concrete, the more aggressive is the attack on the concrete.

1 INTRODUCTION

At the time when concrete was first used as a modern constructional material, and gradually became more popular, it was the general opinion that durability on concrete was by and large unlimited. Improvement of the strength characteristics of concrete was the main aim in the field of development, and it was realized only very slowly that the durability also had to be regarded as a separate characteristic of as great importance as the strength.

The deterioration of concrete can be related to internal factors, that is, the cause of damage observed may originate in concrete itself in its components or in processes taking place between these components. This may be quite independent of or only partly conditioned by the external factors. To the last category belong alkali-aggregate reaction or alkali-silica reaction. Speculations and laboratory works may tend to emphasize the chemical aspect of deterioration of concrete exposed to seawater, while field experience repeatedly tend to emphasize that a main factor in the durability of such structure is a good initial quality of concrete. Therefore, the fundamental research should be directed towards thorough investigation of those extra-ordinary conditions under which good quality of concrete has proved not to be a sufficient guard against deterioration.

Alkali-Silica reactions can be characterized in brief as follows: In concrete, a chemical reaction takes place between alkalis and reactive silica in moist conditions, The alkalis taking part in the process are sodium and potassium hydroxides, which most frequently originate in the cement but which can also be supplied by the surroundings. The reactive silica is silica in amorphous or low crystalline phase and may occur as minerals. An important contribution to the processes and mechanism of alkali-silica reaction has been made by Power and Steinour[1,2]

2 EXPERIMENTAL PROCEDURE

(i) Specimen preparation

Two grades of concrete 30 and 40 used in this research were determined through the process of a normal mix design for concrete. Batching was done by weight and mixing was achieved by using a laboratory batch mixer. 150mm x 150mm x 150mm cube moulds were used in casting the specimen. The cubes were compacted by electrically operated table vibrator to a density of 2435 kg/m^3 which was used during the mix design. The cubes (120 No. for each concrete grade) were cured in the water trough for 28 days.

(ii) Preparation of Alkáli media

The alkali/water proportions required for the various concentrations of alkalis was determined by calculation, and thereafter mixed volumetrically to achieve the desired percentages of concentrations of the alkalis.

(iii) Subjection of cubes to alkaline media

The cubes of the two grades of concrete were immersed in 0, 20,40,60 and 80 percent concentrations of sodium hydroxide, potassium hydroxide and calcium hydroxide. Three different immersion periods (7 days, 14 days and 28 days) were used.

(iv) Testing

At the end of the various Immersion periods (7 days, 14 days and 28 days), three concrete cubes for each of the grades of concrete were removed from each of the four different concentrations of the three different alkalis (NaOH, KOH and $Ca(OH)_2$). These cubes were thoroughly rinsed with tap water and air dried in the laboratory for 24 hours. They were weighed to determine their densities and later crushed. The average crushing load was taken as the compressive strength of the concrete after each immersion period.

3 RESULTS

The results were compiled, computed and summarized in Tables 1 and 2 below:

TABLE 1: COMPRESSIVE STRENGTH OF GRADE 30 CONCRETE AFTER IMMERSION IN THE VARIOUS ALKALI MEDIA

ALKALI CONCENTRATION	STRENGTH BEFORE IMMERSION (N/mm^2)	STRENGTH AFTER 7DAYS OF IMMERSION (N/mm^2)	STRENGTH AFTER 14DAYS OF IMMERSION (N/mm^2)	STRENGTH AFTER 28DAYS OF IMMERSION (N/mm^2)
0% (All alkalis)	30.96	32.29	33.93	35.26
20% NaOH	30.96	32.59	35.26	37.63
KOH	30.96	32.44	34.97	38.52
$Ca(OH)_2$	30.96	34.82	37.04	38.22
40% NaOH	30.96	33.04	37.63	37.93
KOH	30.96	32.89	35.26	38.67
$Ca(OH)_2$	30.96	36.44	38.89	40.00
60% NaOH	30.96	32.15	36.45	37.33
KOH	30.96	32.00	34.07	39.56
$Ca(OH)_2$	30.96	34.08	36.45	38.96
80% NaOH	30.96	31.41	34.66	36.89
KOH	30.96	31.26	32.59	38.67
$Ca(OH)_2$	30.96	33.63	36.15	38.52

TABLE 2: COMPRESSIVE STRENGTH OF GRADE 40 CONCRETE AFTER IMMERSION IN THE VARIOUS ALKALI MEDIA

ALKALI CONCEN-TRATION	STRENGTH BEFORE IMMERSION (N/mm^2)	STRENGTH AFTER 7DAYS OF IMMERSION (N/mm^2)	STRENGTH AFTER 14DAYS OF IMMERSION (N/mm^2)	STRENGTH AFTER 28DAYS OF IMMERSION (N/mm^2)
0% (All alkalis)	40.07	41.04	41.92	42.52
20% NaOH	40.07	41.18	42.07	42.82
KOH	40.07	41.19	42.08	43.11
$Ca(OH)_2$	40.07	41.18	42.22	42.81
40% NaOH	40.07	41.33	42.82	45.48
KOH	40.07	42.07	43.85	45.78
$Ca(OH)_2$	40.07	41.48	42.67	43.85
60% NaOH	40.07	40.59	41.93	40.00
KOH	40.07	40.89	42.22	46.67
$Ca(OH)_2$	40.07	40.44	41.03	42.96
80% NaOH	40.07	40.30	41.48	43.41
KOH	40.07	40.15	41.03	45.33
$Ca(OH)_2$	40.07	40.15	40.59	41.48

FIG.1: COMPRESSIVE STRENGTH VS CONCENTRATION

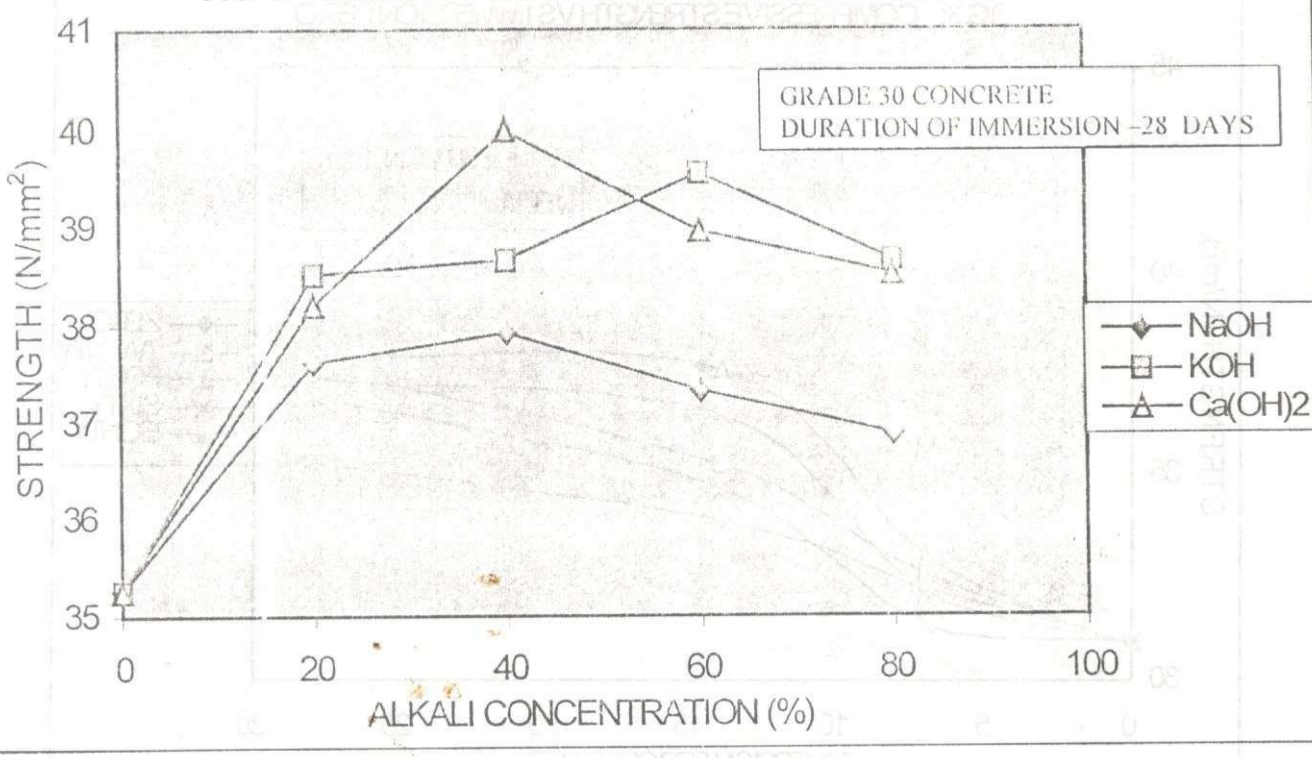


FIG.2: COMPRESSIVE STRENGTH VS CONCENTRATION

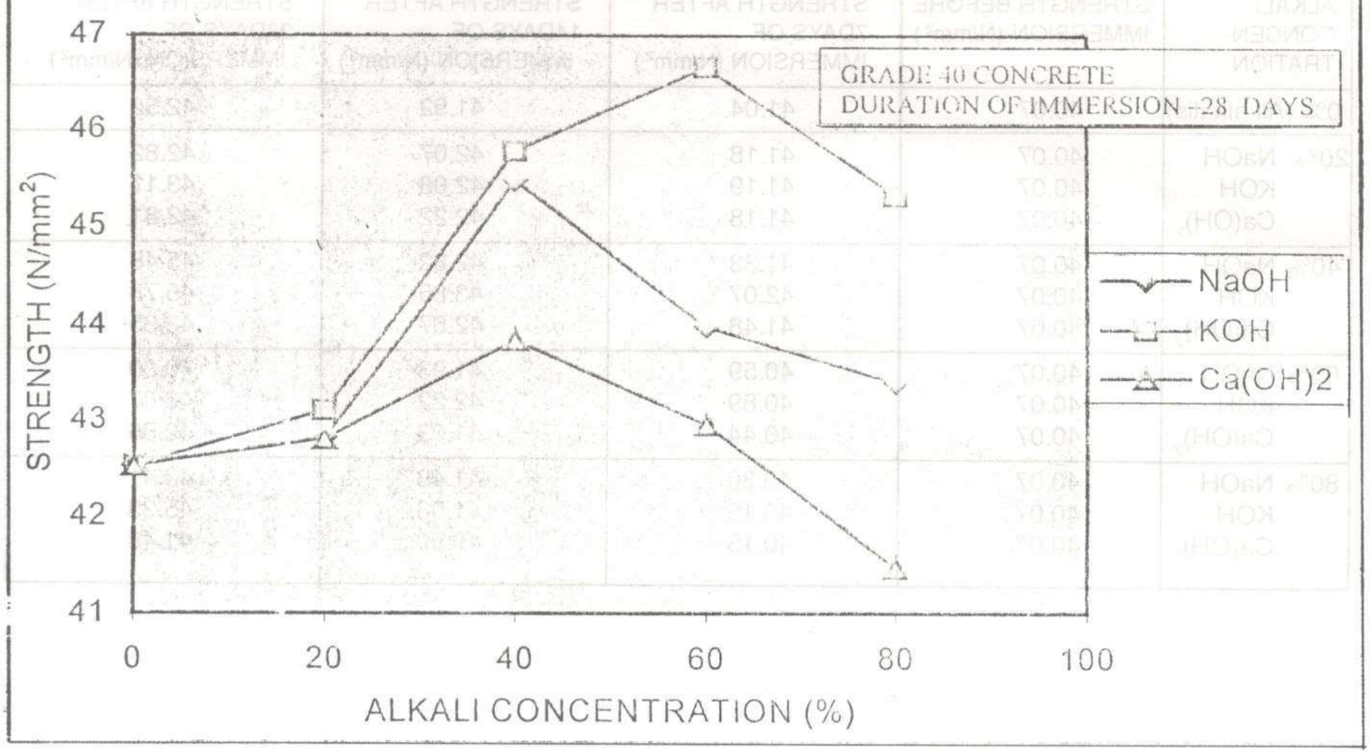


FIG.3: COMPRESSIVE STRENGTH VS IMMERSION PERIO

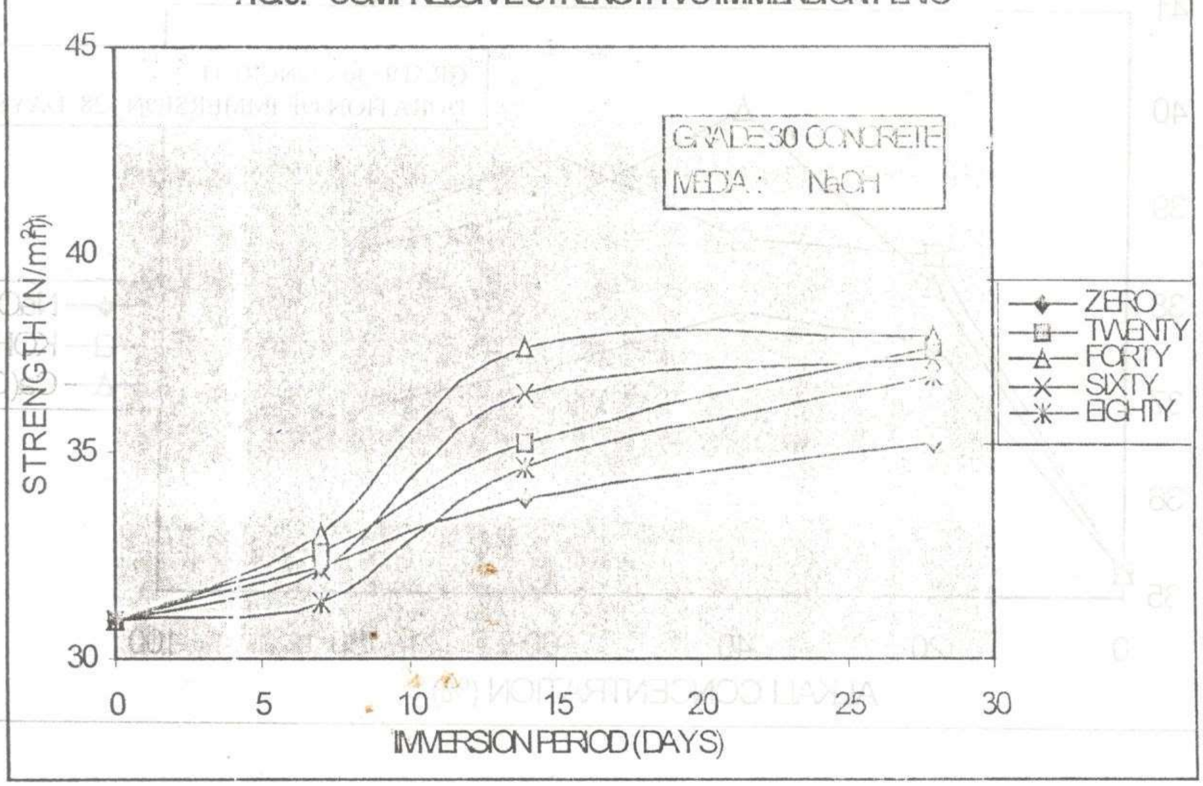
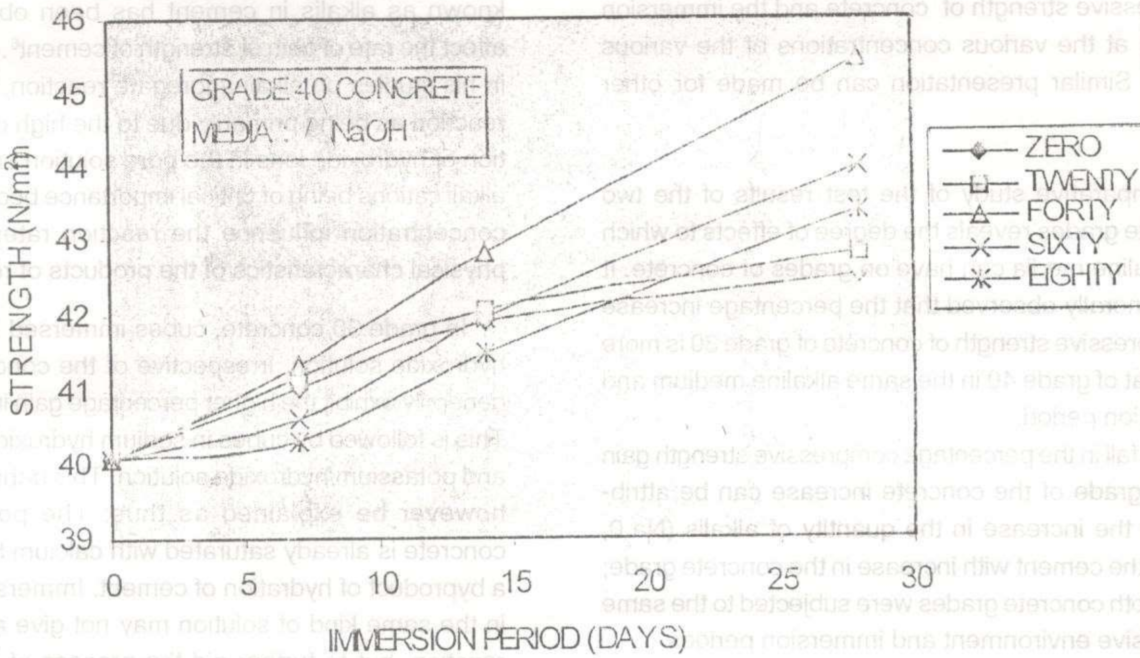


FIG.4: COMPRESSIVE STRENGTH VS IMMERSION PERIOD



ANALYSIS AND DISCUSSION OF RESULTS

The results of the laboratory work are analysed and discussed in this section. The 28 days mean compressive strength of grades 30 and 40 before immersion are 30.96 N/mm^2 and 40.07 N/mm^2. The test results of the effect of various concentrations of alkali (NaOH, KOH and $Ca(OH)_2$) on the compressive strength of concrete grades 30 and 40 are presented in Tables I and 2 for the various immersion periods. The results when plotted on graphs accordingly, are shown in figures 1 and 4 above (typical).

For all the alkalis used in this research work, It was observed that compressive strength of the cubes increased with increasing concentration of alkali up to a concentration of 40 percent beyond which further increase in the alkali concentration will result to fall in compressive strength (that is loss of strength). However, there is an exception in the compressive strength of cubes immersed in potassium hydroxide at the end of 28 days of immersion. Here, there is an increase in the compressive strength of the cubes up to 60 percent concentration of potassium hydroxide beyond which it starts falling.

The variation of compressive strength of cubes with the varying concentration of alkaline solution can be explained thus: There is a progressive increase in the compressive strength value for cubes in zero percent concentration of alkali up to 40 percent of alkali and beyond which it starts falling. The alkali concentration up to 40 percent in most of the test results can be regarded as being less than the minimum concentration of alkali[5]; that can trigger any alkali-aggregate reaction. At lower concentration of alkali, the hydration process is aided, thereby resulting to higher strength value when compared with cubes of the same age immersed in water.

As the concentration of alkaline media is increased, a stage is reached when the concentration of the hydroxide ions will increase significantly over that of the pure saturated calcium hydroxide solution in the pore of the concrete. At this stage, attack on reactive aggregate can be expected on concrete having pore solutions of elevated hydroxide ions concentration[3].

It can therefore be said, in this case, that concentration of alkaline media above 40 percent will result in production of elevated hydroxide ions concentration which will now attack the aggregate; hence there will be loss of strength. Furthermore, the gain in compressive strength was found to depend on the duration of Immersion. The longer the immersion period in the alkaline media, the more the strength gained. Figures

3 and 4 show the typical relationship between the compressive strength of concrete and the immersion periods at the various concentrations of the various alkalis. Similar presentation can be made for other alkalis.

Comparative study of the test results of the two concrete grades reveals the degree of effects to which the alkaline media can have on grades of concrete. It was generally observed that the percentage increase in compressive strength of concrete of grade 30 is more than that of grade 40 in the same alkaline medium and immersion period.

The fall in the percentage compressive strength gain as the grade of the concrete increase can be attributed to the increase in the quantity of alkalis (Na_20, K_20) in the cement with increase in the concrete grade; since both concrete grades were subjected to the same aggressive environment and immersion periods.

The relative effect of all these alkalis on concrete depends on the chemical activity. The greater the tendency for an electron to be donated for chemical reaction the greater the reactivity. The ease of loss of electron for chemical reaction is in this increasing order: Calcium ions, sodium ions and potassium ions; and hence increased reactivity. Potassium ions has the highest reactivity with the product of hydration of cement ($3CaO(sio_2)_2.\ 3H_20 + 3Ca(OH)_2$) when compared to other alkali ions of the same concentration, and in the same reaction processes.

The following are the possible products of reactions of the product of hydration of cement with alkalis used in the research.

$$3CaO(si0_2)_2.3H_20 + 3Ca(OH)_2 + 6KOH$$
$$3K_2O(si0_2)_2.3H_2O + 6Ca(OH)_2 \quad (1)$$

Product of hydration of cement

$$3CaO(si0_2)_2.3H_2O + 3Ca(OH)_2 + 6NaOH$$
$$3Na_2O(si0_2)_2.3H_2O+6Ca(OH)_2 \quad (2)$$

$$3CaO(si0_2)_2.3H_2O + 3Ca(OH)_2 + 6Ca(OH)_2$$
$$3Cao(si0_2)_2.3H_2O + 9Ca(OH)_2 \quad (3)$$

From the above equations, the nature of the products and their relative concentrations has effect on the rate of gain of strength.

Oxides of sodium and potassium, Na_2O and K_20, known as alkalis in cement has been observed to affect the rate of gain of strength of cement[6]. Diamond[3] in his studies on alkali-aggregate reaction, views the reaction as being primarily due to the high concentration of hydroxide ions in the pore solution but with the alkali cations being of critical importance because their concentration influence the reaction rates and the physical characteristics of the products of reaction[4].

In grade 30 concrete, cubes immersed in calcium hydroxide solution, irrespective of the concentration, generally exhibit the higher percentage gain in strength. This is followed by cubes in sodium hydroxide solution and potassium hydroxide solution. This behaviour can however be explained as thus: The pore of the concrete is already saturated with calcium hydroxide, a byproduct of hydration of cement. Immersing cubes in the same kind of solution may not give any visible reaction, but to further aid the process of hydration. On the other hand, the concentration of sodium hydroxide and potassium hydroxide is sufficient to significantly alter the reaction in the pore of the concrete. Calcium hydroxide in the product thus play the predominant role.

In the case of grade 40 concrete, this implies that we have more oxides of sodium and potassium of cement in the system. This however affected the relative strength gain of cubes immersed in all the alkalis. The chemical reactivity of the alkalis played the major role.

This resulted into cubes immersed in potassium hydroxide solution generally producing the highest percentage strength gain. This is due to the high chemical reactivity of potassium ions as mentioned earlier compared to others.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following conclusions can be drawn from the results of this research.

1. The concrete cubes immersed in water (control cubes) increased steadily in compressive strength from 30.96 N/mm² to 35.26 N/mm² at the end of 28 days of immersion for grade 30 concrete. Likewise, a steadily increase in compressive strength from 40,07 N/mm² to 42.52 N/mm² at the end of 28 days of immersion was recorded for grade 40 concrete.

2. For all the alkaline media, the compressive strength of the cubes increased with increase in the concentration of alkali up to a point beyond which further increase in alkali concentration will result to fall in compressive strength.

3. Due to the fall in the compressive strength value after reaching a peak, it can presumably be said that the aggregate used in this research consist of some unsuitable alkali reactive material.

4. The compressive strength of cubes in the same concentration of alkali increases with the duration of immersion. The longer the immersion period in the alkali media, the more the strength gained.

5. Attack on concrete by alkaline environment can be influenced by the grade of concrete. Lower percentage compressive strengths were recorded for grade 40 concrete when compared to grade 30 concrete. Hence, higher grades of concrete are more susceptible to alkali attack because of the high intrinsic alkali content.

RECOMMENDATIONS

The following recommendations have been made based on the findings of this research.

1. Concrete structures should not be allowed to be subjected to a concentration of more than 40 percent of any of the three alkalis used in the research.

2. Alkali reactive aggregate should be avoided in concrete works. Also, cement having high alkali content should be avoided. Deterioration of concrete can be as a result of the alkali aggregate reaction.

3. Since with increase in the grade of concrete, the strength gain decreases, exposure of concrete of high grade should be controlled.

4. Industrial chemical manufacturers and dealers should be educated on the dangers inherent in storing industrial chemicals on unprotected concrete floor.

SUGGESTIONS FOR FURTHER RESEARCH

1. Investigation into whether curing weak concrete in alkaline solution will improve its strength.

2. Strength assessment of alkali-seeded concrete.

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