

Destructive Effects of Alkali Solution of Sodium Hydroxide (Caustic Soda) to Concrete

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Abstract:

In this paper, the effect of alkali solution of sodium hydroxide (NaOH) on structural concrete was studied using mortar-bars specimens as models in a laboratory experiment. Mortar-bars made with varied cement contents and water/cement ratios were immersed in a solution containing more than 10% NaOH by concentration, and were observed for 10 weeks. The result was expansion and total softening of the concrete mortar-bars. Recommendations were that concrete structures exposed to NaOH either as liquid or gas should be protected with one or more of these: Several coat of oil paint, enamel paint or chlorinated rubber paint, to prevent direct contact of alkali and concrete, use of pozzolanic cement and use of non-reactive aggregates.

Keywords: Caustic soda, Destructive, Concrete and Porous.

Background to the Study

Alkali solutions are often erroneously viewed as friendly to concrete, especially on knowing that $Ca(OH)_2$ in concrete has strong protective effect on both concrete and reinforcement.

However, caustic soda (NaOH) is known to be very harmful to concrete.

Sodium hydroxide solution increases the solubility of the main products of hydration in hardened concrete-silicates and aluminates- while inhabiting that of $Ca(OH)_2$ (Moskvin, 1980). The tables that follow (table 1.0a and 1.0b) show the results of experiments in which solubility of calcium silicates and $Ca(OH)_2$ were measured; and calcium silicates measured as the quantity of silicates found in distilled water in which concrete mortar was immersed and NaOH increased to over 10% by concentration.

Table 1.0a Solubility of silicates in solution of NaOH, g/L

SOLUTION PH	1	2	3	4.2	5.7	7.7	10.26	10.6
SOLUBILITY, S10 2IN G/L	0.14	0.15	0.15	0.13	0.11	0.10	0.49	1.12

Table 1.0b solubility of $\text{Ca}(\text{OH})_2$ IN SOLUTION OF NaOH

TEMPERATURE (°C)	0	0.4	1.6	2.67	5	8	20
20	1.17	0.94	0.57	0.39	0.18	0.11	0.02
50	0.88	0.65	0.35	0.20	0.06	0.02	Traces

Source: Moskvina, 1980

Another aspect of damage caused to concrete by alkali solution is stirring up of alkali-silica reaction in concrete. This happens when reactive aggregates (aggregates containing active silica) is used, and when the alkali content of the cement is above 0.6 percent. Nowadays, cements of low alkali content are now being manufactured as a regulation in cement industry, and this has eliminated almost totally all cases of alkali-silica reaction; however in the presence of NaOH solution in contact with concrete the reaction still occurs (shetty, 2009).

Hardened concrete is generally a porous material. Its porosity is contributed by two major factors. Firstly, a hardened concrete mortar is a little smaller in volume than the total volume of water and cement that chemically formed it. This causes micro-pores around the cement particles in the cement paste.

Secondly, the mixing water for concrete is always more than the minimum needed to fully react with the cement powder due to the fact that some quantity of water is needed for lubrication of the aggregate for easy mixing. As the fresh concrete sets, this excess water collects near the aggregates and eventually form interconnected pores and continuous capillaries within the concrete mass. The high porosity of concrete makes it a permeable mass with large surface area exposed to aggressive chemicals (Neville, 1996).

In Nigeria local construction industry is still at its fledgling stage. This is why the reporter thinks it necessary to highlight the effect of alkali solution on concrete as an alert.

Experiments and Method

Materials and processing:-

1. Aggregate:

The aggregate used for the experiment was granite aggregate; the light colored type known to contain basalt, and is more reactive than the dark one. (Lea, 1976). The aggregate particles were broken up into very small pieces, and then to powder by rolling on a hard surface-only aggregates passing through sieve size 37micrometer were used for the experiment.

2. NaOH pallets: this is available in most local markets with chemical dealers. They appear as white flakes contained in plastic bottles.

3. Other materials include distilled water and ordinary Portland cement powder.

Apparatus:

The apparatus used in the experiment include a large-size veneer caliper of capacity 300mm and accuracy of 0.02mm, an electronic weighing balance, and wooden moulds of dimensions 25mm x 25mm x 250 mm (7 in number), glass measuring cylinder and a flat glass plate.

Procedures for experiment:

Concrete mortar-bars of the following mixes and water /cement ratios were cast into the moulds: 1:3, w/c of 0.55; 1:3, w/c of 0.65; 1:3, w/c of 0.85; 1:6, w/c of 0.55; 1:6 w/c of 0.65; 1:6 w/c of 0.85; and another 1:3, w/c of 0.55 for control. These 7 specimens were allowed to set for 24 hours, and followed by water curing for three weeks. After curing, the control specimen was placed in distilled water of depth above the specimen's thickness; all contained in a plastic bowel. The remaining six specimens were placed inside a bowel containing the same distilled water but 10percent NaoH pallets dissolved in it. The initial lengths of the specimens were measured prior to immersion, and their new lengths were measured at one week intervals for ten weeks, using the veneer caliper atop the glass plate. The concentration of the sodium hydroxide solution was increased weekly by 0.5% (on weekly bases) after measurements to ensure a high PH (above 10.7) necessary for alkali-silica reaction to occur (Moskin 1980).

The results of the experiment are shown in table 2.0(a) i.e the weekly measurements taken. The percentage changes in lengths of the specimens were also obtained and recorded in table 2.0(b).

Table 2.0a Effect OF NaOH Solution on the Length of Specimens

PARTICULAR SPECIMEN				NEW LENGTHS OF SPECIMENS IN NAOH SOLUTION									
S/N	MIX	W/c	Original length	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
1	1.3	0.55	250.90	251.18	251.20	251.92	250.92	250.80	250.70	250.60	250.60	250.84	250.90
2	1.3	0.62	254.26	251.44	254.6	254.22	254.16	254.14	254.12	254.12	254.12	254.18	254.20
3	1.3	0.85	253.66	253.70	253.63	253.60	253.60	253.66	253.62	253.54	253.58	253.56	253.60
4	1.6	0.55	250.10	250.10	249.99	249.85	249.85	249.85	249.85	249.85	249.85	249.85	249.85
5	1.6	0.65	250.00	250.08	250.08	250.08	249.72	249.72	249.72	249.72	249.72	249.72	249.72
6	1.6	0.85	253.18	253.22	253.20	252.98	252.94	252.94	252.94	252.94	252.94	252.94	252.94
Control	Control	Control		254.68	254.68	254.66	254.64	254.60	254.60	54.56	254.6	24.54	254.52
7	1.3	0.55	254.68										

Table 2.0b Naoh Solution on the Length of Specimen

PARTICULAR SPECIMEN				PERCENTAGE INCREASE IN LENGTHS OF SPECIMENS IN NAOH SOLUTION									
S/N	MIX	W/c	Original length	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
1	1.3	0.55	250.90	0.11	0.12	0.01	0.01	-0.04	-0.08	-0.12	-0.12	-0.02	0
2	1.3	0.65	254.26	0.07	0	-0.02	-0.04	-0.05	-0.06	-0.06	-0.06	0.03	-0.02
3	1.3	0.85	253.66	0.02	-0.01	-0.02	-0.02	-0.02	-0.02	-0.03	-0.05	-0.04	-0.02
4	1.6	0.55	250.10	0.04	0.04	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10
5	1.6	0.65	250.00	0.03	-0.03	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
6	1.6	0.85	253.18	0.02	0.01	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09
Control Specimen				0	0	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06
7	1.3	0.55	254.68										

Visual observations showed general loss of strength in all the specimens immersed in NaOH solution- a level of softening detectable with a little pressure with fingers which made accurate measurement hard to attain for some of the specimens in the last few weeks of the experiment. However, the control specimen which was immersed in distilled water increased in strength throughout the 10-week experiment period.

Analysis of Results

A look at the graphs in figures, 1.0(a) and (b), which are the schematic presentation of table 2.0(b), shows an initial positive slope for about two weeks (expansion) then a nearly constant negative slope for the next four weeks (contraction) and another positive slope (expansion) for about 3 weeks. This is true for curves 1,2 and 3, but for curves 4,5 and 6 the last expansion ended up in flat tails. On the other hand, the control specimen showed constant negative slope (constant rate of contraction) throughout the period of experiment.

The first positive slope (expansion) is probably due to the fact that the specimens were recovering from drying shrinkage that occurred between the time of removal from curing tank and the time of commencement of the experiment, which was about 24 hours. The contraction period that followed (for all the specimens) is as a result of continued hydration-hardened mortar is a little smaller in volume than the fresh mortar. The final period of expansion (positive slope) is supposedly caused by the product of alkali-silica reaction (Moskvin, 1980) which is highly expansive at high PH. The expansion is greater for lower w/c ratio probably because the expansive products easily fill-up the pores of such concretes; specimens 4, 5, 6 may have experienced the same expansion but for the remarkable softening of the specimens which did not allow accurate measurement to take place. The reader should also note that, while expansion was inversely proportional to w/c ratio, softening was directly proportional to w/c ratio.

In fact, all the specimens immersed in NaOH solution showed marked softening, which increased with w/c ratio and reduced with cement content. This is caused by the disilusion of the basic silicates and aluminates responsible for the strength of a hardened concrete. Only the control specimen which was immersed in distilled water experienced uninterrupted hydration and continuous gain in strength for the whole period.

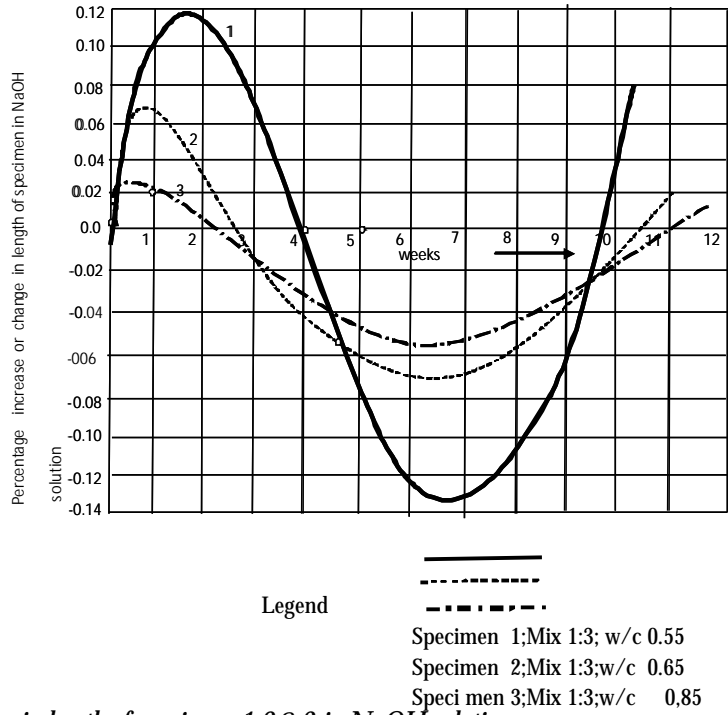


FIG 1.0a Change in length of specimens 1,2&3 in NaOH solution

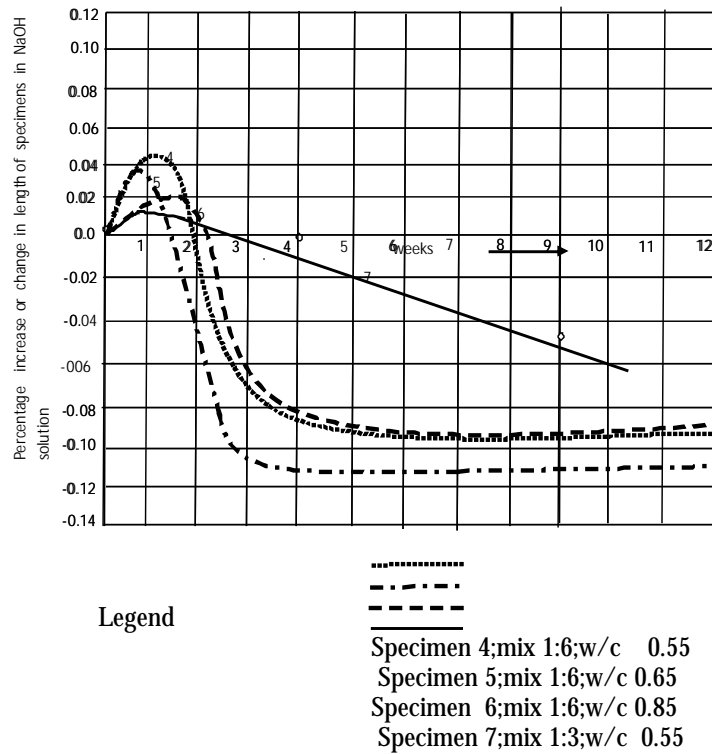


FIG 1.0b: Change in length of specimens 4,5,6 in NaOH solution & Specimen 7 in distilled water

Recommendation and Conclusion

Alkali solution has remarkable deteriorative effects on concrete in two major ways: desolusion of main compounds of hardened concrete (softening) and causation of Alkali-aggregate reaction (expansion).

The following protective measures should be taken where necessary.

1. Make a dense concrete that can take paint, and coat the surfaces with several layers of oil paint, enamel paint, chlorinated rubber paints, etc, to prevent contact with alkali solution.
2. Use pozzolanic cement or add pozzolanic materials to the cement to react with alkaline content of the fresh concrete and thereby reduce the alkalinity of the fresh concrete.
3. Use mixture of aggregate types so that reactive aggregates will be reduced in quantity, especially when reactive aggregates are suspected.
4. Alternative building material, such as steel, may be used, especially in factories where NaOH is manufactured or used as raw material

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