EFFECT OF DESTROYER FACTORS ON STRENGTH AND DURABILITY OF CONCRETE STRUCTURES (WITH SPECIAL REVIEW ON ALKALI-SILICA (ASR) REACTION)

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Abstract - In general, one of the most important goals that are considered in the construction of concrete process, are concrete durability and strength and it's sustainability in different weather consitions. Therefore, it is necessary to pay attention to this issue in the various stages of concrete structures because they will have a direct influence on the life of the concrete structures and the cost of their maintenance. Identifying the destructive factors affecting concrete is another important factor. In this article, we try to study the conditions and factors affecting the durability of concrete, specially the Alkali-Silica Reaction(ASR).

Keywords - Concrete, Alkali-Silica Reaction(ASR), Destroyer Factors, Durability, Strength.

I. INTRODUCTION

Designers of concrete structures, often tend to look at the characteristics of material resistance factor. For various reasons, they should be aware of another important factor of the material, which is the durability factor. Since the correct mixing, pouring and treatment of concrete under normal conditions affect the durability of concrete, various early degradation situations of the concrete may occur due to non-observance of the above in concrete structures. Generally, water is involved in various types of concrete damage and, due to its penetration through the pores in the solid body, causes it to degrade. Therefore, the structure of water and its destructive effect on porous aggregates, as well as the permeability control factors of cement paste, aggregate and concrete, should also be investigated. In addition, it is necessary to evaluate the physical effects, mechanisms and control of various degradation situations of the concrete. Additionally, enough attention should be paid to the implementation of concrete in saline water (marine environments), so that when concrete structures are exposed to saline water, the physical and chemical effects will occur at a time. In this research, we have tried to control and eliminate the factors by identifying the destructive factors affecting the strength and durability of the concrete to achieve concrete with high resistance and durability. For this purpose, this paper focuses on the study of the effects of alkaline-silica reaction (ASR).

II. COMPRESSIVE STRENGTH OF CONCRETE

According to the Iranian concrete code, Compressive strength is a characteristic of resistive concrete, with a maximum of 5% of all resistances measured for the concrete grade may be less than that. In practice, in the operating conditions of the workshop, concrete is considered to conform to the specification and acceptable to conform to the terms of the clause.

C6,C8,C10,C12,C16,C20,C25,C30,C35,C40,C45,C50

The numbers after C indicate the compressive strength of the concrete in MPa and the factors affecting it are as follows. (figure 1)

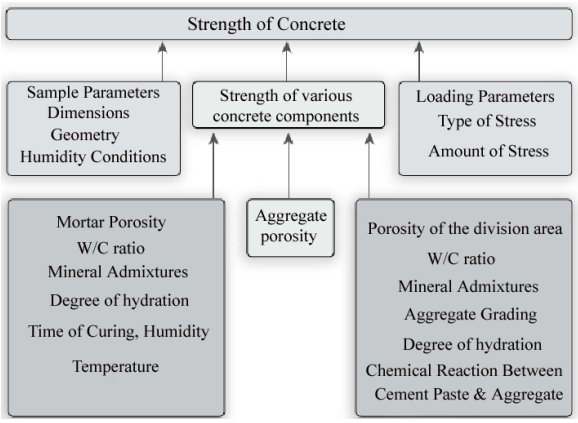


Fig.1. Factors affecting concrete strength

It should be noted that the direct determination of the porosity of concrete components and mortars is impossible. In addition, the real response of the concrete to the stresses is influenced by various factors. In order to better understand the factors, they can be classified into three distinct categories:

a. Characteristics and proportion of materials
b. Curing conditions
c. Various test parameters

III. CHARACTERISTICS AND PROPORTION OF MATERIALS

Before making concrete mixtures, in order to obtain concrete with sufficient resistance, the first step is to select the appropriate materials and their mixing ratio. In practice, many of the factors in the mixing design

are interdependent, so the effects of each one can not be exactly differentiated.

a. Water to cement (W/C) ratio:

In 1918, as a result of extensive experiments at the Lewis Institute (University of Illinois), the relationship between water to cement ratio and concrete strength was determined, which later became known as water-to-cement law of Abram. The inverse relationship between water to cement ratio and concrete strength was given as follows:

$$f_c = \frac{k_1}{k_2^{(w/c)}} \quad (1)$$

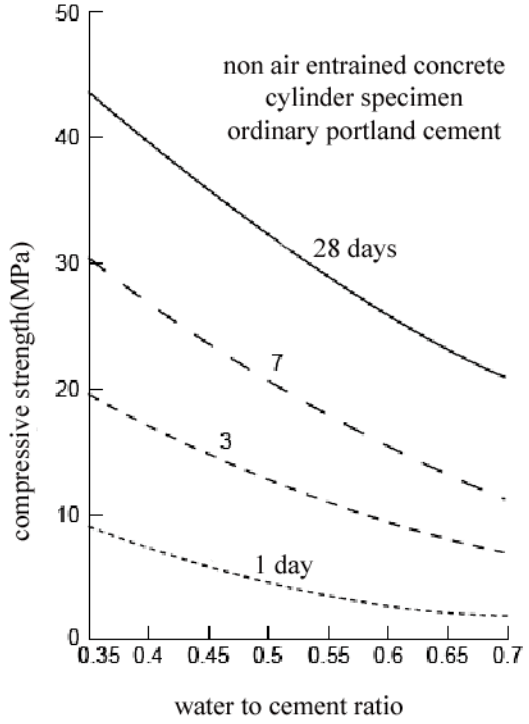


Fig.2. Effect of water to cement(w/c) ratio and wet curing on concrete strength

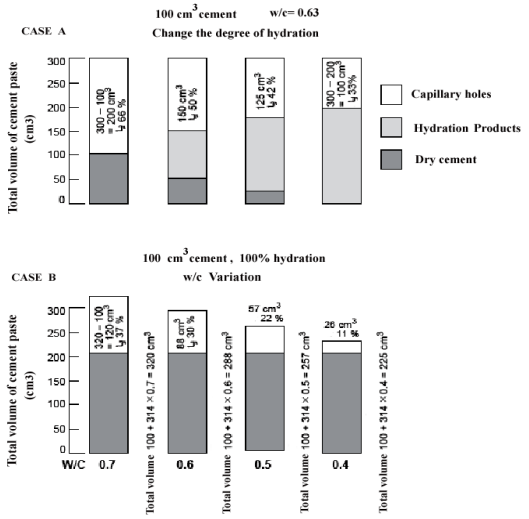


Fig.3. Changes in capillary porosity due to changes in water to cement ratio and degree of hydration

Where w/c is water to cement ratio in concrete mixture, k1, k2 are the experimental constants curves are also presented to illustrate the relationship between water to cement ratio and concrete strength under wet curing conditions, as shown in Fig. 3.

In addition, the effect of the change in water-to-cement ratio on porosity is shown in Fig. 4.

IV. MECHANISM OF ALKALI-SILICA REACTION(ASR) IN CONCRETE

In general, the main reaction in the ASR phenomenon is the reaction between the silica in the aggregate and the hydroxide ions (OH-). In the early stages of hydration of cement, calcium ions are combined together, but potassium and sodium ions remain in the solution and eventually combine in calcium silicate (C-S-H) and monosulfate (AFm) hydrates. Research conducted in 1990 suggested the use of anti-icing chemicals such as potassium acetate, potassium formate, sodium acetate and sodium formate because the chemicals are less harmful to the environment compared to other materials such as ethylene glycol. Some of the chemicals in hardened cement interact with calcium hydroxide, increases the PH value and, as a result, increases the probability of damage to aggregates (due to an ASR attack).[1]

As a result, the chemicals cause expansion and cracking of laboratory samples and reduce the hardness of the concrete, which is measured using the modulus of dynamic elasticity (DME). In some samples, depending on the test method and the reactivity of the aggregates, expansion occurs, so that the expansion does not depend on the alkaline amount of the cement.

The damage caused by the Alkali-Silica Reaction (ASR) in concrete is a phenomenon that was first studied in north america in 1940 and was evident in many countries.

Studies show that the amount of air, as compared with other factors mentioned, is a more important variable and in the affected concrete with ASR increases its expansion. With regard to the above, if the use of reactive aggregates is used in the production of high-performance concrete (HPC), there will be a risk of ASR occurrence.[2]

Soluble alkalis raise the pH to about 13 or more. In most cases, the amount of alkali in the free water depends on the amount of soluble alkalis in the cement. When attacking hydroxide ions, if the silica is well crystallized, the damaged points will only be on the outer surface of the aggregate but if there is not sufficient crystallization of silica in the aggregate

structure, more damaged points will be created. (Figures 4 & 5)

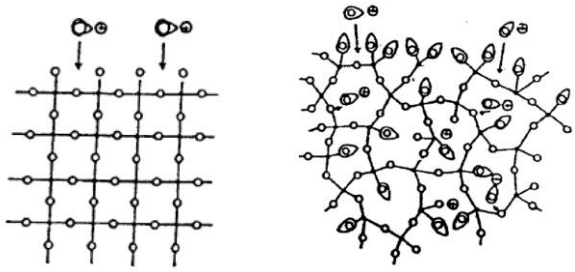


Fig.4. The attack of alkali solutions to silica

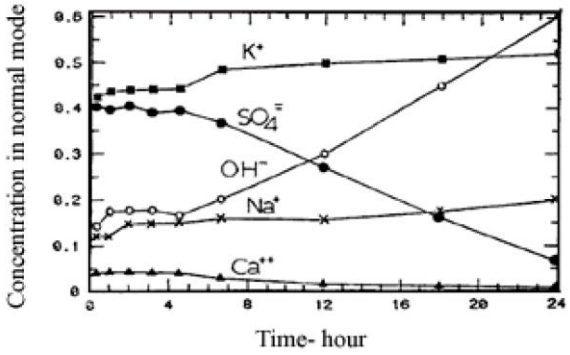


Fig.5. The relationship between time and concentration of solution in cement paste

In general, the amount of damage in concrete structures depends on the amount of water absorbed by the gel and its degree of expansion. Although the alkaline-silica gel can also be swollen in low relative humidity, but the RH of the gel should be more than 80% so that the gel becomes swollen. The shape of cracks due to ASR are Y shaped. In the below photo, you will see the crack formed at Hoover Dam (Figure 6)

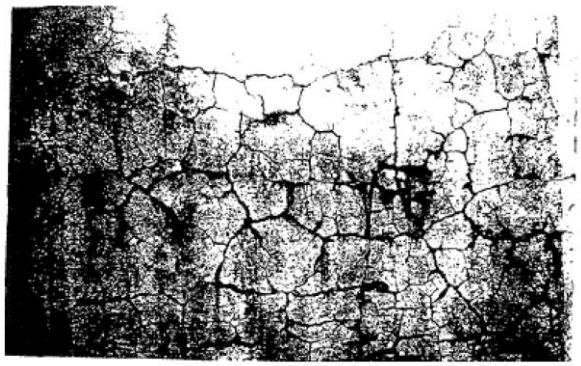


Fig.6. Y shaped cracks in the Hoover dam due to Alkali-Silica Reaction(ASR)

As mentioned above, reactive aggregates should not be used in concrete to prevent ASR phenomena. Types of reactive aggregates include:

- Non-crystalline silica or silica with incomplete crystallization such as apaline, cristobalite, nap, flint
- Quartz with low crystallization (usually found in gnesis), quartzite
- Cruciferous igneous rocks like Pumice

The mechanism of occurrence of ASR can be described using Figure 7 as follows:

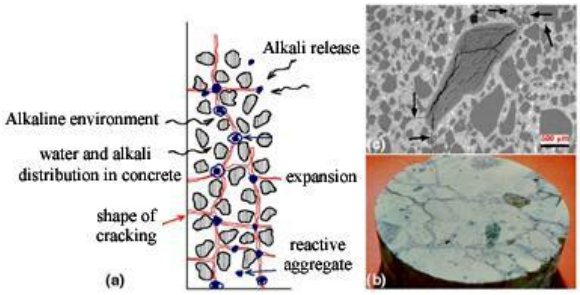


Fig.7. Cracking of concrete due to alkali-silica reaction (ASR)

a) Mechanism

b) Gel formation, which causes expansion and cracking.

c) The polished concrete section, which shows the nap particles with internal cracking of the section.

Other remarkable points in order to deal with the ASR phenomenon are the concrete mix design. Because factors such as the size of the aggregate and its consumption, the proportion of water to cement and the amount of air, will affect the reaction. For example, Hobbs, in his report, refers to the amount of aggregate that affects the expansion of a large amount. (Figures 8 & 9)

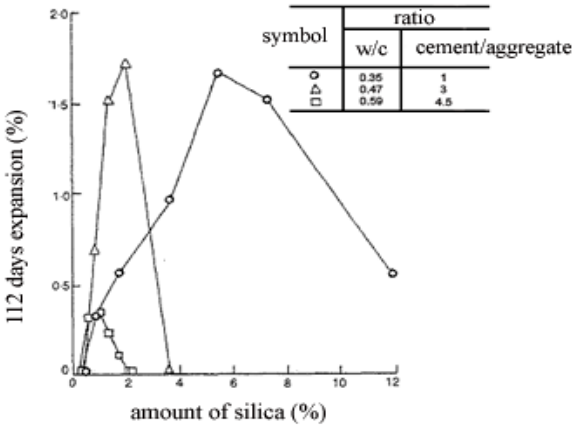


Fig.8. The relationship between the amount of silica and the expansion rate w / c = 0.4
Aggregate / cement ratio = 2.75
Alkali amount = 6 kg / m3

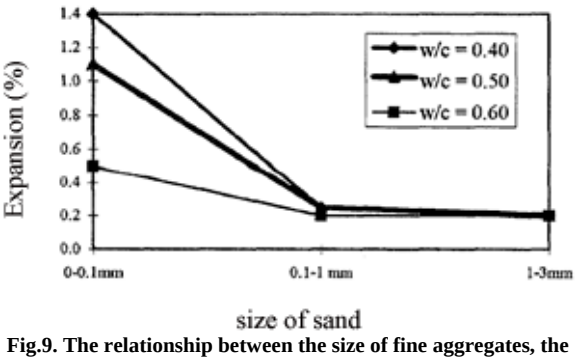


Fig.9. The relationship between the size of fine aggregates, the water to cement ratio and the amount of expansion

The high amount of water to cement ratio can increase or decrease the expansion, which depends on other factors such as age of concrete and aggregate size.[3]

V. USING OF LITHIUM ADMIXTURES IN REDUCING ASR

For over 50 years, lithium compounds have been used in concrete to reduce the ASR-induced expansion in laboratory samples. The effect of lithium on ASR expansion on laboratory samples can be shown as follows:

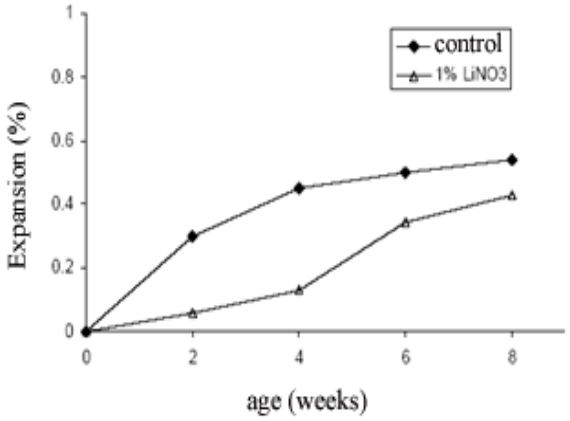


Fig.10. Using of lithium nitrate to reduce expansion due to ASR (McCoy & Caldwell,1951)

Other lithium-containing compounds, such as LiOH, can also be used to increase the hydroxyl ion (OH-) contained in the solution, which results in an increase in its pH. When some lithium-containing admixtures such as LiOH, Li2CO3 and LiF are used inadequately, they can increase the expansion of ASR. In addition, some lithium salts such as LiF and Li2CO3 have little solubility. Therefore, their use in concrete mixtures is not very suitable.

At the same time, Li2CO3 does not increase the pH of the solution and is more suitable for controlling expansion in the high reactive aggregates compared to other lithium compounds.

A. Effect of lithium admixtures on the behavior of concrete at early ages

While extensive research has been conducted on the beneficial effects of lithium in controlling the expansion of ASR, at the same time, little research has been done on the effect of lithium admixtures on other concrete properties. Does using an high amount of lithium admixtures can cause negative effects on concrete properties at its earliest stages?

Typically, lithium is used in combination with special materials such as fly ash to reduce the damage caused by ASR. By using fly ash in concrete, the effect of lithium is exacerbated, because the use of fly ash in Portland cement reduces calcium (Ca) as compared with silicon (Si) in calcium silicate hydrates. In addition, it has been shown that the presence of lithium in hydrate cement may be better than Na + or K +. Therefore, the particular effect of increasing Li in hydration products reduces the free lithium content. Free lithium is involved in ASR-induced expansion reactions and may affect other plastic and hardness properties of concrete.

B. EFFECT of Lithium admixtures on workability of concrete

While workability, usually measured in the laboratory using the results of the slump,so little research has been done on the effect of lithium admixtures on workability.

Slump of concrete is measured with the following characteristics:

- w/c= 0.35
- Cement type II
- Use 13-21% by weight of cement from fly ash
- Use of super plasticizer admixtures

Wang concluded that the use of high alkaline cements would reduce the amount of slump.[4]

C. Effect of Lithium admixtures on the setting time

Some reports indicate that the use of lithium admixtures reduces the setting time of Portland cement and calcium aluminate. While other researches suggests that lithium nitrate may not have much effect on it. The result was that the addition of lithium had no apparent effect on its setting time. In another study, with a 3% increase in alkali content, the setting time was reduced. In general, lithium salts are considered as accelerators in alumina cements. Other reports indicate that the amount of lithium consumed may affect its setting time. Chemical admixtures such as CaCl2 act as a condenser accelerator when used with a low amount, and when used with high doses, it acts as a constraint inhibitor. Therefore, the amount of (doses) of lithium salt used and its effect on the soluble solution of pH is very important in determining the effect of lithium on its setting time.

D. Effect of lithium admixtures on the strength of concrete

The increase in strength and the initial strength of the concrete are of particular importance in the construction of concrete structures. If you use lithium admixtures, it will be important to check the compressive strength of the concrete. In pavements, bending strength is more important than compressive strength. In a test carried out by Thomas, assuming cement variability, the compressive strength of lithium-containing concrete (75% and 100% LiNO3) on 3, 7, 28, 56 and 90 days was almost near lithium-free concrete. (Figure 11)

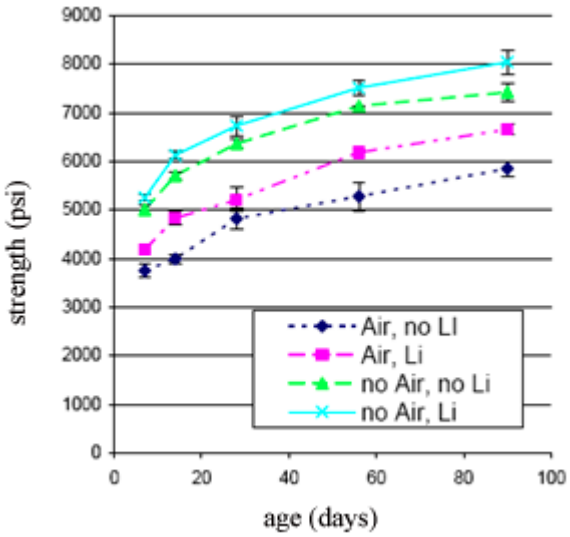


Fig.11. Change in compressive strength of concrete in different days relative to the presence or absence of air and lithium

VI. CONCLUSION

In general, the different results from the study of the ASR phenomenon are as follows:

1. As a result of the ASR reaction, the hydroxide ions are introduced into the neutral solution of cement paste and reactive silicon present in aggregates.

2. The main product of the ASR reaction is the creation of an ASR gel, which is located in the around of the aggregates and cement paste. In the presence of moisture, the ASR gel expands and causes significant membrane pressure. The result of this pressure is the appearance of fine cracks in concrete. Research shows that the maximum expansion caused by ASR depends on a variety of parameters, which are:

- Volumetric cracking (fracture)
- Type and size of reactive aggregates
- The composition and amount of cement alkali
- Increasing the strength of concrete
- Concrete mixing ratio (water to cement ratio, ...)

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