

# The effect of cement alkali content on ASR susceptibility of mortars incorporating admixtures

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## Abstract

In this study, the effects of three types of plasticizing chemical admixtures (modified lignosulfonate, sulfonated naphthalene formaldehyde and polycarboxylate based) on deleterious expansion due to alkali–silica reaction (ASR) have been investigated. Two different types of cements with low (0.53 Na<sub>2</sub>O eq.) and high (0.98 Na<sub>2</sub>O eq.) alkali contents, a non-reactive crushed limestone as fine aggregate and a reactive river sand were used within the scope of the experimental program. ASR tests were conducted according to accelerated mortar bar method (ASTM C 1260). Additionally the flow value, dry unit weight, capillary water absorption and compressive strength tests were performed. Test results indicated that mortars prepared with inert fine aggregate caused no significant expansion, regardless of cement type, admixture type and dosage. However, for mixes containing reactive sand, admixtures increased or decreased the expansion values (compared to plain mortars) depending on the alkali content of cement used. The magnitude of change of expansion also depended on the type and amount of admixture incorporation which have a dominant effect on stability and compactability of mortars. The high-alkali cement usually revealed the ASR expansion augmentation behaviour of admixtures. In contrast, low alkali cement decreased the expansion values compared to the control specimens.

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## 1. Introduction

Alkali–silica reactivity in concrete is a chemical reaction involving alkali hydroxides, usually derived from the alkalis present in the cement used, and reactive forms of silica present within aggregate particles. This chemical reaction also requires water to produce the alkali silica gel reaction product, which swells with the absorption of moisture. Damage due to alkali–silica reaction (ASR) in concrete is a phenomenon that was first recognized in the US in 1940. ASR has caused expansion and cracking to concrete structures exposed to external moisture in a number of countries. In the course of time, safe non-reactive sources of aggregate have become scarce. Furthermore, cement companies have fewer options for producing low-alkali cement. Pre-heaters in modern dry-process cement plants have led to an increase in the alkali content of cement made from given raw materials. The alkali

content, therefore, has to be controlled but limiting the alkali content too severely results in increased energy consumption. A more efficient dust collection also increases the alkali content of the cement when the dust is re-incorporated into the cement because the dust contains a large amount of alkalis [1]. As an important disadvantage, high-alkali cements may usually increase the ASR susceptibility of concrete. So now-a-days, risk of deterioration due to ASR preserves its importance [2–6].

Related factors which can play important roles in the formation of ASR can be listed as follows: amount of available moisture, nature of reactive silica, amount of reactive silica, particle size of reactive material, amount of available alkali from different sources, porosity of concrete, pre-existing cracks, temperature, drying–wetting cycles, etc. All these factors and mitigating measures (incorporation of mineral admixtures and lithium-based chemical admixtures) were comprehensively studied in related literature [7–17].

However, the effects of plasticizing chemical admixtures in case of cements with different alkali contents on ASR

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expansion have not been fully investigated. Only a few studies have addressed the effects of these admixtures. In one study, Wang and Gillott [18] have concluded that plasticizing chemical admixtures used with opal as the reactive aggregate increased expansions.

The aim of this study is to put forward a relationship between ASR and plasticizing chemical admixture type and dosage with different types of cements. For this purpose, three types of plasticizing chemical admixtures from different origin were tested with two types of cements (high alkali and low alkali) at varying dosages. The flow value, dry unit weight, capillary water absorption and compressive strength and ASR tests were performed on mortar specimens.

## 2. Research significance

Use of low-alkali cement may help forestall ASR where the potential exists, but the material may not be always available. Control of the alkali content of cement may be impossible since new regulations strictly restrict the amount of fugitive dust from cement plants. In modern dry process cement plants, captured cement dust is often thoroughly re-incorporated to the finished cement product. Cement dust contains excessive amounts of alkalis; this leads to the increase of ASR potential of the finished product, thus increasing its ASR potential. For this reason, the ASR susceptibility of high-alkali cements in combination with different types of plasticizers should be investigated.

## 3. Experimental study

### 3.1. Materials

In this study, two different types of cements with low (0.53 Na<sub>2</sub>O eq.) and high (0.98 Na<sub>2</sub>O eq.) alkali contents

were used. The physical, chemical and mechanical properties of cements are listed in Table 1.

A non-reactive crushed limestone from Bornova, Izmir, Turkey served as inert fine aggregate and river sand from Ahmetli, Izmir and Turkey served as reactive sand. The mineralogical origins and physical properties of fine aggregates are given in Table 2 and their gradations are presented in Fig. 1.

Three types of plasticizers from different origins were used. The first one is a modified lignosulfonate-type normal plasticizer (M), the second is a sulfonated naphthalene formaldehyde-type superplasticizer (S) and the third is a polycarboxylate-type hyperplasticizer (P) all conforming the ASTM C 494 standards [19]. The physical and chemical properties of plasticizers are presented in Table 3. Distilled water was used in all mixes.

### 3.2. Mix proportions, specimen preparation and test methods

The experiment program was based on several factors. Two separate experiments were designed. Set “H”, the high-alkali cement set, and set “L”, the low-alkali cement

Table 2  
Mineralogical origins and physical properties of sands

	Inert fine aggregate	Reactive river sand
Mineralogical composition	Carbonate 98%, Quartz 0.5%	Quartz 24%, Carbonate 4.5%, Schist and Gneiss 51%, Feldspar 6.5%, Tourmaline 3%
Specific gravity	2.59	2.63
Water adsorption (%)	1.21	1.30

Table 1  
Physical, chemical and mechanical properties of cements used

Chemical analysis			Compressive strength (MPa)			
	%	H <sup>a</sup>	L <sup>b</sup>	Days	H	L
CaO	61.51	61.51	63.7	2	22.0	25.4
SiO <sub>2</sub>	20.44	20.44	19.68	7	39.5	41.1
Al <sub>2</sub> O <sub>3</sub>	6.22	6.22	5.75	28	47.4	50.6
Fe <sub>2</sub> O <sub>3</sub>	3.22	3.22	3.00			
MgO	2.44	2.44	0.90			
Na <sub>2</sub> O	0.34	0.34	0.18			
K <sub>2</sub> O	0.98	0.98	0.53			
SO <sub>3</sub>	1.50	1.50	2.78			
Cl	0.005	0.005	0.01			
LOI	2.14	2.14	2.84			
Free CaO	0.98	0.98	1.55			
Insoluble residue	0.21	0.21	0.70			
				Physical properties	H	L
				Consistency water (%)	29.6	28.8
				Initial setting time (min)	150	135
				Final setting time (min)	185	245
				Volume stability (mm)	2	2.5
				Blaine (m <sup>2</sup> /kg)	320	340
				Specific gravity	3.15	3.14

<sup>a</sup>H = High-alkali cement (0.98% Na<sub>2</sub>O eq.).

<sup>b</sup>L = Low-alkali cement (0.53% Na<sub>2</sub>O eq.).

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