ALKALI–SILICA REACTION BETWEEN THE CEMENT MATRIX AND ACCELERATING ADMIXTURES

Bo-Ra Choi[1], Su-Jin Lee[1], Byung-Tak Hong[1], Jae-Wan Lee[1], Jong-Pil Won[1], Wan-Young Kim[2]
[1]Department of Civil & Environmental System Engineering, Konkuk University, Seoul, 143-701, Republic of Korea
[2]Dam Engineering Research Center, Korea Institute of Water and Environment, Daejeon, Republic of Korea

Introduction

The alkali–aggregate reaction (AAR) has received considerable attention and publicity since Stanton reported it in 1940 [1]. The alkali–silica reaction (ASR) is a chemical reaction between the alkalis in cement and various silica minerals in the aggregate. The reaction product is an alkali–silica gel, which can lead to cracks and overall expansion. The reaction can only proceed if sufficient moisture, high alkalinity, and reactive minerals are present. If any one of these three factors is absent, then the ASR will not proceed. In addition, the expansion is influenced by the alkali content, particle size of the reactive aggregate, water, temperature, and time of exposure [2].

Recently, controversy has arisen over some of the accelerating admixtures used in cement-based composites because they contain high alkali. Therefore, this study examined the alkali–silica reaction between the cement matrix and accelerating admixtures.

Experimental

Materials

Type I Portland cement from two different sources was used. The cement was selected based on equivalent alkali contents: 0.81% (low alkali) and 1.14% (high alkali).

Two types of aggregate were used: non-reactive sand and reactive andesite aggregate.

Two types of accelerating admixtures were used: a cement-based mineral admixture (CSA) and aluminate. Their equivalent alkali contents were 13.52 and 18.81%, respectively.

Experimental procedures

The ASTM C 1260 accelerated mortar bar test method was used to determine the expansion of the mortar bars. The amount of accelerating agent used was 5% of the mass of the cement. The notation used to identify each mixture is given in Table 1.

Table 1 Notation used to identify each mixture

Type of admixture	Cement	
	Low alkali	High alkali
None	Plain L	Plain H
CSA	L-CSA	H-CSA
Aluminate	L-AN	H-AN

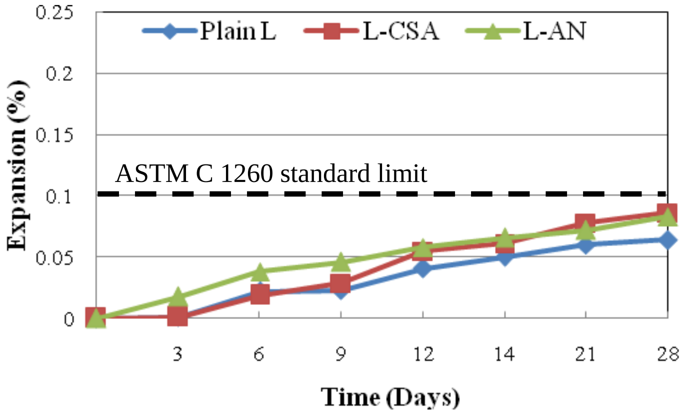
Morphological investigations included scanning electron microscopy (SEM), energy dispersive x-ray spectroscopy (EDS), and polarizing microscopy. This permitted the visualization and characterization of the mortar bars.

Results and Discussion

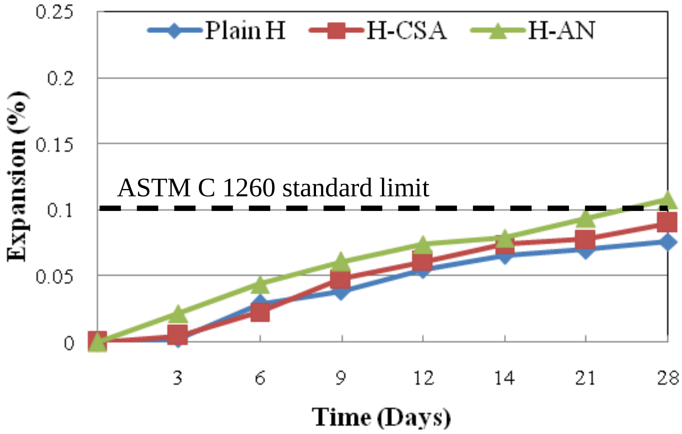
Expansion tests

The expansion test results presented here are the average values of the expansion in three mortar bars cast from each mixture.

Figure 1 shows the expansion test results for the non-reactive sand. The accelerating admixtures generally increased the expansion compared to the plain mixes. However, the 14-day expansion of each mortar bar was less than 0.1%. Therefore, detrimental expansion did not occur.



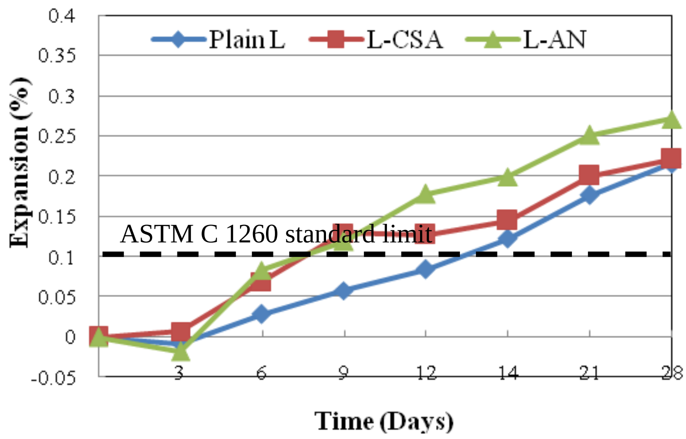
(a) Low alkali cement (Na_2O_e = 0.81%)



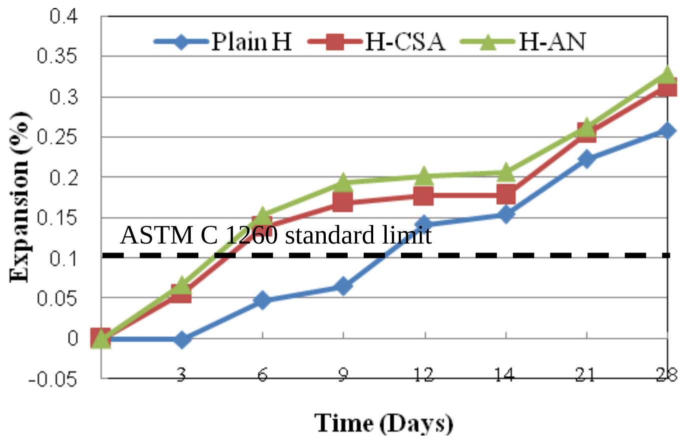
(b) High alkali cement (Na_2O_e = 1.14%)

Fig. 1 Expansion–time relationship of the nonreactive sand mixtures

Figure 2 shows the expansion test results for the andesite. Each mortar bar made using reactive aggregate had expanded more than 0.1% at 14 days. When using an accelerating admixture, the expansion was greater than for the plain mixtures. In addition, high alkali cement produced more expansion than low alkali cement. All of these observations are thought to result from the difference in the total alkali content. The expansion continued after 14 days.



(a) Low alkali cement ($Na_{2}2O_e$ = 0.81%)



(b) High alkali cement (Na_2O_e = 1.14%)

Fig. 2 Expansion–time relationship of the reactive aggregate mixtures

Microstructural examination

No reaction product was found on the surface of mortar bars with non-reactive aggregate. The EDS analysis revealed that the mortar bar compositions were very close to those of the starting material. The polarizing microscope analysis showed the same result.

By contrast, SEM observations of the mortar bars made using the reactive aggregate confirmed that all of the samples were affected by ASR, since the sample surface was covered with alkali–silica gel. It was difficult to discern the morphology, but the EDS analyses revealed that their compositions were very close to those reported for general alkali–silica gels. A reaction rim and cracks were found using polarizing microscopy (Fig. 3). More gel products were found after 28 days.

Conclusions

This study examined the alkali–silica reaction between the cement matrix and accelerating admixtures. The major results obtained in this study may be summarized as follows.

- Using non-reactive aggregates, detrimental expansion due to the alkali–silica reaction did not occur, regardless of the equivalent alkali contents of the accelerating admixture. SEM observations, coupled with EDS analysis, confirmed this.
- Using the reactive aggregate, the expansion of all mortar bars exceeded 0.1% at 14 days. As the total alkali content increased because of the accelerating admixture, more expansion occurred. The expansion was greater after 28 days than after 14 days. These results confirm that the expansion due to the alkali–silica reaction is influenced by the alkali content and exposure time.

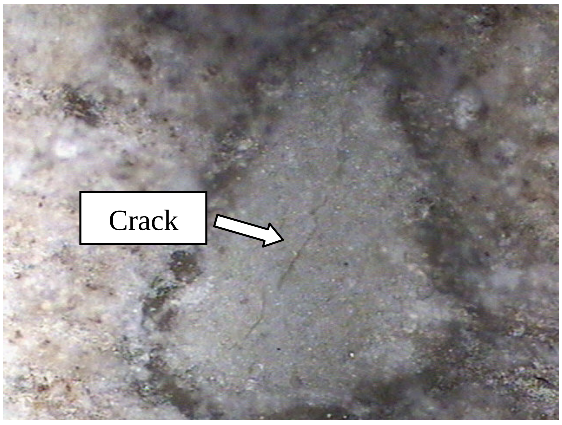


Fig. 3 Polarizing microscope image of H-AN using reactive aggregate after immersion in 1 N NaOH for 28 days at 80°C

References

1. Stanton, T.E., Expansion of concrete through reaction between cement and aggregate. *ASCE*, **66** (1940) 1781-1811.
2. V.S. Ramachandran, Alkali-aggregate expansion inhibiting admixtures, *Cement and Concrete Composites*, **20** (1998) 149-161.
3. André Carles-Gibergues, Martin Cyr, Interpretation of expansion curves of concrete subjected to accelerated alkali-aggregate reaction (AAR) tests, *Cement and Concrete Research*, **32** (2002) 691-700.
4. Ssang-Sun Jun, Hyo-Min Lee, Ki-Young Seo, Jin-Yeon Hwang, Chi-Sub Jin, Preventive measures on alkali-silica reaction of crushed stones, *Journal of Korea Concrete Institute*, Vol.17, No.1, 129-137, February 2005.
5. M. Davraz, L.G nd z, Reduction of alkali silica reaction risk in concrete by natural (micronised) amorphous silica, Construction and Building Materials, **22** (2008), 1093-1099.
6. X. Feng, M.D.A. Thomas, T.W. Bremner, K.J. Folliard, B. Fournier, Summary of research on the effect of $LiNO_3$ on alkali-silica reaction in new concrete, *Cement and Concrete Research*, **40** (2010) 636-642.