ENGINEERING JOURNAL

Article

Effects of Moderate Calcium Oxide Fly Ash on Expansion of Mortar Bar Due To Thai Reactive Aggregates

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Abstract. This paper reports the effect of local pozzolan on expansion of mortar bar due to local potentially reactive aggregates, greywacke. The study, based on the accelerated test method, investigated ability of moderate calcium oxide fly ash to control the length change due to chemical reaction between certain aggregates and alkalis in cement. Percentage variation of lignite fly ash from 20 to 50 yielded different benefits on expansion control. The highest percentage replacement showed the best result in reducing expansion from 0.17% to 0.03% and from 0.43% to 0.07% at 16 and 30 days after casting, respectively. The findings provided background information that would affect aggregate screening process adopted in the country and the potential mitigating method for local potential reactive aggregate.

Keywords: ASR, expansion, fly ash, greywacke.

ENGINEERING JOURNAL Volume 16 Issue 3
Received 18 November 2011
Accepted 29 February 2012
Published 1 July 2012
Online at http://www.engj.org /
DOI:10.4186/ej.2012.16.3.101

This paper is based on the poster presentation at the German-Thai Symposium on Nanoscience and Nanotechnology 2011—Green Nanotechnology of the Future, GTSNN 2011, in Nakhon Ratchasima, Thailand, 13-16 September 2011.

DOI:10.4186/ej.2012.16.3.101

1. Introduction

Concrete structures deteriorate in many ways. Among the latter, chemical deterioration, particularly alkali-silica reaction (ASR) has been of grave concern. ASR, reaction between some certain aggregate types and alkali in cement, results in expandable gel when moisture is available. Over a prolonged period, this causes losses of concrete integrity and durability. The difficulties in arriving at mitigation measures are compounded by the wide variations in cement and aggregates. Since Stanton reported his finding on ASR in 1940 [1], a large number of research works have been conducted in many areas, including the mitigation [2-4]. It is recognized that no single technique or material can be completely and successfully applied for all cases.

After the first evidence of ASR was reported in Thailand in 2009 in a mass foundations project [5], this phenomenon has been receiving increasing attention. Lacking in information on local materials and their behaviors in concrete has been the problem at the very start.

Many research works have focused on mitigation measures for new structures where the use of potential aggregates is unavoidable [6-7]. Several chemical admixtures and pozzolan types have been found to be variously effective[8]. Different types of pozzolan have been reported for their effective expansion control, including fly ash [9-10]. The effectiveness of fly ash, particular Type F, in reducing ASR expansion have been widely reported[7, 11].

The use of local fly ash in Thailand's construction industry has been significantly increasing [12-13]. This could be the results of the improvement in concrete properties, as well as environmental and economic consideration. There has been little information on fly ash and aggregates in the expansion control aspects. It is the aim of this study to rectify this.

2. Research Objectives and Its Significance

This paper aims to verify the effectiveness of moderate calcium oxide lignite fly ash in suppressing ASR-induced expansion of local potential reactive aggregates. The results of the study are expected to provide the information on long term expansion and cracking due to the use of local aggregates with potential for ASR.

3. Experimental Program

3.1. Materials

Local aggregates and fly ash were used throughout this study.

3.1.1. Aggregates

The aggregate was greywacke from a source in the east of Thailand with the production rate larger than 150 tons/hour. This aggregate was identified as a potentially reactive aggregate in the previous study [14]. Greywacke has been associated with the occurrence of ASR in several concrete structures [15], although the reactivity varied [16]. Detailed mineralogical study of the aggregate was conducted to provide information on the degrees of reactivity of the materials, as shown in Table 1. The specific gravity and water absorption of the studied aggregates were 2.64 and 0.75% respectively. The crushed aggregates which were graded in accordance with the requirement given in ASTM C1260-01[17] and ASTM C1567-04 [18] were used throughout this study.

3.1.2. Fly Ash

Local fly ash from Mae Moh, the main source of Thailand was used. The chemical compositions were as follows: total amount of SiO_2, Al_2O_3 and Fe_2O_3 70.36%, CaO 18.12%, and SO_3 3.55%. The details are shown in Table 2. The spherical shape of fly ash particles with mean diameter of 1.83 micron and the results of SEM and XRD analysis are shown in Fig. 1 [19]. Since the amount of calcium oxide in this fly ash was moderate, its effect on concrete was expected to be different.

3.1.3. Cement

Commercially available Type I Portland cement was used.

Table 1. Chemical composition of Greywacke aggregate [19].

Code	Type	Definition	% Calcite	% Quartz	% Dolomite	% Muscovite	% Microcline	% Albite	% Clinochlore	% Diopside	% etc	% sum
TTGW	Greywacke	East coastal greywacke	12.3	27.6	-	16.3	3.5	27.5	10.6	-	2.2	100

Table 2. Chemical compositions of type I cement and fly ash [19].

Oxide	Composition, %									
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO_2	SO_3	LOI
Cement	18.74	5.22	3.20	65.30	0.82	0.08	0.50	0.06	2.80	2.75
Fly ash	36.35	19.86	14.15	18.12	2.82	1.33	2.30	-	3.55	0.55

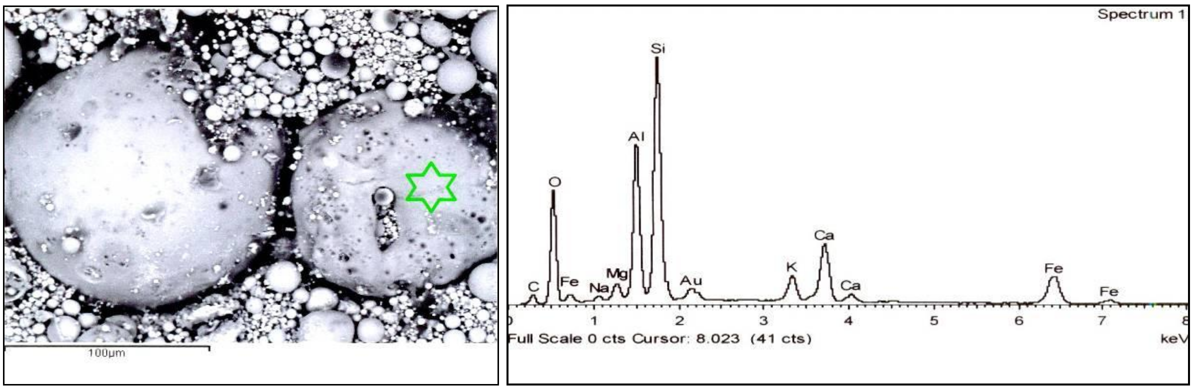

Fig. 1. Typical particle shape of fly ash (a) and XRF analysis for chemical compositions [19].

3.2. Specimen Preparation

Control specimens, 25x25x285 mm. mortar bar, were prepared according to ASTM C 1260 using mixture with w/c of 0.47 and graded potential reactive aggregates [17]. In addition to the control, three sets of specimens were prepared, using fly ash as cement replacement at the percentage of 20, 35 and 50. Similar water to binder ratio of 0.47 and preparation procedure were used as in control samples.

3.3. Test Methods

3.3.1. Length Measurement

All specimens were demolded 24 hours after casting and stored in water at 80°C for 24 hours. Then, using length comparator, and following the Accelerate Mortar Bar Test (AMBT): ASTM C1260 [17] and ASTM C 1567[18], the reference length and the accelerated length changes were measured every two days.

DOI:10.4186/ej.2012.16.3.101

Acceleration was accomplished by immersion of the specimens in 1N NaOH solution at 80°C. The measurements ended at 28 days.

3.3.2. Screening Test

After the final measurement, specimens were broken and uranyl acetate solution was sprayed on the freshly broken surface. The surface was then, rinsed off with distilled water and observed under UV light. This method was proposed by Natesaiyer and Hover [20] and has been accepted as an alternative method in ASTM C856-04 Annex [21].

4. Results and Discussion

4.1. Aggregates Identification

Mineralogy investigation, using XRD analysis, confirmed that the chosen greywacke from this source composed of calcite (12.3%), quartz (27.6%) and albite or feldspar (27.5%), Muscovite (16.3%), Microcline (3.5%), and Clinochlore (10.6%), were also present. Crystalline formations of the oxides are as shown in Fig. 2.

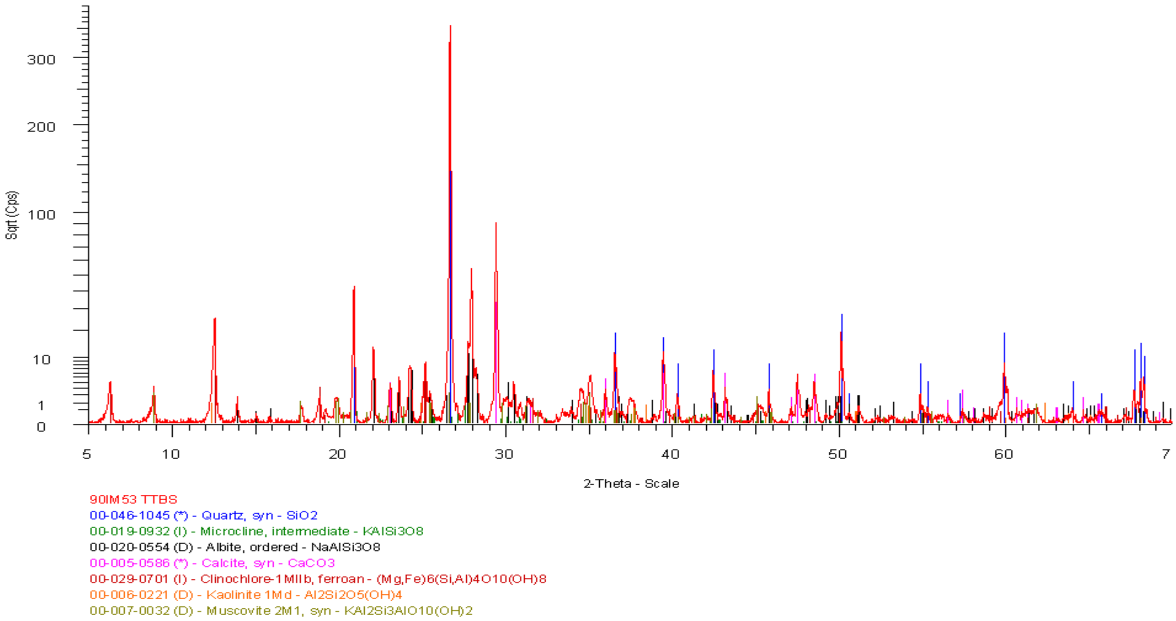

Fig. 2. XRD analysis for composition of greywacke.

4.2. Length Changes

The expansion test results of the control and the fly ash cement mortar bars, are shown in Fig. 3. Expansion of the control mortar specimen (M) was 0.167% at 16 days after casting, with continuously increasing trend. Compared to the average expansion data of 0.23% from the preliminary study of similar type and grading from the same source of aggregate and using the same testing method as shown in Fig. 4 [14], the average expansion of aggregates was slightly less. The differences could be from the natural variations in aggregate properties. However, the observed trend in this study indicated reactivity of the aggregate.

The uses of fly ash (20%, 35% and 50%) in mortar samples M/PFA20, M/PFA35 and M/PFA50 yielded clear differences in effectiveness in expansion reduction. These expansions were 0.10%, 0.04% and 0.03% compared to that of 0.167% of the control, at 16 days after casting, with trend lines suggesting continued expansion beyond the 16 days. At 30 days, M/PFA50 yielded lowest average expansion of 0.067%, compared to that of 0.434% of the control. M/PFA20 did not show an impressive expansion reduction, compared to the higher percentage replacement. A previous study report satisfactory expansion reduction with higher percentage of Class C fly ash, or lower percentage of class F fly ash [22], the results of this study followed the same trend.

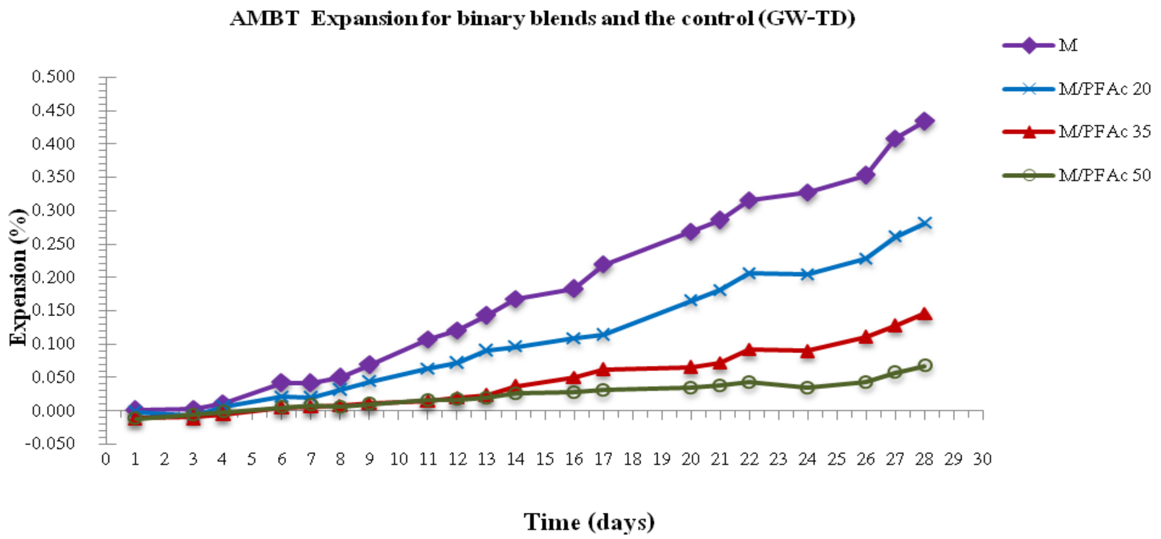

Fig. 3. Development of (average) expansion with time of binary blends and the control (M).

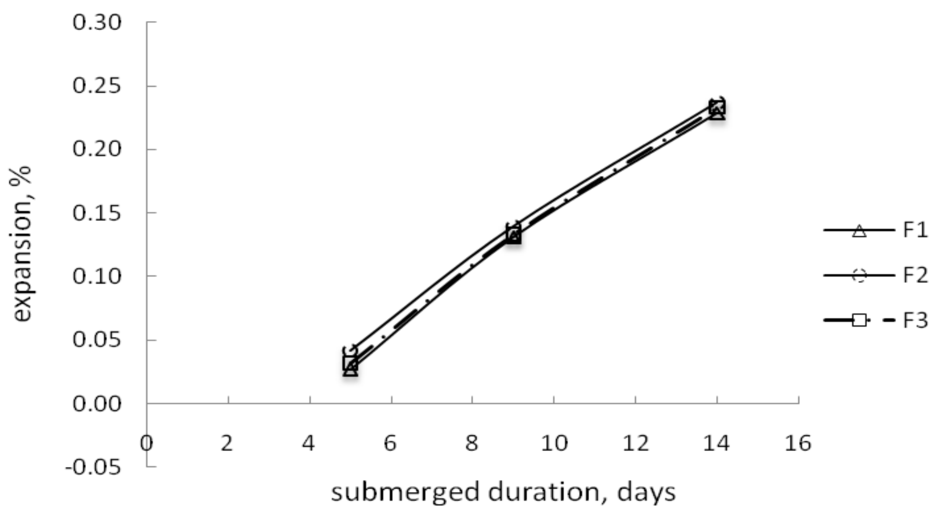

Fig. 4. Development of expansion with time of greywacke aggregates from same source, from preliminary study [14].

4.3. Fluoresced Rim Examination in Screening Test

From Fig. 5(a), several patches of fluoresced rims were observed in control specimen as indicated by red circles. Compared to (a), many reflected rims were also observed in the 20% replacement in (b), but less in the replacement of 35% in (c) and of 50% in (d).Rectangles show fluoresced aggregates' rim with internal crack. Although these results are qualitative, they suggested that increasing fly ash increased the control of aggregate reactivity. The finding was supported by expansion test results.

DOI:10.4186/ej.2012.16.3.101

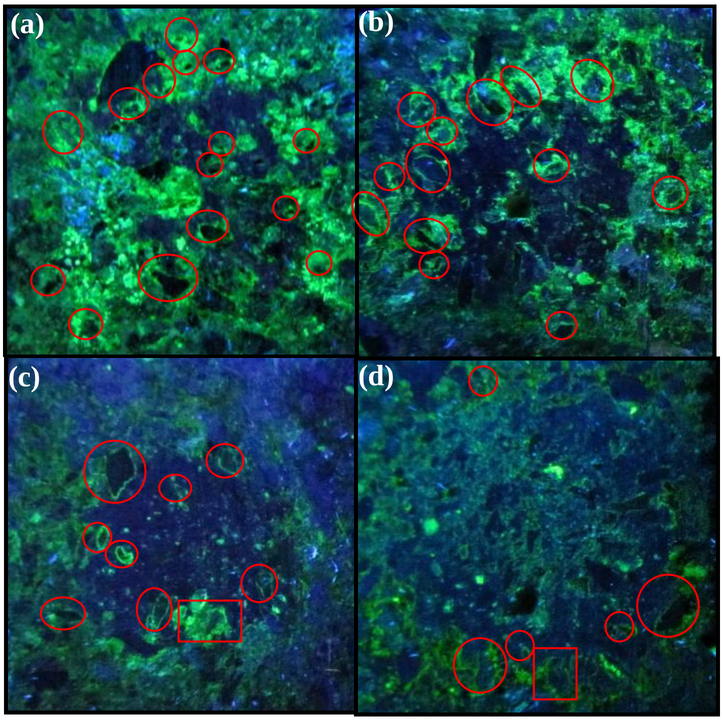

Fig. 5. Observed fluoresced rims in the cut samples with different fly ash after accelerating: (a) 0%, (b) 20%, (c) 35% and (d) 50%.

5. Conclusions

For the materials used and the applied test methods in this study, the following conclusions were drawn:

(1) Moderate calcium oxide fly ash reduced ASR expansion of mortar bar.
(2) From AMBT test results, percentage of fly ash replacement of 50 provided the greatest expansion reduction, expansion from 0.17% to 0.03% and from 0.43% to 0.07% in 16 and 30 days after casting, were observed, respectively.
(3) Screening test from mortar bar samples showed the same trend as expansion test results.
(4) Using the proper percentage replacement, local fly ash showed the potential as supplement material for mitigation if the reactive aggregates must be used.

Acknowledgements

This study is funding supported by the Kasetsart University Research and Development Institute. The supported materials and their information as well as some conducted test from Siam Research and Innovation Co., LTD. and CPAC Inc. Ltd, are greatly appreciated. Also partial equipment support from Rajamagala University of Technology Phra Nakhorn is recognized.

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