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EFFECT OF FLY ASH TYPE ON ASR EXPANSION OF POTENTIAL REACTIVE AGGREGATES

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ABSTRACT

This paper investigated the suppression effects of different fly ash types on expansion behavior of mortar bar, using the potential reactive aggregates from the east coastal area of Thailand. The accelerated mortar bar test and petrographic screening methods were used to identify potential aggregates before further study. The sedimentary rock, greywacke from large scale aggregate production companies was used to study the influence of different pozzolan; Class C Thai fly ash and class F Japanese fly ash, on their expansion. Different fly ash influenced differently in expansion control. The effect of fly ash for ASR mitigation depended on fly ash type, percentage replacement and aggregates type. Direct dependency of pozzolanic reactivity on expansion was not clearly observed from this study.

Keywords: Reactive aggregates, expansion, accelerated test, greywacke, fly ash.

1. INTRODUCTION

The reported expansion and cracking due to the chemical deterioration; Alkali silicate reaction (ASR) has been reported worldwide in several types of infrastructure since 1940 (ACI221.1R 1998,Crucq 2005, Thomas and Ramlochan 2002). However this deterioration type is not prevalent in Thailand. The first reported case in 2009 led to the awareness of the lacking local data for mechanism understanding, prevention and mitigation measures for the future case (Sujjavanich, Suwanvitaya et al. 2011). For the new construction where the uses of potential reactive aggregates are uncertain or unavoidable, mitigation measures become an important issue.

The use of pozzolan particular fly ash has been successfully reported for expansion control in many cases (D.S. Lane and Ozyildirim 1999; S.Diamond 1981). However, different effects are recognized, depend on nature of ash such as types, chemical composition and mineralogy as well as the mineralogy and reactivity of aggregates (L. J. Malvar 2006; Michael Thomas 2011).

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The benefit of fly ash on expansion control may result from the lower alkali from fly ash-cement replacement system, lower the alkali hydroxide concentration in pore solution and lower the Ca/Si ratio of CSH with increase the negative charged surface and the better ability to retain more alkali (Na+K) (M.S.Y. Bhatty and N.R. Greening 1978; Michael Thomas 2011; S.-Y. Hong and F.P. Glasser 1999). Although the use of local fly ash in Thailand's construction industry has been reported for more than a decade, there is a little information on fly ash for ASR expansion control of aggregates is available(Somnuk TANGTERMSIRIKUL 2005; Sangsuwan.C and Sujjavanich.S 2011).

Since processed aggregates from some sources in the east coastal area of Thailand have been reported potentially reactive (Sujjavanich S., Wonkhamchan W. et al. 2012), this study aimed to investigate the possibility and effectiveness of fly ash for mitigation measures.

2. RESEARCH OBJECTIVES AND ITS SIGNIFICANCE

This paper aims to verify the effectiveness of different fly ash type; the local high calcium oxide fly ash from Thailand and the low calcium oxide fly ash from Japan, in suppressing ASR-induced expansion of greywacke aggregates. The results of the study are expected to provide the information on expansion behavior due to the use of local potential aggregates and the different fly ash types.

3. EXPERIMENTAL PROGRAM

3.1. Materials

Local aggregates and two fly ash types were used throughout this study.

3.1.1. Aggregates

Greywacke from one aggregate mine in the east of Thailand, with the production rate larger than 150 tons/hour using for construction industry was used in this study. This aggregate was identified as a potentially reactive aggregate in the previous study (S.Sujjavanich, et al. 2011). Several concrete structures using greywacke aggregates were reportedly affected from ASR (Richardson 2005). In addition, this rock type is likely to provide additional alkali to the system from long term leaching and worsen the ASR reaction (Thomas, et al. 2011).

Detailed mineralogical study of the aggregate in Table 1. was conducted to provide information on the degrees of reactivity of the materials. Aggregates which were crushed and graded in accordance with the ASTM requirement were used throughout this study(American Society for Testing and Materials 2003).

3.1.2. Fly ash

Two types of fly ash (FA) in this study are Thai fly ash and Japanese fly ash. Thai lignite fly ash (class C) from the main source of Thailand; Mae moh are spherical particles with mean diameter of 1.83µm with total amount of SiO_2 Al_2O_3 and Fe_2O_3 70.36%, Cao 18.12%, SO_3 3.55%, Na_2O 1.33% and K_2O 2.30%. (Innovation and Technology Division 2010). This leads to the calculated value of $Na_2O_{equiv.}$ Of 2.84% .

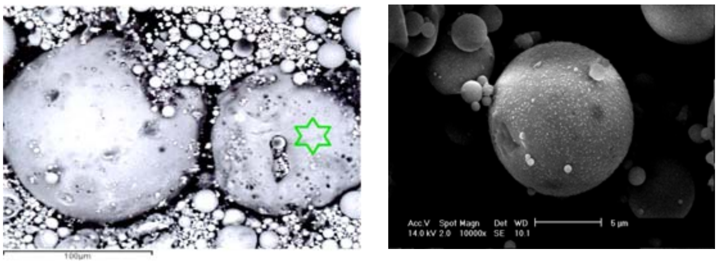
Spherical Japanese fly ash, a typical class F which is commercially available in Japan composed of the total amount of SiO_2 Al_2O_3 and Fe_2O_3 95.24%, Cao 0.629%, SO_3 0.188%, Na_2O 1.053%, K_2O 0.238%. These higher content of SiO_2 and Al_2O_3 accompanied with the significantly lower content of CaO are observed, compared to those of Thai fly ash.. The slightly lower calculated $Na_2O_{equiv.}$ of 1.21% is lower than that of Thai fly ash.

3.1.3 Cement

Commercially available Type I Portland cement was used.

Table 1: Chemical composition of Greywacke aggregate (Innovation and Technology Division 2010)

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
FA(T)	36.35	19.86	14.15	18.12	2.82	1.33	2.30	-	3.55	0.55
FA(J)	66.89	25.36	2.98	0.63	0.26	1.05	0.24	-	0.19	



Particle shape of High calcium oxide fly ash(left) and low calcium oxide fly ash (right)

4. RESULTS AND DISCUSSION

The results of the tests are as follows:

4.1 Aggregates identification

The XRD analysis and mineralogy investigation of the greywacke from this source are shown in Fig.1.The composition are calcite (12.3%), quartz (27.6%) and albite or feldspar (27.5%), Muscovite (16.3%), Microcline (3.5%), and Clinochlore (10.6%). Some compositions particular quartz and feldspar are in same range of some reported greywacke as a slow late type (O.Mielich and H.W.Reinhardt 2009).

The observed scattering of sand stone and the shale stone likely suggested the possible slump deposit of rock fragment during rock formation. The quartz is mainly observed. In base material between crushed particles, lots of the chloride (Chl) and the Illite (Ill) and a little muscovite and the cryptocrystalline quartz(Cry-Qtz) are observed. A little metamorphism might be occurred.

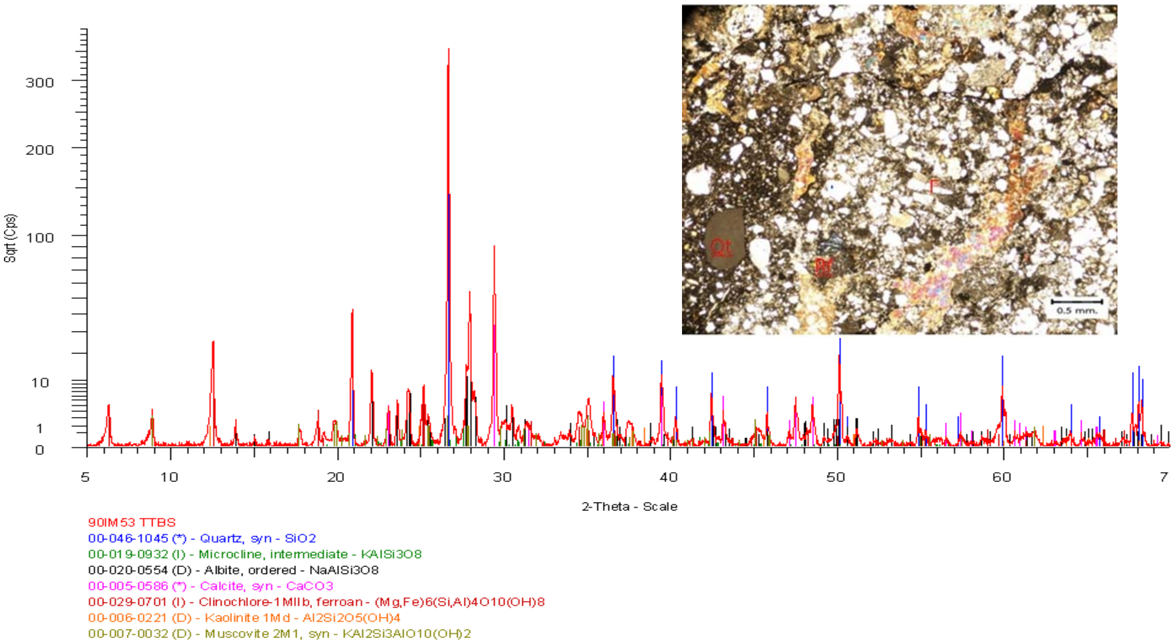


Fig.1. XRD analysis for compositions of greywacke.

4.2 Length changed

The results of accelerated expansion tests of mortar bars (AMBT) using greywacke aggregates, under curing conditions in 1N NaOH solution at temperature of 80°C. were shown in Fig. 2. The average expansion was larger than that of 0.20% at 14 days of immersion, the limit suggested by ASTM C-1260. The clear trend of continuous expansion indicated potentially deleterious expansion and the potential reactivity of aggregates from this source.

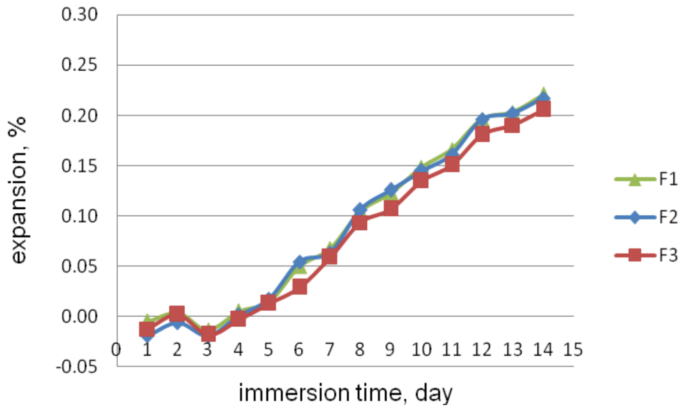


Fig.2. Development of expansion with time of the control mortar bars.

4.3 Effects of different fly ash types

Although fly ash has been world widely recognized for its potential capacity in ASR expansion control, it's not the case for all fly ash. The high Cao content of lignite fly ash has been recognized for its potential capacity in ASR expansion control (Malvar and Lenke 2006). However, some works indicated the unsuitability of high calcium oxide fly ash (> 10%) for ASR mitigation(Glauz D.L., Roberts D. et al. 1996).

Two different fly ash with significance difference in calcium oxide content were used in this study. The expansion test results of the control and the fly ash cement mortar bars with 20 % of cement replacement are shown in Fig.3. Expansion of the control (F-control) was 0.20% at 14 days after immersion or 16 days after casting, with continuously increasing trend. The samples with high calcium oxide fly ash (F-high CaO) did not show an impressive expansion reduction. However, the samples with low calcium oxide content significantly reduced the expansion.

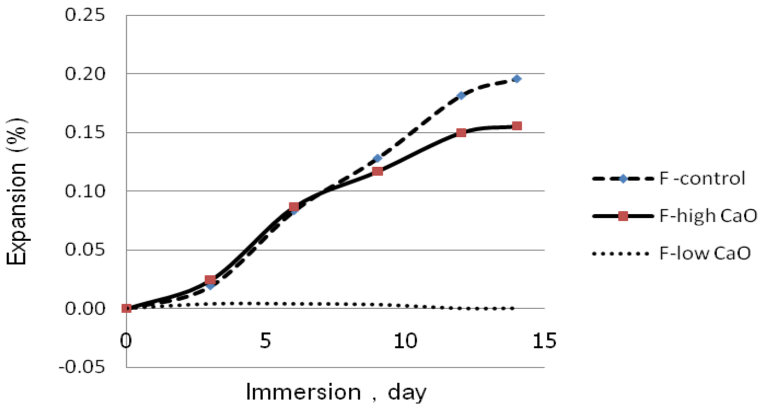


Fig.3 Expansion of mortar bar with different fly ash types

For 20% replacement, the results indicated the unsuitability of this lignite fly ash (high calcium oxide >18%) for ASR mitigation. The higher amount of cement replacement provided the better expansion control as shown in Fig.4(Sangsuwan.C and Sujjavanich.S 2011). These expansions were 0.10%, 0.04% and 0.03% compared to that of 0.167% of the control, at 16 days after casting. The trend lines suggested the continued expansion beyond this age. At 30 days, F-high CaO-50 yielded lowest average expansion of 0.067%, compared to that of 0.434% of the control. The effect of fly ash type in this study followed the same trend of other scholar 's work, the satisfactory expansion reduction with higher percentage of Class C fly ash, or lower percentage of class F fly ash. However, in addition to mineralogy and chemistry of fly ash, fineness of this material are also affect its effectivenes in expansion control (Malvar and Lenke 2006).

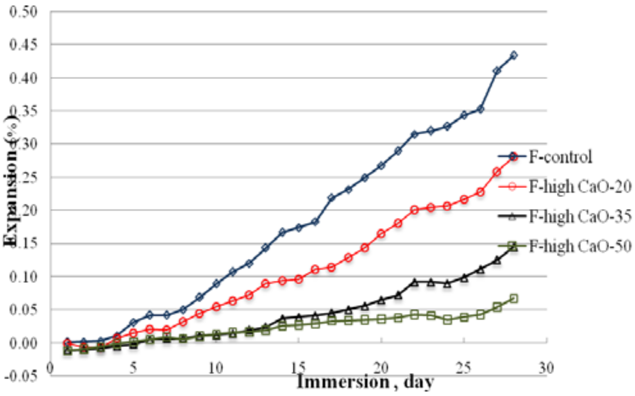


Fig.4 Expansion of mortar bar with different percentage replacement of high calcium oxide fly ash(Sangsuwan.C and Sujjavanich.S 2011)

To identify the reactivity effect of both fly ashes, the test for strength reactivity index at the age of 28 days was also conducted as a part of this study. The compressive strength ratio of sample with percentage cement replacement of 20 and without fly ash were 0.76 and 0.80 for high and low calcium oxide fly ash. The observed slight difference in pozzolanic reactivity between these two pozzolans which were cured and tested in room temperature might imply a slight dependence of normal pozzolanic reactivity on ASR expansion control. However, it is recognized that high temperature might affect pozzolanic reactivity differently.

5. CONCLUSIONS

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

(1) The studied- local greywacke showed the potential as reactive aggregates. Mineralogy and XRD analysis of the base material were in the same range of some reported slow late reactive greywacke.

(2) From AMBT test results, high calcium oxide local fly ash performed differently from the low one. The conventional percentage replacement of 20 slightly reduced expansion from ASR effect. (3) The higher percentage than 20 was required for expansion control. The largest expansion reduction at 30 days which was reduced to 0.067%, compared to that of 0.434% of the control was observed for F-high CaO-50.

(4) The low calcium oxide fly ash at the normal replacement level of 20 significantly reduced ASR expansion of mortar bar, to almost no-expansion level.

(5) The effectiveness of fly ash for expansion mitigation depended on fly ash type, percentage replacement and aggregates type.

(6) Using the proper percentage replacement, the local fly ash showed the potential as supplement material for mitigation if the reactive greywacke aggregates cannot be avoided.

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