



# Concrete microstructural responses to the interaction of natural microfines and potassium acetate based deicer

Jessica M.S. Silva<sup>a,\*</sup>, Steven M. Cramer<sup>a</sup>, Marc A. Anderson<sup>b</sup>, M. Isabel Tejedor<sup>b</sup>, Jose F. Muñoz<sup>a,1</sup>

<sup>a</sup> University of Wisconsin-Madison, 2620 Engineering Hall, 1415 Engineering Dr, Madison, WI 53706, United States

<sup>b</sup> University of Wisconsin-Madison, 109 Water Science and Engineering Laboratory, 660 N. Park St., Madison, WI 53706, United States

## ARTICLE INFO

### Article history:

Received 13 July 2012

Accepted 4 October 2013

### Keywords:

Microfine  
Concrete (E)  
Microstructure (B)  
SEM (B)  
Alkalis (D)

## ABSTRACT

This study investigates the chemical interactions and microstructural changes natural microfines induce in concrete laboratory specimens subjected to potassium acetate deicer. Microfines (material smaller than 75  $\mu\text{m}$ ) from 5 aggregate sources around the US were characterized and methodically added to concrete. Microscopy and petrographic testing were conducted with the goal of determining why the combination of the microfines and deicer causes deterioration of concrete. Microfines containing a high content of phyllosilicates showed the greatest impact on the concrete structure when exposed to potassium acetate deicers. In all cases, crystals of potassium sulfate were found in abundance throughout the system. ASR gel was not found to be the major form of deterioration although the degradation mechanism mimicked these effects.

© 2013 Elsevier Ltd. All rights reserved.

## 1. Introduction

ASR related problems were reported in western states where high fines were observed in paving concrete later subjected to potassium acetate deicer. It was suspected that aggregates with high quantities of microfines were contributing to the interaction of the deicers and concrete. It has been suggested previously that airfield pavements that have been exposed to potassium acetate deicers have been linked to deterioration from the alkali silica reaction (ASR) [1]. To determine if microfines have an additional impact to pavement deterioration, the “dirty aggregates” used possessed a layer of microfines (particle size smaller than 75  $\mu\text{m}$ ). It is generally recognized that during the mixing of concrete a layer of microfines that coat the aggregates can totally or partially detach from the aggregate and enter the bulk region of the mortar or remain attached to the surface of the aggregate and form a part of the interfacial transition zone (ITZ) [2]. Based on location, one can imagine two different scenarios by which microfine coatings may affect the quality of concrete; one by changing the chemistry of hydration and the associated microstructural properties of the mortar, and the other by disrupting the bond between the aggregate and the cement paste [2–4].

In a general classification, naturally occurring microfines are typically divided as stone dust, clay particles, or calcium carbonate [3,5]. It has been shown that the mineralogy of the material will dictate

the changes that may occur within the concrete [2,6–10]. It is important to understand the type and quantity of microfine as some types in small quantities can add beneficial effects. However, certain materials in concrete exposed to potassium acetate based deicer (KAc Deicer) could combine to induce the ASR. Grattan-Bellew [11] claims that when certain types of alkali-bearing clays (such as illites) are present within the matrix of certain rock types, these clays can potentially dissolve upon exposure to alkaline solutions to further augment the alkali levels in the concrete, and thus increase the potential for developing the ASR. On the other hand, the microfines could be participating in some other reaction mechanism responsible for deterioration. As reported by Rangaraju ASR was found in several airfields however, it was not experimentally confirmed in each airfield exposed to deicer leaving some interactions to be defined that maybe impacting the deterioration seen [12].

The overall objective of this study was to determine the role that microfines play in the development of concrete deterioration when exposed to KAc Deicer. The research involved work predominantly in the laboratory aimed at: 1) determining the potential for deterioration of concrete in the presence of KAc Deicer in the absence and presence of mineral fines; and 2) developing an understanding of the mechanism by which microfines affect the micro-structure and hydration products in concrete with fines introduced as coatings on aggregates (“dirty aggregates”). By investigating the mechanism of deterioration, mitigation techniques could be more successfully implemented in order to avoid future occurrences of deterioration. The information reported in this publication is part of a larger study, and more information regarding additional tests, for example details on expansion and material reactivity, can be found in the thesis on this topic [13].

\* Corresponding author at: University of Wisconsin-Madison, 2620 Engineering Hall (Academic Affairs), 1415 Engineering Dr, Madison, WI 53706, United States.

E-mail addresses: [jmsanfil@gmail.com](mailto:jmsanfil@gmail.com) (J.M.S. Silva), [cramer@engr.wisc.edu](mailto:cramer@engr.wisc.edu) (S.M. Cramer), [nanopor@wisc.edu](mailto:nanopor@wisc.edu) (M.A. Anderson), [mitejedo@wisc.edu](mailto:mitejedo@wisc.edu) (M.I. Tejedor), [jose.munoz.ctr@dot.gov](mailto:jose.munoz.ctr@dot.gov) (J.F. Muñoz).

<sup>1</sup> Present Address: Turner-Fairbank Highway Research Center; Federal Highway Administration (FHWA); 6300 Georgetown Pike McLean, VA 22101, United States.

**Table 1**  
Coarse aggregate and microfine material combinations used for test specimens.

Specimen type	Aggregate type	Aggregate source	Microfine source					
			CA	CO	UT	WI	WY	Control (none)
Concrete cylinders	Coarse and fine	WI	x	x	x	x	x	x
		UT	x	x	x	x	x	x
Mortar cubes	Coarse and fine	WI		x	x	x		x
		UT		x	x	x		x
Mortar bars (C1260)	Fine	WI	x	x	x	x	x	x
		UT	x	x	x	x	x	x

## 2. Materials and methods

Five different sources of natural microfines were combined with either a reactive or nonreactive aggregate to study a total of twelve combinations of these materials. Each of the various combinations can be found in Table 1. Concrete and mortar specimens were formed and subjected to various environments and then analyzed by various means in order to characterize the possible reactions occurring between the microfines and chemical solutions to which they were subjected.

### 2.1. Materials

For all specimens in this study, concrete and mortar were made from Type I Portland cement utilizing two aggregate and five microfine sources. The Type I Portland cement composition is detailed in Table 2 and conformed to ASTM C150. The aggregate material came from either Utah or Wisconsin as a known reactive granitic gravel and unreactive dolomitic gravel source respectively. The microfines were extracted from five different aggregate pit-run materials allowing for various mineralogies to be studied in hopes of determining which constituents caused the greatest effect on concrete when exposed to the KAc Deicer. The presence of carbonate and clay minerals on the microfine material was determined by X-ray diffraction (XRD) and thermogravimetric analysis (TG) and the outcomes are summarized in Table 3 [13]. The concrete and mortar poured in the laboratory from these materials were then subjected to various environments with primary emphasis on the KAc Deicer which consisted of 50% by weight potassium acetate solution in water with a corrosion inhibitor. In the concrete specimens only, one multi-component synthetic air entraining agent composed of primarily resin was employed.

The microfines were extracted from their original pit-run source material in either a washing manner or from dry sieving. In order to make a representative microfine coating, the microfines were recombined in a ratio that matched the original extracted ratio. From the collected microfines, the “dirty aggregates” were manufactured by submersing as received cleaned and dry aggregate in mixtures of water and microfines. Approximately  $1.5\% \pm 0.1\%$  (by coarse aggregate weight) microfines adhered to both unreactive Wisconsin (WI) aggregate and reactive Utah (UT) aggregate. The total quantity of microfines consisted of the aggregate coating and additional microfines added to the fine material. (An additional 3.5% based on total aggregate weight was added to the fine material.) Additionally, the microfines naturally incorporated in the plant washed coarse aggregate, were not removed for practical reasons. The Wisconsin fine aggregate contained 0.8% microfines by weight and 1.7% for the Utah fine aggregate.

### 2.2. Specimens

There were three specimen types incorporated in this study, 1) concrete cylinders, 2) mortar cubes, and 3) mortar bars. Concrete specimens were prepared to assess the impact of the microfines in concrete exposed and unexposed to potassium acetate commercial pavement deicer. The concrete mix design is shown in Table 4, and corresponding aggregate gradations fell within the ASTM C33 specifications with the exception of the added microfines. Even with large additions of air entraining agent, there was an expected difficulty in achieving the target air content. However, one agent was used for all concrete cylinder specimens with addition levels recorded in Table 4. A total of 24 concrete cylinders measuring 4 in. in diameter and 8 in. in length were formed from the various microfine/aggregate combinations and subjected to two environments. The parameters of the concrete specimens are found in Table 4. One set of each of the twelve combinations of materials was subjected either to 100% humidity at 38 °C (100 °F) or submersed in KAc Deicer solution at 38 °C (100 °F).

The mortar cube specimens measured 2 × 2 × 2-in. (51 × 51 × 51-mm) with two 3/4-in. (22-mm) microfine-coated stones embedded. Microfines were not added to the bulk of these specimens as in the concrete specimens leaving the total microfine content only that which adhered to the aggregate. Three of the microfine sources with both types of aggregates underwent testing (see matrix of samples in Table 1). In one cube two non-reactive (Wisconsin) stones were placed and in a second cube two ASR reactive (Utah) stones were placed. Both stones from each cube were coated with one source of microfines except in the case of the control. A depiction of the cubes is displayed in Fig. 1. The three microfines were selected based on their unique characteristics. Mortar was mixed in the ratio of 2:1 sand:cement, and 0.45 w/c with no air entraining admixture. The mortar was mixed and poured in two even layers. At each layer, one coated aggregate piece was placed into position. The cubes were cured under wet burlap for 24 h. After this initial curing, the specimens were submersed in one of three solutions at one of two temperatures, either 38 °C (100 °F) or 80 °C (176 °F). The solutions were 1) water, 2) solution of 0.8 M NaOH and 5 M potassium acetate, and 3) 5 M potassium acetate. The microstructure of the stone-cement paste interface was analyzed at 4 days and 56 days after casting.

Lastly, the mortar bar specimens were created according to the ASTM C 1260 standard with the exception of the microfine content. Microfines were added in the same proportion as the concrete specimens (11.6% of the fine aggregate weight) in addition to the required material as identified in the standard. The specimens were cured for 24 h at room temperature under wet burlap. Specimens were then submersed in 1 N NaOH at 80 °C (176 °F) and measured according the standard specifications. All microfine and aggregate source combinations were evaluated with these specimens as noted in

**Table 2**  
Cement composition in percentages.

SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	SO <sub>3</sub>	K <sub>2</sub> O	Na <sub>2</sub> O	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	Mn <sub>2</sub> O <sub>3</sub>	SrO	Total
20.05	4.64	2.68	63.31	2.39	2.52	0.43	0.23	0.22	0.13	0.12	0.06	99.48%
	Alkalis Eq. = 0.51%			C3S = 60%		C3A = 7.8%		C2S = 12.3%		C4AF = 8.2%		

Download English Version:

<https://daneshyari.com/en/article/1456341>

Download Persian Version:

<https://daneshyari.com/article/1456341>

[Daneshyari.com](https://daneshyari.com)