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5 December 2005

Mr. Craig Abernathy
Research Specialist
Montana Department of Transportation
2701 Prospect Ave.
P.O. Box 2001001
Helena, MT 59620-1001

Re: Addendum to FHWA/MT-05-005/8158-03 "Development of High-Performance Concrete Mixtures for Durable Bridge Decks in Montana Using Locally Available Materials" -
Final Report of alkali-silica reactivity testing of Montana aggregates
WJE No. 2001.2245

Dear Mr. Abernathy:

WJE was retained by the Montana Department of Transportation to help them develop a cost-effective, indigenous high performance concrete (HPC) for use in bridge deck applications. This investigation was conducted with two objectives: 1) identification of the optimum cementitious matrix and 2) evaluation of the performance of this matrix in combination with aggregates readily available in Montana. This testing was reported in the project report titled, FHWA/MT-05-005/8158-03 "Development of High-Performance Concrete Mixtures for Durable Bridge Decks in Montana Using Locally Available Materials".

BACKGROUND

Since the main objective of this project was to produce the most durable concrete possible, the potential for alkali-silica reaction (ASR) was evaluated in the locally-available fine and coarse aggregate sources proposed for use in the HPC. ASR, a reaction between active forms of silica that are present in certain kinds of natural aggregate and the alkali environment produced in concrete by portland cement, is harmful to concrete since the alkali-silicate gel that is produced over time will swell and may produce cracking in the concrete. Repair of structures affected with ASR cracking is very difficult and replacement is often the only solution. Therefore, ASR is a potential limiting factor in the long-term performance of the concrete and so must be considered in the overall selection of materials when designing concrete mixtures for maximum durability.

The aggregate sources tested for ASR reactivity were selected to geographically cover the State and are from JTL Group-Billings, JTL Group-Missoula, United Materials - Great Falls and Fossum Redi-Mix - Glasgow. This study was initiated because little information was available regarding the reactivity of these aggregates.

The ASR investigation was conducted in a preliminary phase and then, when this preliminary data suggested more work was needed, in an in-depth phase. Preliminary testing was performed to determine the potential for the selected Montana aggregates to develop ASR using the rapid ASTM C1260 "Standard Test Method for Potential Alkali Silica Reactivity of Aggregates (Mortar Bar Method)." The initial phase of the ASR testing was reported in the original project report. This testing indicated potentially deleterious expansion may occur with some Montana aggregate sources. The C1260 mortar-bar test is very severe and may result in aggregate being classed as potentially reactive when it is not reactive. However, it is an inexpensive, rapid and definitive test to determine whether an aggregate is unreactive. In other words, if the aggregate is shown to be innocuous further testing is usually unnecessary.

Because all of the Montana aggregates tested in this study with ASTM C1260 demonstrated potential for deleterious behavior, a second evaluation phase was initiated. The second phase consisted of 1) a petrographic examination (ASTM C295) of the fine and coarse aggregate samples to identify the reactive materials in the aggregate and 2) testing according to ASTM C1293 "Standard Test Method for Concrete Aggregates by Determination of Length Change of Concrete Due to Alkali-Silica Reaction". The complete findings of the petrographic examinations are provided in the project report, but can be summarized by stating that the content of potentially deleterious particles in the coarse aggregates from the four sources examined ranged from 19.7 to 35.0%, and in the fine aggregates from 9.8 to 22.8%. The readily available forms of reactive particles were much less, however, the potential for ASR exists in all sources.

The ASTM C1293 testing procedure is the ASR-related test method that most closely simulates in-place aggregate performance and is generally considered to conclusively determine whether ASR may be expected in the field. However, this involves long-term testing, taking up to two years, and the results of the testing program were not available at the time that the final report on the HPC mixture development study was completed. The purpose of this letter is to provide those longer-term results.

TEST METHODS

The C1293 test is conducted on concrete, not mortar as is used in the ASTM C1260 test procedure. The concrete is produced with the fine and coarse aggregates proportioned in the same ratio used in the actual mix design but with an artificially high alkali content, achieved by adding sodium hydroxide flakes to produce a Na_2O equivalent alkali content of 1.25% by mass of cement. Since the final HPC mixtures generated during the mixture optimization phase of this study contained supplementary cementitious materials (SCMs), two rounds of testing were conducted: 1) the ASTM C1293 test was conducted using the standardized procedure on the aggregate alone and 2) a modified ASTM C1293 test, substituting candidate cementitious matrix combinations, was also conducted to assess the impact of the SCMs on the performance of one of the aggregate sources in this modified cementitious paste. The aggregate that appeared most susceptible to ASR based on ASTM C1260 testing and petrographic analysis is from Billings and so this aggregate was selected for testing using the modified C1293 test. Four cementitious concretes were tested. They were chosen based on the mixture designs examined in the durability testing program containing additions of 5% silica fume only, 7% silica fume and 20% slag, and 7% silica fume and 20% Class C fly ash, and an additional mix containing 5% silica fume and 20% Class F fly ash. All replacements are given by volume of cement.

TEST RESULTS

The aggregate potential for ASR is classified according to the Appendix to the ASTM C1293 method, which states "Work has been reported from which it may be inferred that an aggregate might reasonably be classified as potentially deleteriously reactive if the average expansion of three concrete specimens is equal to or greater than 0.04% at one year."

The expansions of the concretes produced with the four aggregate types in the ASTM C1293 test are presented in Figure 1. As can be seen in these graphs, only the United Great Falls aggregate did not exceed the potentially deleterious threshold of 0.04% at one year. However, the expansion continued through two years suggesting that, despite "passing" the test guidelines, this aggregate may also be susceptible to long-term ASR, if conditions are unfavorable.

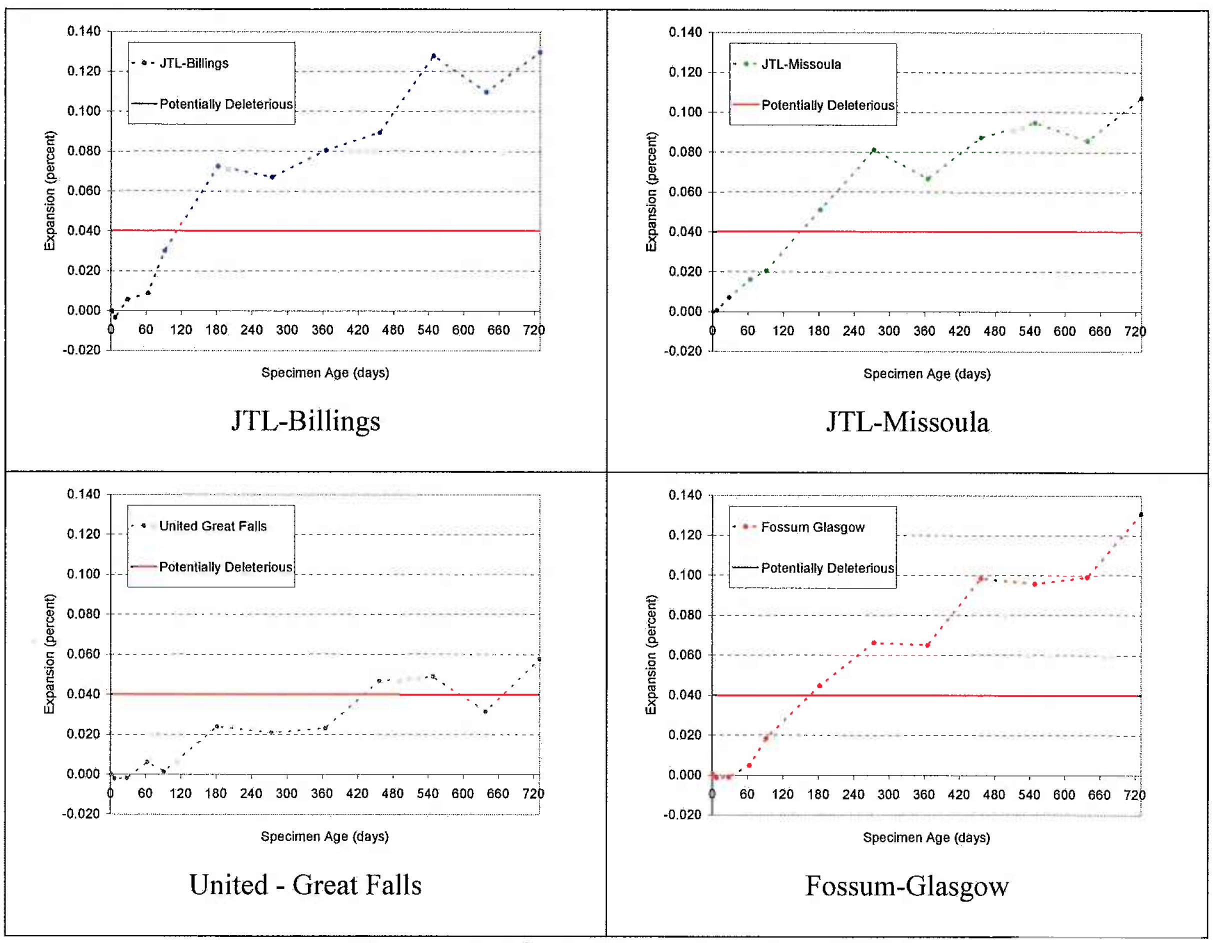

Figure 1. C1293 Results for all tested sources

During testing using the modified version of the C1293 test, the data representing the initial measurements of the specimens was inadvertently destroyed and so this test was conducted twice. The combined results of both tests are given in Figure 2, which was generated by combining the six months of data from the second iteration of this testing with the last eighteen months of measurements from the first. The actual data from this testing and the standard C1293 testing is given in the appendix of this letter. Figure 2 shows the influence of each SCM combination relative to the expansion measured with the JTL-Billings aggregates in a cement-only matrix. All four SCM combinations effectively eliminated all expansion in this test.

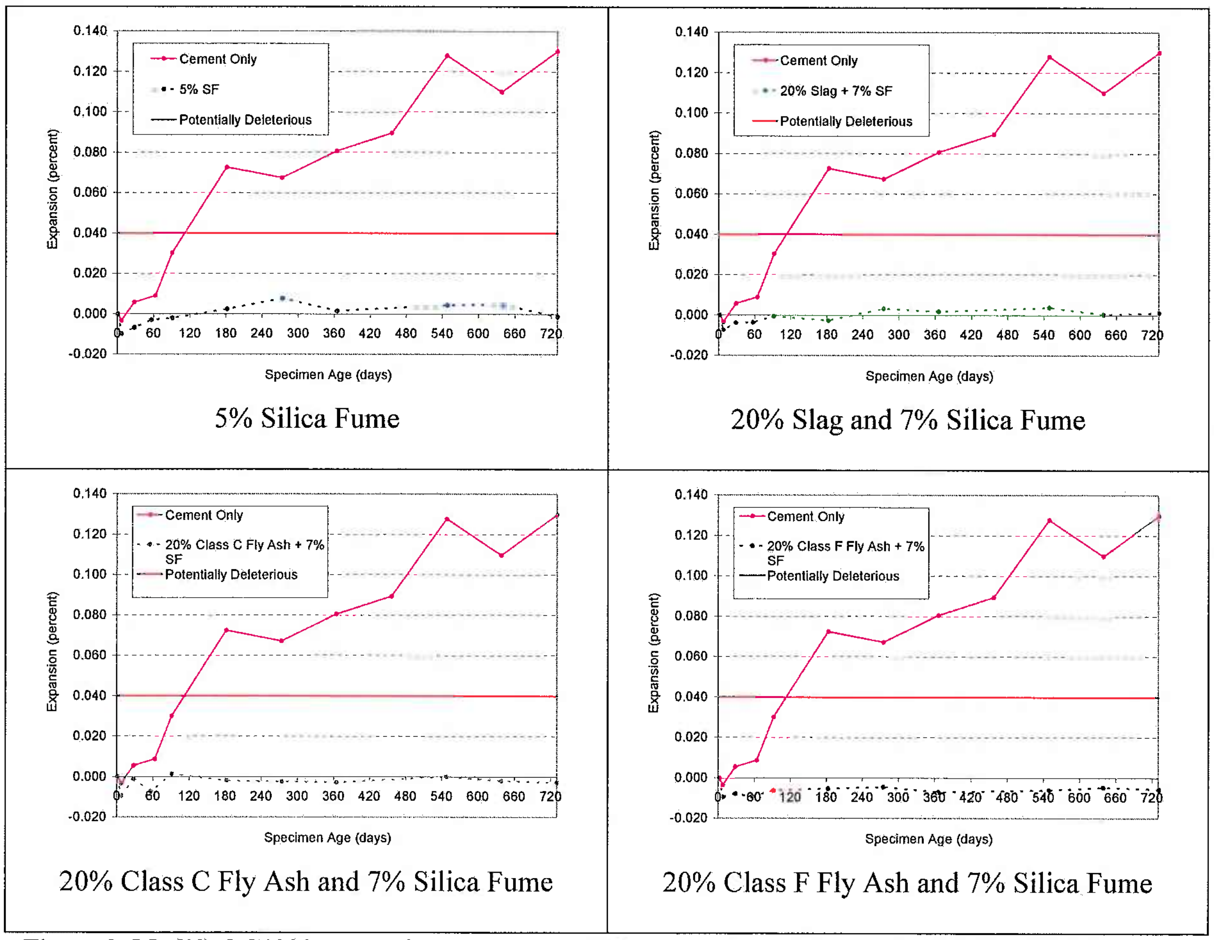

Figure 2. Modified C1293 results for combinations of SCMs and JTL-Billings aggregate compared with JTL-Billings performance in cement only concrete.

SUMMARY

Testing using ASTM C1260 and C1293 procedures and the petrographic examination suggest that three of the four aggregate sources are susceptible to potentially deleterious ASR, and the fourth may also be marginally at risk. However, all four of the concretes produced with the JTL-Billings aggregates and the proposed SCM combinations saw little or no expansion. Therefore, it is strongly recommended that concretes produced using this aggregate contain silica fume or silica fume with some other form of SCM. It should be noted that the actual performance on any other combination of aggregates and SCMs not tested here can only be predicted based on direct testing. This testing also can not predict field performance that may be affected by other environmental factors.

Please call if you have any questions concerning these results.

Very truly yours,

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

John Lawler/pts

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Associate III

Paul D Krauss

Paul D. Krauss, P.E.
Project Manager

Appendix - Expansion of C1293 and modified C1293 Specimens

Expansion in ASTM C1293 testing (cement only)

Age (days)	Expansion (%)			
	JTL-Billings	JTL-Missoula	United Great Falls	Fossum Glasgow
1	0.000	0.000	0.000	0.000
7	-0.003	0.001	-0.002	-0.001
28	0.006	0.007	-0.002	-0.001
63	0.009	0.016	0.006	0.005
91	0.030	0.021	0.001	0.018
182	0.073	0.051	0.024	0.045
274	0.067	0.081	0.021	0.066
365	0.081	0.067	0.023	0.065
456	0.089	0.087	0.047	0.098
548	0.128	0.095	0.049	0.096
638	0.110	0.086	0.031	0.099
730	0.130	0.107	0.058	0.131

Expansion in Modified ASTM C1293 testing (SCM combinations)

Age (days)	Expansion (%)							
	5% SF		20% Slag + 7% SF		20% Class C Fly Ash + 7% SF		20% Class F Fly Ash + 7% SF	
	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
1		0.000		0.000		0.000		0.000
7		-0.010		-0.007		-0.010		-0.009
28		-0.007		-0.004		-0.001		-0.008
56		-0.003		-0.004		-0.007		-0.009
91		-0.002		0.000		0.001		-0.006
182	0.000	0.002	0.000	-0.003	0.000	-0.002	0.000	-0.005
274	0.005	0.001	0.006	0.000	-0.001	0.000	0.001	-0.010
365	-0.001		0.004		-0.001		-0.002	
548	0.002		0.006		0.002		-0.001	
638	0.002		0.003		0.000		0.001	
730	-0.004		0.004		-0.001		0.000	