Alkali-Silica Reactivity in the State of Montana

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1 Problem Statement

Concrete can be susceptible to expansive reactions between alkalis in the portland cement and reactive forms of silica in the aggregates, which can ultimately reduce the lifespan of the concrete resulting in costly repairs or even replacement. While alkali-silica reactivity (ASR) has been documented as an issue in many states, little work has been conducted to determine the presence/potential of ASR in Montana.

2 Background

While research on ASR in Montana is scarce, the research that has been conducted thus far indicates that some of Montana's aggregate sources are susceptible to ASR [1, 2]. In particular, Lawler and Krauss [2] tested four aggregate sources from geographically diverse areas in Montana, and found three of these aggregates to be reactive, with the fourth being somewhat reactive. They also demonstrated that the reactivity of these aggregates could be mitigated by the use of supplementary cementitious materials. The Montana Contractor Association (MCA) recently sponsored a project to establish a database of ASR tests that have been conducted in the state by various sources (e.g., contractors, batch plants, and testing companies). In particular, ASTM C1260 and C1293 results were sought. However, the researchers in this investigation found that the majority of tests that have been conducted in the state have successfully included supplemental cementitious materials to mitigate potential ASR reactions. Thus, these tests are not useful in determining the underlying reactivity of the aggregates.

Despite the apparent potential for ASR in Montana, no cases of actual ASR have been documented in the state. The lack of documented cases may be due to several factors. First, cases may exist, but have not had an outlet for documentation. Further, ASR occurs in the presence of moisture and the relatively dry Montana climate may be preventing/reducing deleterious ASR. Finally, the use of supplementary cementitious materials and chemical admixtures, which have become more common in conventional concrete mixtures in the state of Montana, may be reducing the presence of ASR.

3 Objectives

The primary objectives of the proposed research are to evaluate the potential for deleterious ASR in the state of Montana, and to develop a testing protocol for identifying potential reactive aggregates. This research will also identify/document existing ASR damage in the state, and investigate the potential underlying geological features that may contribute to the presence of reactive aggregates. Finally, this research will explore the efficacy of potential mitigation techniques employed to limit the effect of ASR.

4 Business Case

This research will provide MDT with a better understanding of reactive aggregates (including severity) and a better understanding of potential ASR issues in the state of Montana. This information will be helpful in promoting sustainability and extending the service life of Montana concrete pavements and structures. Further, the collaboration with the Montana Contractors Association will increase the impact/benefit of this research, as they too would help disseminate results and use this information to increase the service lives of concrete pavements and structures.

5 Research Plan

The proposed research will be carried out in two phases. The first phase of research, proposed herein, will be focused on developing an ASR testing protocol suitable for Montana aggregates, and confirming/documenting cases of ASR damage in the state. The second phase of research (to be proposed at a later time) will involve testing the reactivity of numerous systematically selected fine and course aggregate sources from across the state, with the testing protocol developed in the first phase of research. The second phase of research will confirm the efficacy of the testing methods in the proposed protocol, and it will identify potential reactive aggregate sites in the state. Test results from both phases of research will then be compared to geological survey maps to determine any correlations, and to evaluate the potential of using these maps to identify other reactive aggregate sources. Further, this information may be used to develop a map of potential reactive aggregates in the state.

The first phase of research will begin with a literature review on the topic (Task 1). Task 2 will consist of developing a suitable/reliable testing protocol for aggregates in Montana. Potential cases of ASR in the state will be confirmed/documented in Task 3. Finally, all test results will be fully analyzed and a final report will then be produced that documents all work performed and results obtained (Task 4).

Task 0 – Project Management

The Principal Investigator for this project will manage the project in terms of contractual compliance, budget and schedule, administrative tasks, and communications with the Technical Panel. Dr. Michael Berry of the Civil Engineering Department at Montana State University will serve as the Principal Investigator for the project. He will be the primary contact and assume the majority of the project management responsibilities.

Major deliverables (e.g., quarterly progress reports, task reports, final report) will follow MDT reporting requirements and formats, and will first be sent to the Technical Panel for review and comment.

Task 1 – Literature Review

As this research moves forward, it is essential to be aware and take advantage of any work completed to date by other investigators/organizations. A comprehensive literature review will be conducted to evaluate the state-of-the-practice, and recent advances in ASR detection/mitigation. For example, the feasibility of using a newly developed methodology [3] for testing for reactive aggregates will be investigated; this methodology is a hybrid between the existing ASTM C1260 and ASTM C1293 testing methods, and has been shown to provide accurate results in significantly less time than the ASTM C1293 testing protocol (56 days rather than 1 year).

This literature review will also include an investigation into existing specifications of the Federal Highway Administration (FHWA), the Federal Aviation Administration (FAA), and neighboring state departments of transportation regarding testing/mitigation of ASR, and the supporting documentation that led to these specifications.

Task 2 –Determination of ASR Testing Protocol

This task will be focused on developing a quick/reliable testing protocol for Montana aggregates, and will take into consideration what is learned in Task 1. This task will also take into consideration existing test data that has been gathered by private and public entities across the state.

This testing protocol will be used in the second phase of research to confirm the efficacy of this methodology, and to determine the reactivity of Montana aggregates. Based on what is learned in the second phase of research, this methodology may be modified accordingly.

Task 3 –Identify and Document Cases of ASR Damage in the State

This task will be focused on identifying/documenting potential ASR damage in the state. This task will begin with a survey of the Montana concrete industry (e.g., aggregate suppliers, batch plant operators, contractors, concrete testing laboratories, and public agencies) to determine if they are aware of any concrete roadways/bridges/buildings/dams that have been potentially damaged by ASR. Once potential cases have been identified, the research team will travel to the site and extract samples for further testing to confirm the presence/severity of ASR.

These samples will be examined for ASR presence/severity using several methods. First, the concrete samples will be tested with the Los Alamos Staining method [4] to determine the presence of ASR;

however, this testing method is incapable of determining the severity of ASR expansion, and subsequently if ASR is the primary cause of the observed damage. Therefore, after a positive identification of ASR, the samples will also be examined through petrographic analyses. Specifically, the samples will be analyzed with the following testing protocols to definitively identify the presence/severity of ASR and subsequent damage.

- Comprehensive petrographic analysis per ASTM C856, which examines a polished slab that represents the full length of the core. This test examines air entrainment, depth of potential carbonation, characterizes cracks/microcracks, identifies rock types that are commonly susceptible to ASR, and identifies secondary deposits such as ASR gel and ettringite, which is commonly abundant in concrete with ASR.
- Scanning electron microscopy (SEM) with energy-dispersive x-ray spectrometry (EDS) per ASTM C1723. Along with higher magnifications, this test allows for in situ chemical analyses of materials in a microstructure, and with this can positively identify if ASR gel is present.
- Damage Rating Index (DRI) analysis. This analysis inventories indicators of ASR in the concrete cores by subdividing cores into 25 x 25 mm (1 x 1 in.) cells and tabulating the number of various features that are associated with ASR (examples include reaction rims, debonded aggregates, deposits of gel in voids, deposits of gel in microcracks, etc.). This provides a method to compare levels of deterioration between different cores.

Once identified, the test results and key aspects of the concrete samples will be documented (e.g., location, potential gravel pit where aggregates originated and the underlying geographical features, average humidity, average temperature, exposure, etc.) In addition to documenting this information in the final report, a website will also be created and maintained by MSU that will provide an outlet for future observations of ASR damage in the state/region.

It should be noted that the proposed budget has been developed assuming that a total of five sites will investigated. In particular, this assumption directly affects the proposed travel and contracted services budget items.

Task 4 – Analysis of Results and Reporting

The results from this work will be thoroughly analyzed in this task.

A comprehensive final report that includes all data, analyses, and recommendations will be written in conformance with MDT's standard research report format to thoroughly document the findings of this project. The report will be concise and include all pertinent information to aid state DOTs in adopting an efficient/effective way of identifying/mitigating potentially reactive aggregates. A draft report will be sent to MDT to be distributed to the Technical Panel for review and comment. The results of the project will also be disseminated, as appropriate, to the professional community through presentations at various conferences and/or through journal papers. A four-page "Project Summary Report" will be written and submitted to MDT near the end of the project to summarize the background, methodology, results and recommendations of this research.

Task reports will be written to summarize work associated with the following major activities.

- Task 1 Report—Summarize results of literature review.
- Task 2 Report—Summarize proposed testing protocol.

Quarterly progress reports will be submitted to provide updates on the administrative aspects of the project, such as progress regarding the deliverables, schedule and budget. It should also be noted that the literature review will be updated during the preparation of the final report to include any work that may have been completed after the completion of Task 1.

6 MDT Involvement

MDT will be involved in several aspects of the proposed research. Specifically, feedback from MDT will assist in determining the proposed testing protocol, and identifying potential ASR damage in the state. Further, in keeping with standard requirements, MDT will review and comment on task reports, quarterly progress reports, the final report, and the project summary report.

7 Products/Presentations

The products to be delivered during this project include the following items.

- Kick-off meeting and subsequent notes.
- Annual/interim meeting to be held after the first year of research.
- 7 quarterly progress reports.
- 2-task reports (Task 1 and Task 2).
- Annual/interim meeting.
- Draft final report and executive summary describing the research methodology, findings, conclusions, and recommendations, followed by a final report addressing comments and suggestions from the Technical Panel.
- Final presentation.
- Draft project summary report.
- Implementation report and meeting.
- Performance measures report.
- Project Poster

8 Implementation

MDT will use the information gathered in this and a potential future phase of research to guide decisions/policies related to ASR. Specifically, this research will provide MDT with a better understanding of ASR potential (e.g., existing damage, potential underlying geographical features), and a standard procedure for quantifying this potential. This work could eventually lead to modifications to material specifications requiring ASR testing for concrete aggregates.

9 Schedule

The estimated project schedule is shown in Table 1. The total proposed duration of the project is 24 months, with an estimated start date of March 1, 2018, and an estimated completion date of February 28, 2020. A draft final report will be sent to the Technical Panel two months prior to the end date to provide sufficient time for review and revision.

Table 1: Project Schedule

Task/Milestone	Quarter (after start of work)							
	1	2	3	4	5	6	7	8
Task 0: Project Management	X	X	X	X	X	X	X	X
Task 1: Literature Review	X	X						
Task 2: Testing Protocol Development		X	X	X				
Task 3: Identify and Document Cases of ASR		X	X	X	X	X	X	
Task 4: Analysis and Reporting						X	X	X

10 Budget

The total estimated cost of this project is $101,428 as seen in Table 2, with $66,428 being requested from MDT and $35,000 being supplied by MSU and a Montana Contractor's Association fund. A breakdown of contracted services is provided in Table 3, which covers the petrographic analyses of concrete samples from five locations potentially damaged by ASR. The cost per sample is also included in this table, which amounts to $3,000 per sample. It should be noted that the funds for two Los Alamos staining kits are included in this budget, which would allow for the preliminary testing of approximately 20 samples. The pay rates and benefit rates of the investigators are provided in Table 5. Projected expenditures by task are shown in Table 6. A breakdown of MDT total costs by state and federal fiscal years are provided in Table 7.

The research team was also asked by the MDT technical panel to provide an estimate of conducting the aggregate tests proposed in the second phase of this research. This additional testing is estimated at approximately $3,000 per aggregate source, which would include testing aggregates according to ASTM C1260, ASTM C1293, and the newly developed method discussed in [3]. Therefore, the total direct cost for testing 10 aggregate samples would be approximately $30,000. A 25 percent indirect cost rate would apply to $25,000 of this cost, which would amount to $6,250. Therefore, the total estimated cost of testing 10 aggregate sources from across the state would be an additional $36,250. This would bring the total estimated cost requested from MDT to approximately $102,678.

Table 2: Project Budget by Item

Item	Total
Salaries	$49,129
Benefits	$8,700
In-State Travel	$3,113
Contracted Services (Petrographic Analysis)	$15,000
Materials/Supplies (including Los Alamos Staining Kits)	$2,200
Participant Support (Graduate Student Tuition)	$10,000
Total Direct Costs	$88,143
MSU/MCA-Contribution	-$35,000
MDT Total Direct Costs	$53,143
Overhead on MDT Portion- 25%	$13,286
Total Project Cost	$101,428
Total MDT Project Cost	**$66,428**

Table 3: Breakdown of Contracted Services

Item	per sample	Budget for 5 samples
Petrographic Anslysis (ASTM C856)	$1,500	$7,500
SEM-EDS (ASTM C1723)	$750	$3,750
Damage Rating Index - DRI	$750	$3,750
Total	$3,000	**$15,000**

Table 4: Breakdown of Travel Costs

Item	Cost
Cost of Mileage (assuming 500 miles round trip)	$288
Hotel Room (2 rooms)	$200
per diam (2 people)	$66
Total/trip	$554
Total for 5 trips	$2,768
Kickoff/Annual/Final Presentation - Helena (200 miles round trip)	$345
Total	**$3,113**

Table 5: Pay Rate and Benefits

Name of Principal, Professional, Employee, or Support Classification	Hourly Rate	Benefit Rate
Michael Berry	$55.50	30%
Graduate Student	$15.14	10%
Business Mgr.	$41.77	33%
Admin Staff	$26.00	33%

Table 6: Project Budget by Task

Task	Budget
0 - Project Management	$5,816
1 - Literature Review	$16,065
2 - Development of Testing Protocol	$16,065
3 - Identify and Document ASR Damage	$38,025
4 - Final Report and Dissemination of Results	$25,457
Total	**$101,428**

Table 7: State and Federal Fiscal Year Breakdown of MDT Budget

	State Fiscal Year			Federal Fiscal Year		
	2018	2019	2020	2018	2019	2020
Total MDT Project Cost	**$11,071**	**$33,214**	**$22,143**	**$19,375**	**$33,214**	**$13,839**

11 Staffing

Dr. Michael Berry will be the Principal Investigator and will be the primary manager and point of contact with the MDT project manager. The Principal Investigator will be responsible for ensuring that the objectives of the study are accomplished, executing the project tasks, and preparing the written reports. A graduate student will also be employed on this project.

The research team is well qualified, experienced and available to conduct the proposed research. The level of effort proposed for the research team will not be changed without prior consent of the Technical Panel. The following subsections describe some of the qualifications and experience of project personnel.

11.1 Dr. Michael Berry - Principal Investigator

Dr. Berry is an Associate Professor in the Civil Engineering Department at MSU and has a research background in concrete materials, and the behavior of reinforced concrete structures subjected to earthquake excitations. More recently his work has focused on alternative materials and their use in transportation applications and structural elements. He currently serves on several ACI committees including: Committee 555 - Recycled Materials in Concrete, and Committee 306 - Cold Weather Concrete.

11.2 Graduate Student

This research will be conducted by a qualified graduate research assistant, under the direction of the PI. Specifically, the students will be responsible for conducting the literature review, collecting samples, conducting some laboratory experiments, organizing and analyzing the data, and helping to synthesize information into the final report.

11.3 Research Team Hours and Availability

It is anticipated that the proposed work associated with this research project will take 2,346 person hours. The number of hours committed to the project by each member of the research team during this time period is shown in Table 8. Key personnel assigned to accomplish the work associated with this project are generally available throughout the duration of this project. In regards to the availability of the graduate student, the proposed project is the sole project that they will be working on throughout the duration of the project. In the event that the level of effort proposed for the principal investigator requires significant modification, written consent will be sought from the Technical Panel to justify and approve this change.

Table 8: Summary of Person Hours by Task

Name of Principal, Professional, Employee, or Support Classification	Task 0	1	2	3	4	Total
Michael Berry	60	40	40	40	150	330
Graduate Student	0	500	500	500	500	2000
Business Mgr.	4	0	0	0	4	8
Admin Staff	4	0	0	0	4	8
Total	64	540	540	540	654	2346

12 Facilities

The facilities in the MSU Civil Engineering Department are sufficient for the proposed research.

13 References

1. Shrimer, F.H., *Progress in the Evaluation of Alkali-Aggregate Reaction in Concrete Construction in the Pacific Northwest, United States and Canada*. 2005, U.S. Geological Survey.
2. Lawler, J.S. and P.D. Krauss, *Development of High-Performance Concrete Mixtures for Durable Bridge Decks in Montana Using Locally Available Materials*. 2005, Montana Department of Transportation.
3. Latifee, E.R. and P.R. Rangaraju *Miniature Concrete Prism Test: Rapid Test Method for Evaluating Alkali-Silica Reactivity of Aggregates*. Journal of Materials in Civil Engineering, 2015. **27**, 10 DOI: 10.1061/(asce)mt.1943-5533.0001183.
4. Guthrie Jr, G.D. and J.W. Carey, *A simple environmentally friendly, and chemically specific method for the identification and evaluation of the alkali-silica reaction.* Cement and Concrete Research, 1997. **27**(9): p. 1407-1417.