Task 2 Report – Development of Testing Protocol

Project Title: Alkali-Silica Reactivity in the State of Montana

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1 Introduction

Alkali-Silica Reactivity (ASR) is a deleterious reaction that occurs in concrete between alkalis present in the portland cement/supplemental cementitious materials and reactive forms of silica in the aggregates. In the presence of moisture, an expansive gelatinous substance forms on the surface of the reactive aggregates, resulting in swelling and ultimately a detrimental map cracking pattern similar to that shown in Figure 1. The damage associated with ASR can lead to reduced life span, costly repairs, and/or the eventual replacement of the concrete.

The primary objectives of this 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 may ultimately investigate the potential underlying geological features that may contribute to the presence of reactive aggregates.

The specific tasks associated with this research are as follows.

Task 1 – Literature Review

Task 2 – Determination of ASR Testing Protocol

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

Task 4 – Analysis of Results and Reporting

This report documents the work completed as part of Task 2 – Determination of ASR Testing Protocol. This report provides a brief summary of the ASR-related testing methods most suitable for use in Montana, and concludes with a brief summary of the recommended testing procedure.

Figure 1: Typical ASR Crack Pattern

2 Aggregate Testing Methods

This section provides a brief summary of the ASR-related aggregate testing methods most suitable for use by MDT.

2.1 Accelerated Mortar Bar Method - ASTM C1260/C1567 – AASHTO T303

The accelerated mortar bar method (ASTM C1260/AASHTO T303) identifies the potential for reactive aggregates within 16-days [1], and is currently the most widely used method for detecting reactive aggregates. ASTM C1567 is very similar to ASTM C1260, but is focused on determining the reactivity of mixtures containing combinations of cementitious materials and aggregates, rather than on just the cement and aggregates. Both of these tests involve immersing mortar bars in an alkaline solution at 80°C (176°F) for 14 days and monitoring their expansion. While these procedures provide rapid and repeatable results, they expose the aggregates to a fairly harsh environment (with an unlimited supply of alkalis and elevated temperatures) and have been known to be overly conservative when compared to results from other testing procedures (e.g., ASTM C1293) and when compared to field performance. Further, this test method does not allow for the testing of coarse aggregates at their standard size; that is, the coarse aggregates must be crushed and sieved according to specific grading requirements.

2.2 Concrete Prism Test - ASTM C1293

This test method is known to be one of the more reliable test methods available for testing the reactivity of aggregates; however, its extended timeframe (1-2 years) limits its use in industry. The test procedure involves casting three concrete prisms with an increased alkali content, and then exposing these prisms to high humidity and elevated temperatures for 1-2 years. The expansion of these prisms is then monitored systematically over the duration of the test. If the resulting expansions are equal to or greater than 0.04% after one year, the aggregate or combination of aggregate and cementitious material is considered to potentially alkali-reactive, and additional petrographic analysis, in compliance with ASTM C856, should be conducted [2]. This method has been shown to have better agreement with field performance than ASTM C1260, however, like ASTM 1260, it has been known to produce false positive results [3]. This test method requires a less stringent procedure for the preparation of the aggregates than ASTM C1260; in that, most of the coarse aggregates do not require crushing prior to testing and can just be sieved according to the specified grading requirement.

2.3 Miniature Concrete Prism Test – AASHTO T380

The Miniature Concrete Prism Test (MCPT) is currently under development and is proving to be the most promising aggregate testing methodology of the three described in this report. This testing methodology is a hybrid between ASTM C1260 and ASTM C1293, using a similar testing procedure to ASTM C1260 with the mix design specified by ASTM C1293. The test specimens for the MCPT (cross-section dimension of 50 mm) are slightly larger than those used in ASTM C1260 (25 mm) and slightly smaller than those used in ASTM C1293 (75 mm). This size allows for the testing of coarse aggregates without the need for crushing, sieving, and combining. The test allows for the detection of potential deleterious ASR within 56 days, and can also test the potential for supplementary cementitious materials and admixtures to mitigate ASR expansions [4]. The MCPT has the advantage over ASTM C1293 by characterizing aggregate reactivity in a significantly shorter duration, while having good correlation with ASTM C1293 test results and field performance.

3 Summary

The aggregate testing methods discussed above were identified as the most suitable for use by MDT. However, the Miniature Concrete Prism Test – AASHTO T380 offers several advantages over the other testing methods. The MCPT has been shown to be more accurate than ASTM C1260, and results are available at 56-days rather than the one year required for ASTM C1293. Further, this method allows for the use of coarse aggregate in its natural state. While this methodology is promising and may be best suited for use in Montana, it is still in its infancy, and has not been widely used in practice. The Idaho Transportation Department is currently funding a research project focused on evaluating the advantages associated with implementing the MCPT within their specifications to quantify the ASR potential of aggregate sources in Idaho [5]. This project is scheduled to be completed in December 2019. In addition to this work being conducted in Idaho, as part of her Master's Thesis work at MSU, Ashton Siegner (the graduate student working on this project) will be testing several aggregate sources from across Montana using ASTM C1260 and the MCPT, and comparing results. If more resources become available, this testing could be expanded to include ASTM C1293 tests and more aggregate sources from across the state. This ongoing work will help in guiding MDT's testing protocol (including acceptance criteria), and this task will be updated accordingly.

4 References

1. ASTM, *ASTM C1260 - Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)*. 2014, American Society for Testing and Materials.

2. ASTM, *ASTM C1293 - Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction*. 2018, American Society for Testing and Materials.

3. Folliard, K., Fournier, B., Ideker, J., Shehata, M., and Thomas, M., *Test Methods for Evaluatin Preventaitve Measures for Controlling Expansion Due to Alkali-Silica Reaction in Concrete.* Cement and Concrete Research, 2006. **36**(10): p. 1842-1856.

4. AASHTO, *AASHTO T 380 - Standard Method of Test for Potential Alkali Reactivity of Aggregates and Effectiveness of ASR Mitigation Measures (Miniature Concrete Prism Test, MCPT)*. 2018, American Association of State Highway and Transportation Officials.

5. Mishra, D. and E. Kassem, *Active Research: Implementing AASHTO TP 110 for Alkali-Silica Reaction Potential Evaluation of Idaho Aggregates*. 2019, Idaho Transportation Department.