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Evaluation of Nebraska's Aggregate Reactivity by the Miniature Concrete Prism Test Method – AASHTO T380

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DEPARTMENT OF TRANSPORTATION

Background

In 2009, the Nebraska Department of Transportation (NDOT) performed a comprehensive investigation of the reactivity of aggregates used in the production of concrete in the state. The reactivity of an aggregate is a contributing factor to Alkali-Silica Reaction (ASR), a deleterious chemical process that causes expansion and cracking of concrete over a period of years. The detailed analysis carried out by the NDOT allowed aggregates to be classified by their reactivity. Based on the reactivity found in the final 2009 NDOT study [1], Supplemental Cementitious Materials (SCMs) could be added in the proper amounts to mitigate the risk of ASR.

In 2016, NDOT began a two-part study to determine if the reactivity of the aggregates used in Nebraska had changed. The first part of this study involved the implementation of a new test, Standard Method of Test for Potential Alkali Reactivity of Aggregates and Effectiveness of ASR Mitigation Measures (Miniature Concrete Prism Test, MCPT) in accordance with AASHTO T380, to evaluate the reactivity of an aggregate. This part consisted of testing aggregates using T380. The compiled data was then compared with the baseline established by the data from the 2009 study, which utilized the ASTM C1260-Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method) and C1293-Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction Standards. The goal was to ensure that the same results would be obtained from both tests before the final implementation of T380, which would save NDOT significant time in testing.

The second part of this study concerned the re-evaluation of Nebraska's aggregates to determine if their reactivity level had changed. The current location of Nebraska's aggregate pits used in this evaluation are shown in Figure 1. This part of the study was critical because the legal locations of aggregate pits occasionally had moved; such a move can change the properties of the aggregate's reactivity. The data obtained in this investigation was compared with the baseline data found in the previous 2009 NDOT aggregate study with the C1293 Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction Standards, commonly referred to as the Concrete Prism Test (CPT). With updated aggregate reactivity information, NDOT's ASR mitigation measures could be re-evaluated.

Study Area

Nine pit locations were selected for this study.

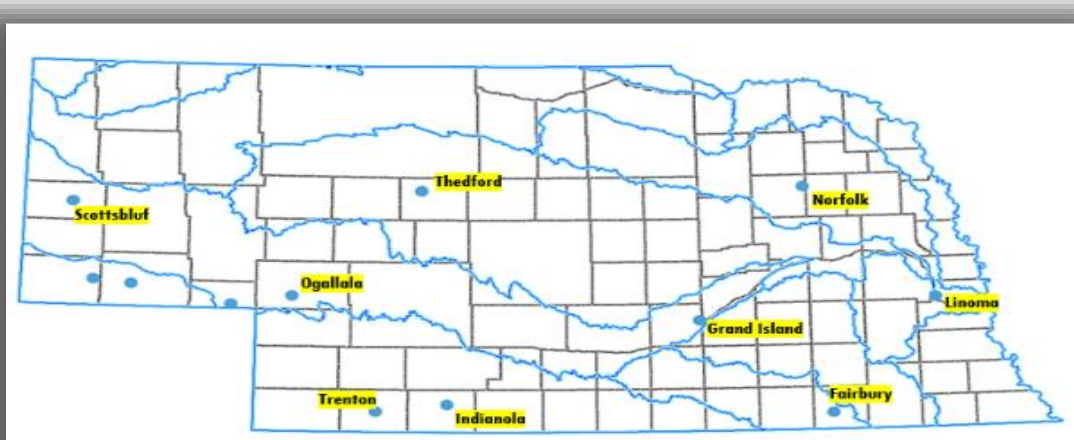


Figure 1. Nebraska aggregate pit locations

MATERIALS

Aggregate: A well-known coarse aggregate limestone was selected with known reactive sand and gravel aggregate.

Reactive Fine aggregate: Siliceous Sand and Gravel from Nebraska

Non-reactive Coarse aggregate: Limestone from Kerford, Nebraska

Cement: Low alkalinity of 0.6% Type I/II cement

Reagents: Reagent grade sodium hydroxide from Fisher Chemicals was used.

Table 1

Property	Limestone (CA)	Sand & Gravel (FA)
Specific Gravity $_{SSD}$	2.66	2.62
Absorption, %	0.9	0.5
*Retained 9.5 mm: (3/8 in.)	57.5%	
*Retained 4.75 mm:(No. 4)	42.5%	
Passing No. 4		Determined based on Absolute Volume Method

**Coarse Aggregate per unit volume of concrete 0.65 of its dry rotted bulk density*

PHASE I

This phase focused on the testing of coarse limestone aggregate to determine its reactivity. The limestone was subjected to ASTM C1260, Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method), which is a 28-day test. The limestone was found to be non-reactive, allowing the aggregate to be used as the non-reactive coarse aggregate in the T380 test method.

PHASE II

This phase evaluated the AASHTO T380, Miniature Concrete Prism Test (MCPT). Aggregates in Phase II were paired with a Type I/II cement to test their reactivity. Potential adoption of the T380 test method required confirmation that T380 test results would correlate with the C1293 tests during the 2009 NDOT study[1]. This investigation used Linoma aggregate in this phase of research. The legal location of the Linoma pit had not changed from the 2009 study allowing direct comparison between 2009 and 2017 test results.

Three concrete mixes were subjected to T380 for this phase. The aggregates were graded in accordance to Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates - AASHTO T 27; coarse aggregate fractions of 57.5 % retained on sieve size 9.5 mm (3/8 in.) and fine aggregate fractions of 42.5% retained on sieve size 4.75 mm (No. 4) in accordance to T 380:

- Fine aggregate fractions (reactive) and coarse aggregate (non-reactive, from Phase I testing) with Type I/II cement.
- 100% (reactive fine and reactive coarse combined) with Type I/II cement.
- 70% fine aggregate (reactive) and 30% coarse aggregate (non-reactive) with Type I/II cement. This 70%/30% split is the Standard NDOT Gradation.

Phase II results are shown in Table 2, along with the reactivity results from the 2009 NDOT study for comparison. The results directly correlate with the mix proportions using the fine side of the reactive aggregate and the coarse side of the non-reactive aggregate following the proportions in accordance to T380. The proportions of 39% - 61% of the reactive aggregate correlated with the reactivity level, however, it should be noted the mix proportions did not follow the T380 test method gradation. The aggregate proportions of 70% and 30% follows the Nebraska's mix design. Phase II provided the starting point the rest of evaluation using the fine side of the reactive aggregate and the coarse side of the non-reactive aggregate.

Table 2

Cement Type	Aggregate Proportion/Grading according to AASHTO T380	Expansion at 56 days according to Table 1 AASHTO T 380	Reactivity According to ASTM C 1293 in 2009 NDOT Study [1]
Type I/II	Fine aggregate (reactive) and coarse aggregate (non-reactive, from Phase I testing) with Type I/II cement.	0.15% (Highly Reactive)	Highly Reactive
	*100% (reactive fine and reactive coarse combined) with Type I/II cement.	0.15% **(Highly Reactive)	
	*70% fine aggregate (reactive) and 30% coarse aggregate (non-reactive) with Type I/II cement	0.19% **(Highly Reactive)	

**Linoma Aggregate is reactive Sand and Gravel and Kerford aggregate is a non-reactive Limestone*
** *The combinations did not follow T 380 grading specifications.*

PHASE III

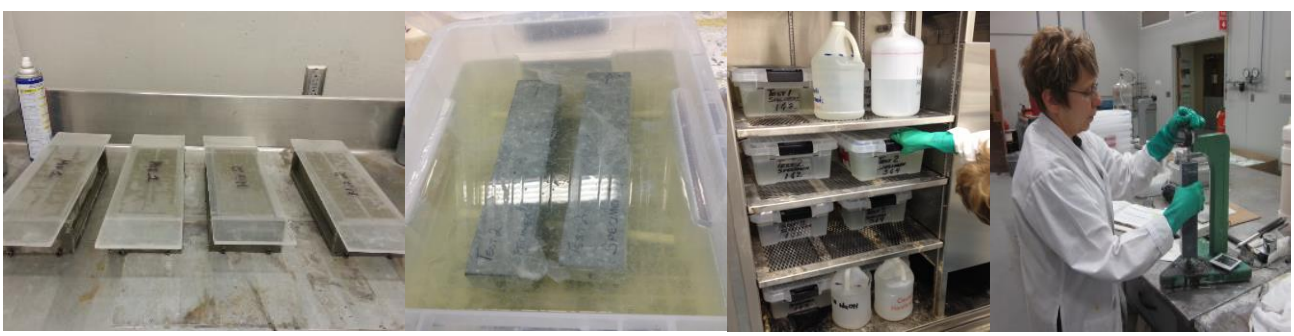
Phase III evaluated the effectiveness of the mitigation measures taken to eliminate the risk of ASR. Each concrete mix was tested with a Type IP (25) cement containing Class F fly ash as an ASR-mitigating constituent. This phase functioned as an additional validation of the T380 method because the effectiveness of mitigation measures was also tested in accordance with ASTM C 1293 in the 2009 NDOT study. Phase III used the same concrete mixes as Phase II with the addition of two additional mixes to simulate actual mix designs used by the Department. These proportions do not follow the requirements of the MCPT as written, but are nonetheless relevant to the Department to establish a baseline for future study.

Table 3 shows Phase III results along with the results with the same aggregate and concrete mixes used in the 2009 NDOT study. None of the mini-prisms used in these mixes showed any expansion at day 56 of the T380 test method, indicating that the ASR risk was completely mitigated by the fly ash in the cement. The fact that these results matched the 2009 NDOT research results using C1293 provided further validation of the T380 method.

Table 3

Cement Type	*Aggregate Proportion/Grading according to AASHTO T380	Expansion at 56 days according to Table 1 AASHTO T 380	Reactivity According to ASTM C 1293 in 2009 NDOT Study [1]
Type IP	Fine aggregate (reactive) and coarse aggregate (non-reactive, from Phase I testing) with Type I/II cement.	0%	0%
	*100% (reactive fine and reactive coarse combined) with Type I/II cement.	0%	
	*70% fine aggregate (reactive) and 30% coarse aggregate (non-reactive) with Type I/II cement	0%	

**Linoma Aggregate is reactive Sand and Gravel and Kerford aggregate is a non-reactive Limestone*
** *The combinations did not follow T 380 grading specifications.*



NDOT Portland Cement Concrete Laboratory

PHASE IV

Phase IV assessed the reactivity of aggregates currently used by the Department. The aggregate reactivity for typical aggregates used by NDOT was compared the reactivity of the baseline values found in 2009. This was done in order to determine ifthe reactivity of the aggregates had changed over time since the previous study. Phase IV also investigated the reactivity of new aggregate pits opened after 2009. These new test results will provide a baseline for future testing in the event the location of one of the new aggregate pit changes. All tests were run using reactive, fine aggregate paired with non-reactive coarse aggregate. Reactivity was tested in accordance with T380 and the results are shown in Table 4. Alongside a comparison of the 2009 study results.

All tests followed the specifications in accordance to T380 with the exception of Mix 5-1, which deviated from the aggregate grading specified in T380. The test results from Mix 5.1 show no correlation to be found with the aggregate's reactivity value found in 2009 study; therefore, the T380 aggregate gradation must be followed as specified in the standard test method.

Based on the results in Table 4, it is evident that 56-day T380 data and 365-day C1293 data shows a high degree of accuracy of the correlation. For the vast majority of aggregates that are moderately, highly, and very highly reactive aggregate, the 56-day T380 expansion can be considered equal to 365-day C1293 expansion. As an example, the Middle Loup River Aggregate (Mix No. 6) identified to be in a different location than the 2009 study, the C1293 and T380 results indicate the aggregate to be highly reactive for both test methods.

Table 4

Mix Identification	Location/ River	Cement Type	Expansion at 56 Days AASHTO T 380	Reactivity Level AASHTO T380@56 days according to Table 1-	Reactivity According to C1293 in 2009 NDOT Study [1]	Reactivity Level by ASTM C1293	SCM reduced due to low alkali cement table 8- AASHTO TP 85
No.1 (Same Agg. Source as 2009 study)	South Platte River Ogallala	Type I/II	0.13%	Moderate Reactive	0.06%	Moderate Reactive	20%-15%
No.2 (Same Agg. Source as 2009 study)	Little Blue River Fairbury	Type I/II	0.11%	Moderate Reactive	0.10%	Moderate Reactive	20%-15%
No.3 (Same Agg. Source as 2009 study)	Platte River Linoma	Type I/II	0.15%	Highly Reactive	0.15%	Highly Reactive	25%-20%
No.4 (Same Agg. Source as 2009 study)	Republican River Indianola	Type I/II	0.24%	Very Highly Reactive	0.45%	Very Highly Reactive	35%-25%
No.5 (Same Agg. Source as 2009 study)	North Platte River Scottsbluff	Type I/II	0.17%	Highly Reactive	0.15%	Highly Reactive	25%-20%
No.5-1 (Same Agg. Source as 2009 study)	North Platte River-Scottsbluff	Type I/II	0.19%	Very Highly Reactive	NA	NA Highly Reactive	35%-25%
No.6 (Different Agg. Source)	Middle Loup River	Type I/II	0.12%	Highly Reactive	NA	Highly Reactive	25%-20%
No.7 (Different Agg. Source)	Norfolk River	Type I/II	0.15%	Highly Reactive	NA	Very Highly Reactive	35%-25%
No.8 (Different Agg. Source)	Grand Island	Type I/II	0.09%	Moderate Reactive	NA	Moderate Reactive	20%-15%
No.9 (Different Agg. Source)	Republican River Trenton	Type I/II	0.12%	Highly Reactive	NA	NA	35%-25%

Correlation between T 380 and C 1293

Table 4 shows the correlation between the 56-day T380 and 1-year C1293 test results for nine of the tested aggregates. Five of the nine aggregates evaluated were from the same aggregate location used in the 2009 study. These five aggregates showed the same level of reactivity for both tests providing a good correlation. The remaining four aggregate pits, mixes No.6, No.7, No.8 and No.9, moved from the 2009 study location but were sourced from a new pit on the same river. They showed the same level of reactivity as in the 2009 study with the exception of Mix No.7 from the Norfolk River, which decreased in reactivity from very highly to highly reactive aggregate. This reactivity change correlated with the C1260 expansion verifying the aggregate reactivity changed for this aggregate source. Expansion limits at 56 days in the T380 method and at 365 days in the C1293 method were used to distinguish the level of reactivity at the specified ages in accordance with T380 and C1293.

Conclusions

The evaluation of nine different aggregates shows the viability of the T380 test method as an alternative to the standard C1293 test method. The T380 assesses the Alkali-Silica Reaction potential of aggregates with the same reliability as C1293 and correlates well with the C1293 test method. Results are obtained within 56 days by T380 compared to 365 days required by C1293. The T380 method at 56 days appears to characterize the aggregate reactivity similarly to C1293 for all the aggregates evaluated in this study. Therefore, T380 will be part of the Department test method for approval of interground/blended cements along with the ASTM C1567-Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate. The Department has changed the specification for approving IP or IT cements to allow the use of T380 after the Department has completed the test method C1567. Per the specification, the mortar bars shall not exceed 0.10% expansion at 28 days while performing C1567. If the expansion is greater than 0.10% at 28 days while performing C1567, then the interground/blended cements shall be tested in accordance with AASHTO T380 using fine aggregate from an approved Platte River Valley and/or Elkhorn River aggregate source with an expansion not greater than 0.02% at 56 days.

Acknowledgements

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2. AASHTO T 380 “Standard Method of Test for Potential Alkali Reactivity of Aggregates and Effectiveness of ASR Mitigation Measures (Miniature Concrete Prism Test, MCPT)”

3. ASTM C 1293 “Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction”

4. AASHTO TP 65 “Standard Practice for Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction”

5. ASTM C 1567 “Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate”

6. Rangaraju, P.R. 2011, —Development of a rapid laboratory test method for assessing alkali- silica reactivity of aggregates‖, interim report, Federal Highway Administration, Solicitation No. DTFH61-08-R-00010.