Nebraska Department of Roads Evaluation of Statewide Aggregate Reactivity -Phase I

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INTRODUCTION

The purpose of this investigation is to study the nature of Nebraska's aggregates' reactivity from various locations across the state. The evaluation is based on the standard test methods for Potential Alkali Reactivity of Aggregates- ASTM C 1260 and ASTM C 1567. The ASTM C 1260 determines and characterizes the reactivity of the aggregates within 28 days according to NDOR specifications and ASTM C 1567 determines the mitigation of ASR with the use of supplemental cementitious materials (SCM).

Phase I - Materials and Experimental Laboratory Testing:

The materials used in this investigation was from 9 different aggregates sources, see Figure 1 below.

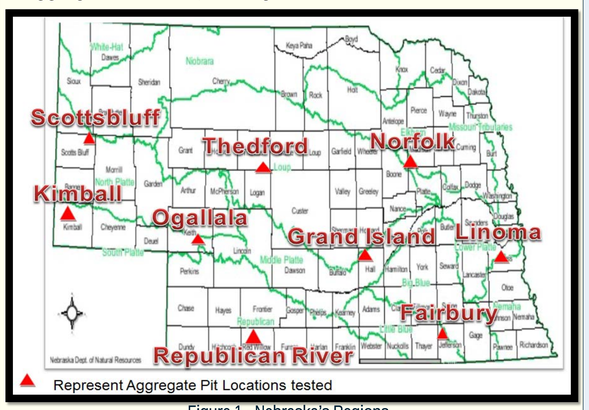

Figure 1 - Nebraska's Regions

All testing followed the ASTM C 1260 and ASTM C 1293. The results of length change are shown in Table 1.

Source of Aggregate	Aggregate Location	Cementitious Material	ASTM C 1260 Results 28 days Duration (%)	ASTM C 1293 Results 1 Year Duration (%)
Platte River	Grand Island	Type I/II	0.39	0.09
Dry Pit	Kimball	Type I/II	0.32	0.21
Republican River	Indianola	Type I/II	0.48	0.45
North Platte River	Scottsbluff	Type I/II	0.46	0.15
South Platte River	Ogallala	Type I/II	0.25	0.06
Middle Loup River	Thedford	Type I/II	0.39	0.19
Little Blue River	Fairbury	Type I/II	0.48	0.10
Elkhorn River	Norfolk	Type I/II	0.57	0.30
Platte River	Linoma-Omaha	Type I/II	0.46	0.15

Table 1 - Phase I Evaluation according by ASTM C 1260 and ASTM C 1293

ANALYSIS OF AGGREGATE REACTIVY ACCORDING TO AASTHO

The analyses of the results were based on AASHTO PP 65-10 2010's special provision guide titled "Determining the Reactivity of Concrete Aggregate and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Construction". The aggregate degree of aggregate reactivity evaluation was guided as shown in Table 2 with the identification of the reactivity classification according to AASTHO Protocol; followed by determining the level of ASR risk as shown in Figure 2 under all concrete exposed to humid air, buried or immersed due to Nebraska's winter condition; as well as the classification of the type of the structure shown on Figure 3, which follows Class S3; followed Figure 4 and Figure 5, which covers the minimum replacement level of SCM for various levels of prevention by reactivity classification.

Table 2 - Degree of Aggregate Reactivity According to Protocol AASTHO PP-65

Aggregate-Reactivity Class	Description of Agg. Reactivity	1 Year Expansion in CPT (%)	14-Day Expansion in AMPT (%)
R0	Non-reactive	<0.04	<0.10
R1	Moderate Reactive	0.040 - 0.120	>0.10 , <0.30
R2	Highly reactive	0.120 - 0.240	>0.30 -<0.45
R3	Very highly Reactive	> 0.240	> 0.45

Figure 2 - *Determining the Level of ASR Risk

Table 2. Determining the Level of ASR Risk

Size and exposure conditions	Aggregate-Reactivity Class			
	R0	R1	R2	R3
Non-massive† concrete in a dry[2] environment	Level 1	Level 1	Level 2	Level 3
Massive† elements in a dry†† environment	Level 1	Level 2	Level 3	Level 4
All concrete exposed to humid air, buried or immersed	Level 1	Level 3	Level 4	Level 5
All concrete exposed to alkalis in service†††	Level 1	Level 4	Level 5	Level 6

†A massive element has a least dimension > 3 ft (0.9 m)
††A dry environment corresponds to an average ambient relative humidity lower than 60%, normally only found in buildings
†††Examples of structures exposed to alkalis in service include marine structures exposed to seawater and highway structures exposed to deicing salts (e.g. NaCl) or anti-icing salts (e.g. potasssium acetate, sodium formate, etc.)

Figure 3 - * Structure Classification

Table 4. Structures Classified on the Basis of the Severity of the Consequences Should ASR† Occur (Modified for Highway Structures from RILEM TC 191-ARP)

Class	Consequences of ASR	Acceptability of ASR	Examples††
S1	Safety, economic or environmental consequences small or negligible	Some deterioration from ASR may be tolerated	▪ Non-load-bearing elements inside buildings ▪ Temporary structures (e.g. < 5 years)
S2	Some safety, economic or environmental consequences if major deterioration	Moderate risk of ASR is acceptable	▪ Sidewalks, curbs and gutters ▪ Service-life < 40 years
S3	Significant safety, economic or environmental consequences if minor damage	Minor risk of ASR acceptable	▪ Pavements ▪ Culverts ▪ Highway barriers ▪ Rural, low-volume bridges ▪ Large numbers of precast elements where economic costs of replacement are severe ▪ Service life normally 40 to 75 years
S4	Serious safety, economic or environmental consequences if minor damage	ASR cannot be tolerated	▪ Major bridges ▪ Tunnels ▪ Critical elements that are very difficult to inspect or repair ▪ Service life normally > 75 years

†Note: this table does not consider the consequences of damage due to ACR. This protocol does not permit the use of alkali-carbonate aggregates
††The types of structures listed under each Class are meant to serve as examples. Some owners may decide to use their own classification system. For example, sidewalks and culverts may be placed in the S3 Class in some jurisdictions.

Figure 5 - *Level of Prevention

Table 6. Minimum Levels of SCM to Provide Various Levels of Prevention

Type of SCM	Alkali level of SCM (% Na_2Oe)	Minimum Replacement Level†† (% by mass)				
		Level W	Level X	Level Y	Level Z	Level ZZ
Fly ash ($CaO \leq 18\%$)	< 3.0	15	20	25	35	Table 7
	3.0 – 4.5	20	25	30	40	
Slag	< 1.0	25	35	50	65	
Silica Fume† ($SiO_2 > 85\%$)	< 1.0	1.2 x LBA or 2.0 x KGA	1.5 x LBA or 2.5 x KGA	1.8 x LBA or 3.0 x KGA	2.4 x LBA or 4.0 x KGA	

†The minimum level of silica fume (as a percentage of cementing material) is calculated on the basis of the alkali (Na_2Oe) content of the concrete contributed by the portland cement and expressed in either units of lb/yd³ (LBA in Table 6) or kg/m³ (KGA in Table 6). LBA is calculated by multiplying the cement content of the concrete in lb/yd³ by the alkali content of the cement divided by 100. For example, for a concrete containing 500 lb/yd³ of cement with an alkali content of 0.81% Na_2Oe the value of LBA = 500 x 0.81/100 = 4.05 lb/yd³. For this concrete, the minimum replacement level of silica fume for Level Y is 1.8 x 4.05 = 8.1%. KGA is calculated by multiplying the cement content of the concrete in kg/m³ by the alkali content of the cement divided by 100. For example, for a concrete containing 300 kg/m³ of cement with an alkali content of 0.91% Na_2Oe the value of KGA = 300 x 0.91/100 = 2.73 kg/m³. For this concrete, the minimum replacement level of silica fume for Level X is 2.5 x 2.73 = 6.8%. Regardless of the calculated value, the minimum level of silica fume shall not be less than 7% when it is the only method of prevention.
†† Note: the use of high levels of SCM in concrete may increase the risk of problems due to deicer salt scaling if the concrete is not properly proportioned, finished and cured.

* *All Figures are referenced from AASTHO PP 65-10*

Figure 4 - * Determining the level of Prevention

Table 3. Determining the Level of Prevention

Level of ASR Risk (Table 4)	Classification of Structure (Table 4)			
	S1	S2	S3	S4
Risk Level 1	V	V	V	V
Risk Level 2	V	V	W	X
Risk Level 3	V	W	X	Y
Risk Level 4	W	X	Y	Z
Risk Level 5	X	Y	Z	ZZ
Risk Level 6	Y	Z	ZZ	††

††It is not permitted to construct a Class S4 structure (see Table 4) when the risk of ASR is Level 6. Measures must be taken to reduce the level of risk in these circumstances.

The analysis through Phase I evaluation shows that Nebraska's aggregate, resulted in Moderate to Very Highly Reactive aggregates, as described in Table 3.

Table 3 represents the classification according to the AASTHO PP-65 specification, the color code representation follows Table 2 according to the level of reactivity:

Aggregate Type Location	ASTM C 1293 1 Year Results (%)	Description of Agg. Reactivity	(Table 1- AASHTO PP 65-10) Aggregate Reactivity Class	(Table 2- AASHTO PP 65-10) Determining the Level of ASR Risk	(Table 3- AASHTO PP 65-10) Determining Level of Prevention	(Table 6- AASHTO PP 65-10) Mim. Replacement Level of SCM	Nebraska's Spec Since Late 2004 IP with 25% Class F
Platte River Grand Island	0.09	Moderate Reactive	R1	Level 3	X	20	✓
Dry Pit Kimball	0.21	Highly Reactive	R2	Level 4	Y	25	✓
Republican River Indianola	0.45	Very Highly Reactive	R3	Level 5	Z	35	✗
North Platte River Scottsbluff	0.15	Highly Reactive	R2	Level 4	Y	25	✓
South Platte River Ogallala	0.06	Moderate Reactive	R1	Level 3	X	20	✓
Middle Loup River Thedford	0.19	Highly Reactive	R2	Level 4	Y	25	✓
Little Blue River Fairbury	0.10	Moderate Reactive	R1	Level 3	X	20	✓
Elkhorn River Norfolk	0.30	Very Highly Reactive	R3	Level 5	Z	35	✗
Platte River Linoma	0.15	Highly Reactive	R2	Level 4	Y	25	✓

Table 3.- Summary of Results and Evaluation According to Aggregate Reactivity

Comparing the results with NDOR's current specifications for minimum replacement levels when using SCM, the study found the Elkhorn River and Republican River are Very Highly Reactive aggregates, which required up to 35 percent SCM replacement. The NDOR's Specification requires up to 25 percent SCM replacement. The continuation of this evaluation will be covered in Phase II using the same aggregates tested in Phase I according to ASTM C 1293 testing (Figure 6) method using Supplemental Cementitious Materials SCM's percentage currently used in Nebraska.

Figure 6 - ASTM C 1293 Specimens Preparation