A Review of Canadian Specifications on ASR, Sulfate Attack…and other Stuff

Not my choice of title…I would have preferred...

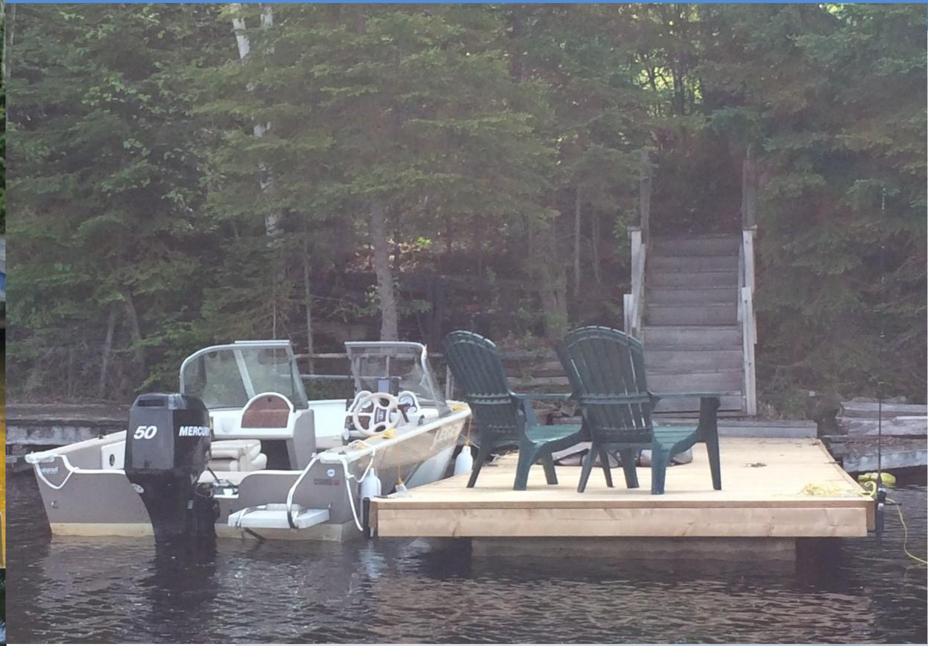
We’re problem solvers!

Nick Popoff, PE
VP Product Performance and Development
St Marys Cement/Votorantim Cimentos

There's a solution…let's do it right…

Let's fix this…and then do some fishing…

Doug's a busy guy…so we made a deal…



Doug bought a new boat…

ADVANCING CONCRETE

We need power…

aci CONCRETE CONVENTION

THE WORLD'S GATHERING PLACE

Back to 1990…ASR was the hot button…not so much sulfates

- ASR SC was under the **CSA Cement** Specifications**-** alkali dependence
- From 1988 to 1994 the ASR SC migrated to the **CSA Concrete** Specifications
- Some familiar names: Fournier, Grattan-Bellew, Thomas, Rogers…and Hooton
  - 2 cement producers and 1 aggregate producer
  - We had Spratt aggregate and discovered several others
- Hooton/Rogers…and the South African ASR..NBRI AMBT
  - Up to that point…the C227 1 year test (38C) was considered the “accelerated” test
- The 90s were a time of fast changes…and harmonization was in vogue.
  - 1991 CANMET and Kingston, ON exposure sites were established
  - 1994 CSA (25A) and ASTM (C1567) adopted the AMBT
  - 2000 CSA (14A) and ASTM (C1293) adopted the CPT
  - 2000 CSA AMBT w SCMs adopted in 2000 (28A) and ASTM 2004
  - 2000 CSA A23.2-27A…which later became ASTM C1778

We had an issue from 2000 to 2004…

- The problem with ASR Mitigation was that everyone was focused on alkalis
- We knew that alkalis were involved in the reaction…but why was there a limit of 1.0%?
- Everyone was familiar with the benefit of SCMs…but were quick to assume that SCMs consumed or diluted alkalis…
- Some producers had used HAPC for over 15 years with SCMs…where was the disconnect?
- A 5 year study resulted in permitting up to 1.15% Na2Oeq in A23.2-27A in 2009.

MITIGATING ALKALI-SILICA REACTION WHEN USING HIGH-ALKALI CEMENTS

R. Doug Hooton [1*], Benoit Fournier[2], Kerrie Kerenidis[3], Raymond Chevrier[4]

Where are we now…

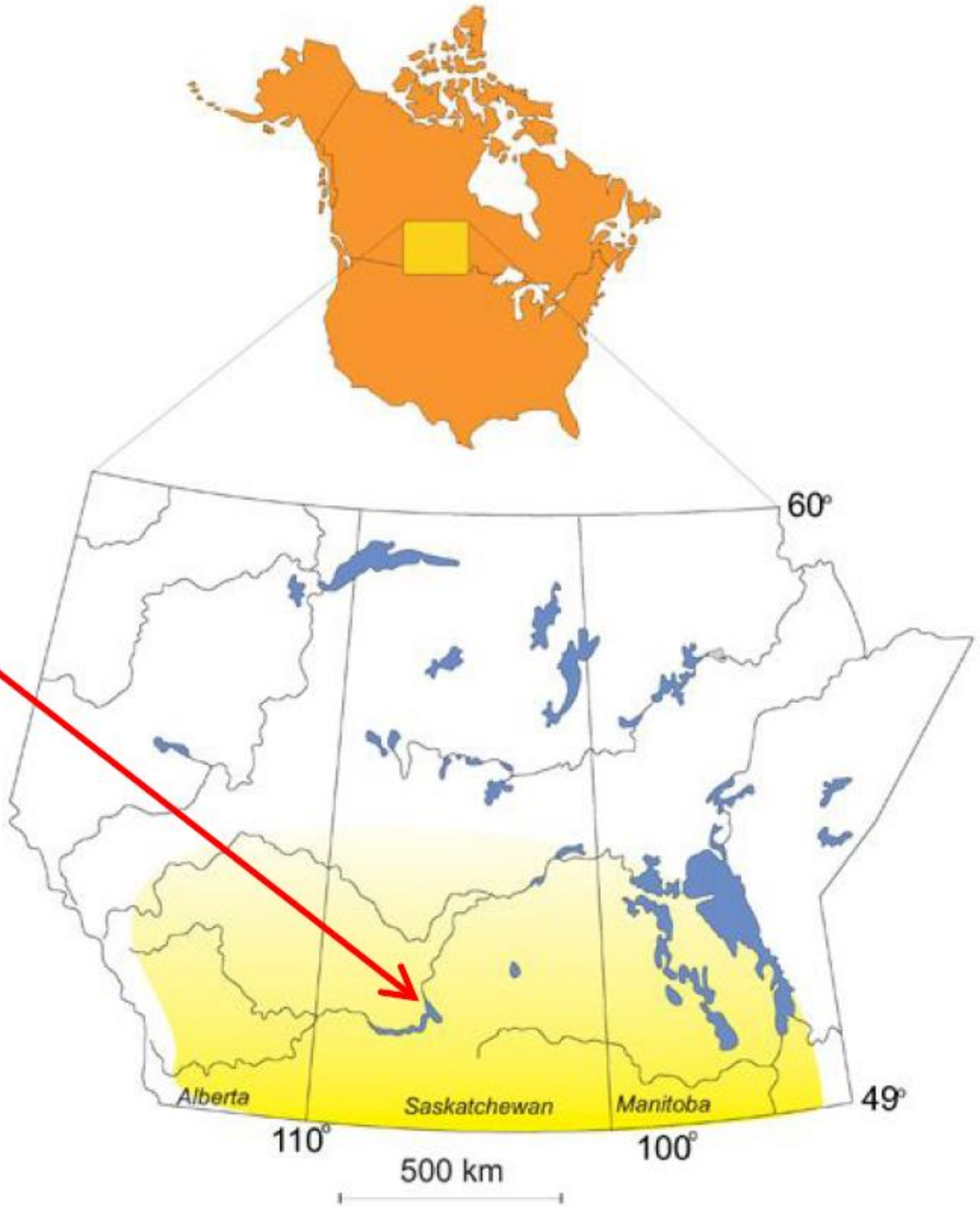
- Currently, the focus is off alkalis and more on the matrix and role of SCMs
- Ca(OH)2 has a more significant role in ASR
- HA SCMs and Cements can be used with reactive aggregates (ie. GGPs)
- Performance tests seem to be working- The current discussion is AMBT vs CPT?

On Sulfate Resistance…

Sulfate soils in Western Canada

Gardiner Dam Exposure Site

0.16 to 0.42% SO_4 found at soil surface (2013) but 1959-67 soils data was as high as 1.1% SO_4



Ref: William M. Last and Fawn M. Ginn, U. Manitoba

On Sulfate Resistance…

- CSA doesn't recognize chemistry as a means of mitigation…and never has
- CSA relies on C452 (5A) and C1012 (8A) performance tests
- Also…50 years of exposure at the Gardiner Dam site
- Concluded that the current performance tests (and concrete specifications) work

Sulfate Resistance and PLC…

Concrete Prisms Sampled

Mix #	Prism #	Cement	Fly ash	[CM] kg/m3	W/CM	% Air	Visual Condition
M259	A4810	Type 10 7.9% C3A	Estevan 3.1% Alk	347 25% FA	0.395	4.1	fine ASR cracks
M259A	A4920	Type 10 9.7% C3A	Estevan 3.8% Alk	347 25% FA	0.40	4.5	fine ASR cracks
M261	A4834	Type 50 3.2% C3A	-	208	0.675	4.9	Good
M261	A4837	Type 50 3.2% C3A	-	208	0.675	4.9	Good
M261A	A4969	Type 50 3.2% C3A	-	208	0.70	4.5	Sulfate Damage
M263	A4860	Type 50 3.2% C3A	-	260	0.55	4.5	Good
M265	A4937	Type 10 9.7% C3A	Estevan 3.8% Alk	415 25% FA	0.355	4.0	fine ASR cracks
M266	A4983	Type 10 7.9% C3A	Estevan 3.8% Alk	485 25% FA	0.33	3.7	fine ASR cracks

- Current requirements will protect the consumer
  - PLC need only meet A5 (C452)
  - PLC + SCMs need to meet A8 (C1012)
- The next steps are to revisit the severity and practicality of the A8 (C1012) test.
- Perhaps continue to work on the alternate mini-bar test (faster results)

On PLCs and Sulfate Resistance…

PCA R&D SN3142

The Durability of Concrete Produced with Portland-Limestone Cement: Canadian Studies

by Michael D.A. Thomas and R. Doug Hooton

PCA R&D SN3285

Sulfate Resistance of Mortar and Concrete Produced with Portland-Limestone Cement and Supplementary Cementing Materials

by R. D. Hooton and M. D. A. Thomas

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PCA R&D SN3285b

Sulfate Resistance of Mortar and Concrete Produced with Portland-Limestone Cement and Supplementary Cementing Materials: Recommendation for CSA A3000

The “Other” Stuff…Performance Specifications

Table 2
Requirements for C, F, N, A, and S classes of exposure
(See Clauses 4.1.1.1.1, 4.1.1.1.3, 4.1.1.3, 4.1.1.4, 4.1.1.5, 4.1.1.6.2, 4.1.1.8.2, 4.1.1.11, 4.1.2.1, 4.3.1, 4.3.5.1, 4.3.5.2, 4.3.7.1, 4.3.7.2, 4.3.7.3, 7.1.2.1, 7.5.1.1, 7.8.1, 7.8.2.1, 8.7.1, 8.7.4.1, 9.3, 9.4, 9.5, A.1, I.4.1.8.6.2, K.4, K.5, L.1, L.3, and O.1.2 and Tables 1, 3, and 17.)

			Air content category as per Table 4[d]		Curing type (see Table 19)			Resistance to chloride ion penetration	
Class of exposure[a]	Maximum water-to-cementitious materials ratio[b]	Minimum specified compressive strength (MPa) and age (d) at test[b,i]	Exposed to cycles of freeze/thaw	Not exposed to cycles of freeze/thaw	Normal concrete	HVSCM-1	HVSCM-2	Chloride ion penetrability requirements and age at test	Bulk resistivity requirement and age at test
C-XL or A-XL	0.40	50 within 56 d	1	[e]	3	3	3	< 1000 coulombs within 91 d[c]	[c]
C-1 or A-1	0.40	35 within 56 d	1	[e]	2	3	2	< 1500 coulombs within 91 d[c]	[c]
C-2	0.45[h]	32 at 28 d	1	n/a	2	2	2	—	—
C-3	0.50	30 at 28 d	n/a	[e]	1	2	2	—	—
C-4[e]	0.55	25 at 28 d	n/a	[e]	1	2	2	—	—
A-2	0.45	32 at 28 d	1	[e]	2	2	2	—	—
A-3	0.50	30 at 28 d	1	[e]	1	2	2	—	—
A-4	0.55	25 at 28 d	n/a	[e]	1	2	2	—	—
F-1	0.50[j]	30 at 28 d	1	n/a	2	3	2	—	—
F-2 or R-1 or R-2	0.55[j]	25 at 28 d	2[f]	n/a	1	2	2	—	—
N	As per the mix design for the strength required	For structural design	n/a	[e]	1	2	2	—	—
N-CF[g] or R-3	0.55	25 at 28 d	n/a	[k]	1	2	2	—	—
S-1	0.40	35 within 56 d	1	[e]	2	3	2	—	—
S-2	0.45[j]	32 within 56 d	1	[e]	2	3	2	—	—
S-3	0.50[j]	30 within 56 d	1	[e]	1	2	2	—	—

[a] *See Table 1 for a description of classes of exposure.*
[b] *The minimum specified compressive strength may be adjusted to reflect proven relationships between strength and the water-to-cementitious materials ratio provided that freezing and thawing and de-icer scaling resistance have been demonstrated to be satisfactory. The water-to-cementitious materials ratio shall*

Exposure Class governs

Performance Specifications…a Canadian Success Story

- Performance Specifications…
  - The industry needs to move towards testing and prequalification to predict performance
  - Some areas where CSA has been successful in bringing everyone together…
  - Leaving more time for fishing…

Thank-you

st marys
cement