Overview of Problems with Deicer Scaling Test Methods
Concretes are cast at 335 kg/m3 (565 lb/yd3) and 6 % air.

Screed surface then after the concrete has stopped bleeding, finish the surface with three sawing-motion passes of a wood strike-off board. Brush the surface with a medium-stiff brush as a final finishing operation.

Curing by moist storage to 14 days and in air for 14 days at 23.0 °C [73.5 °F] and 45 to 55 % relative humidity.

Cover with 4% solution of calcium chloride.

Start 50 cycles of freezing/thawing immediately.
The Problems with the C672 Test

• The current ASTM C672 test:
  – Is qualitative and results are variable
  – Allows freezing from all sides
  – Unfairly penalises fly ash and slag concretes due to inadequate curing prior to exposure.
  – Does not relate well to field performance
  – Is overly severe to fly ash and slag concretes, resulting in 318 and many DOT restrictions on max. SCM levels

• The Quebec BNQ test, essentially adopted by CSA in 2014, gives better relationship to field performance
Paving Slabs, Stoney Creek, Ontario
Placed June 1994 - (Boyd & Hooton, 2008)
June 1994 Field Trials

Six concrete mixtures were cast into pavement slabs which receive truck traffic and de-icing applications at Lafarge’s Slag Plant in Stoney Creek.

Variables:
- Cementing materials
- Curing: curing compound vs 4 days wet burlap and plastic
- Finishing time - early vs normal

Contacts:
- CM = 355 kg/m³
- w/cm = 0.42

Tests:
- Field Performance
- Standard MTO LS412 Scaling Test at 28 days
- LS412 tests after 4 months field exposure
- Temperature monitoring of concrete slabs during winter
1994 Stoney Creek Test Slabs exposed to truck traffic and salt. Still performing well in service.
Lab. Test Slabs Were Finished and Cured The Same As The Pavements
Field Trial Scaling Results

Scaling tests started at 28 days

Laboratory Specimens

Testing Laboratory
- MTO
- Lafarge

Mix Composition

<table>
<thead>
<tr>
<th>Mix Composition</th>
<th>Cumulative Mass Loss After 50 Cycles (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% S</td>
<td>2.50</td>
</tr>
<tr>
<td>35% S</td>
<td>2.00</td>
</tr>
<tr>
<td>25% S</td>
<td>1.50</td>
</tr>
<tr>
<td>10% FA</td>
<td>1.00</td>
</tr>
<tr>
<td>15% FA</td>
<td>0.50</td>
</tr>
<tr>
<td>100% OPC</td>
<td>0.00</td>
</tr>
</tbody>
</table>

0.42 W/CM
Lab Test Slabs Left On Site for 4 Months Then Tested

Stoney Creek 1994
Scaling tests started at 4 months
JUNE 1995
50% SLAG
Curing Compound
Early Finish

JUNE 1995
50% SLAG
Burlap & Plastic
Normal Finish
Stoney Creek after 1 Year

35% Slag OK

50% Slag shows isolated scales over C. Agg. And light scale of F.Agg.
Summary

The standard MTO LS-413 (almost the same as ASTM C672 but with mass loss measurements) is overly severe to SCM concretes unless additional maturity is attained prior to test.

Curing compound is less prone to scaling than wet burlap & plastic.

But we can’t wait 4 months to start the tests.
Fly Ash Barrier wall on Highway 8
Kitchener, Ontario – erected 1986

Photo by M. Thomas
Median barrier near Kitchener, Ontario
*(Chojnacki & Northwood, 1988)*

**Constructed - Summer 1986**

<table>
<thead>
<tr>
<th>Mix</th>
<th>PC  (kg/m³)</th>
<th>FA (kg/m³)</th>
<th>W/CM</th>
<th>Mass loss (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>355</td>
<td>-</td>
<td>0.41</td>
<td>0.31</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>267</td>
<td>88 C</td>
<td>0.41</td>
<td>1.71</td>
</tr>
</tbody>
</table>

OPS LS-412 Lab Scaling Test
Condition after 10 winters, Location 1

25% FA

PC Concrete

D. Hooton
Condition after 10 winters Location 2

PC 9  FA10
PC Concrete  25% FA

D. Hooton
Condition after 10 winters, Location 3

25% FA  PC Concrete

D. Hooton
Results from Laboratory-Cast Samples (Chojnacki & Northwood, 1988)

- Scaling Mass after 50 Cycles (kg/m³)

<table>
<thead>
<tr>
<th></th>
<th>Cement # 1</th>
<th>Cement # 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>10% Fly Ash</td>
<td>2.5</td>
<td>3.0</td>
</tr>
<tr>
<td>25% Fly Ash</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>40% Fly Ash</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Field concrete performs better than lab tests with a limit of 0.8.
Spring in Toronto
What 0.8 kg/m$^3$ scaling looks like on a sidewalk
So the lab test does not mimic reality

• The highway dept. declared fly ash to be poor based on their lab scaling test results, but long-term field performance showed no impact of the fly ash.
CP Tech Center Study
Phase 1 – Field Evaluation

• Pavements and Decks in several states with up to 50% slag were performing well
• Scaling only occurred in isolated locations where there was evidence of re-tempering
• Little additional scaling occurred in C672 tests on cores

Schlorholtz and Hooton
Summary: De-Icer Salt Scaling of SCM’s

ASTM C 672 does not correlate well with field performance and appears to show fly ash and slag concrete at a disadvantage.

Air-entrained concrete with up to 30% fly ash or 35% slag should be resistant to de-icer salt scaling, provided that...

The scaling resistance of any concrete will be impaired if it is of poor quality, has an inadequate air-void system, bad aggregates or is subjected to poor construction practices.

This is a consequence of bad concrete and not fly ash or slag usage.
Phase 2 – Evaluation of Test Methods

- ASTM C 672
- BNQ
- Accelerated curing

- Alternative method proposed
  ASTM WK 9367

Hooton and Vassilev

http://www.intrans.iastate.edu/research/documents/research-reports/deicer_scaling_w_cvr.pdf
Air Void Analysis with 35% Slag Concrete: 2 types of AEA

Mix with 35% slag w/cm = 0.42 using Vinsol resin (left) (Fresh air content = 6.0%) and 106.7ml/m3 Synthetic AEA (right) (Fresh air content = 7.0%).

Air = 3.2%, L = 0.358 mm (0.014in.)  
Air = 7.6 %, L = 0.170 mm (0.007 in.)

With portland cement concretes, the Vinsol resin gave good air void spacings.
Some Findings from Lab Study (D. Vassilev thesis 2012)

- Reducing the w/cm ratio from 0.42 to 0.38 produced the most significant reduction in scaling even with 50% slag content regardless of test method and slag grade used.

- Using synthetic AEA rather than Vinsol Resin gave better hardened air and spacing factor in 35% slag concrete.

- Slabs insulated on the sides and bottom to get 1-Dimensional freezing had much lower scaling than all other slabs at 50 cycles. But thawing part of cycles were longer by about 2hrs.
The New Test: Specific Issues & Changes from ASTM C672

- Osmotic effects are more severe in samples that have not been presoaked in the salt solution (salt water is ponded for 7 days prior to freezing).
- Premature finishing activities have been shown to significantly influence performance (final finishing is removed).
- Insulating the sides of the scaling slabs will minimize the influence of lateral freezing and keep freezing 1-Dimensional.
Proposed New Procedures

1. Cast C672 prisms but only use wood float for initial screed—no final finishing.
2. Cure 7d in moist room at 23C (73F) then wrap in burlap & plastic and cure ay 38C (100F) for 21d.
3. At 28d, cool to 23C and insulate all 4 edges and create dike with 25mm (1in.) rigid styrofoam insulation—seal with silicone.
Proposed New Procedures

2

• Let slabs dry 14d at 23°C in lab air.

• Pond slab surface with 3% NaCl solution, cover with poly film to prevent evaporation, and let sit for 7d at 23°C.

• At 49d, start the freezing cycles as per C672.

• Assess visual condition and measure mass loss at 5 cycle intervals to 50 cycles.

• Calculate cumulative mass loss at 50 cycles.
New CSA A23.2-22C Method

Differs somewhat from this proposal.
1. Uses 6mm thick absorptive geotextile fabric in bottom of the slab forms as in BNQ (we found this to have no impact on results with low w/cm mixes typically tested for scaling resistance---also the fabric sticks to the bottom of the slabs).

2. Allows option for extended moist curing periods prior to 14d drying, until desired strength is obtained.

3. Does not require the insulated sides.

4. Does not have the accelerated curing option.
Spring 2002 1st Sidewalk Trials

- CSA A23.1 Exposure class C2 concrete:
  - 32 MPa minimum,
  - 0.45 maximum water-to-cementitious materials ratio (w/cm),
  - 5 to 8% air content.

- Concrete Sidewalks placed with 0, 25, 35 % Class F fly ash, and a ternary cement with 20% fly ash and 6% silica fume.
- 35 and 50% slag plus ternary cement with 25% slag and 5% silica fume
- City of Montreal “control” was 2% silica fume blended cement
- w/cm = 0.41-0.45, Fresh Air = 5.5 -7.2%
- Hardened Air : 3.6-5.3%, spacing factor 0.14 - 0.21 mm
- Curing compound or 2-days wet burlap and plastic

Deicing salt scaling resistance of concrete incorporating fly ash and (or) silica fume laboratory and field sidewalk test data


N. Bouzoubaa, A. Bilodeau, B. Fournier, R.D. Hooton, R. Gagné, and M. Jolin
Placing and Finishing

Manual placing and bull float finishing

Final finishing with wooden trowel

Laboratory type specimens
Inspection of 2002 Montreal sidewalks in 2003

Note the supply truck accompanying the inspectors
The Good, Bad and the Ugly 2003

Visual = 0-1

Visual = 2-3

Visual = >4
### Visual Ratings at 4 years vs lab tests

<table>
<thead>
<tr>
<th>Visual rating of sidewalk sections</th>
<th>ASTM C672</th>
<th>BNQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (V1)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>35% FA (V2)</td>
<td>2–3</td>
<td>5</td>
</tr>
<tr>
<td>35% slag (V3)</td>
<td>0–1</td>
<td>4</td>
</tr>
<tr>
<td>25% FA (V4)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>25% slag (V5)</td>
<td>1–2</td>
<td>3</td>
</tr>
<tr>
<td>TBC–FA (V6)</td>
<td>&gt;4</td>
<td>5</td>
</tr>
<tr>
<td>TBC–Sg (V7)</td>
<td>0–1</td>
<td>4</td>
</tr>
</tbody>
</table>

**Note:** FA, fly ash; TBC, ternary blend cement; Sg, slag.

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**Deicing salt scaling resistance of concrete incorporating supplementary cementing materials: laboratory and field test data**

N. Bouzoubaâ, A. Bilodeau, B. Fournier, R.D. Hooton, R. Gagné, and M. Jolin
At 4 years: Control = 0 Visual
25% fly ash = 3 Visual
35% fly ash = 2-3 Visual

Deicing salt scaling resistance of concrete incorporating supplementary cementing materials: laboratory and field test data


N. Bouzoubaa, A. Bilodeau, B. Fournier, R.D. Hooton, R. Gagné, and M. Jolin
Fall 2002 2nd Sidewalk Trials

- CSA A23.1 Exposure class C2 concrete:
  - 32 MPa minimum,
  - 0.45 maximum water-to-cementitious materials ratio (w/cm),
  - 5 to 8% air content.

- Concrete Sidewalks placed with 0, 25% Class F fly ash, and a ternary cement with 20% fly ash and 6% silica fume.
- City of Montreal “control” was 2% silica fume blended cement
- 1.5 m × 3.7 m slabs
- Curing compound or 2-days wet burlap and plastic

Deicing salt scaling resistance of concrete incorporating fly ash and (or) silica fume: laboratory and field sidewalk test data

N. Bouzoubaa, A. Bilodeau, B. Fournier, R.D. Hooton, R. Gagné, and M. Jolin

## Fall 2002 Trial Test results

### Visual Ratings: 6 year sidewalk scaling vs lab tests

Table 9. Visual rating of laboratory slabs and sidewalk sections after six winters.

<table>
<thead>
<tr>
<th></th>
<th>Visual rating of laboratory slabs</th>
<th>Visual rating of sidewalk sections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASTM (MC)</td>
<td>BNQ</td>
</tr>
<tr>
<td>VF1- Control</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>VF2- 25% FA</td>
<td>5</td>
<td>2.5*</td>
</tr>
<tr>
<td>VF3- TBC</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

**Note:** A, curing compound; B, wet burlap; FA, fly ash; TBC, ternary blended cement.

*Average results of two samples that did not behave similarly.

In Sidewalks: Curing compound results in less scaling than 2 days wet curing. BNQ test Better matches field performance.
New CSA A23.2-22C Method 2014 (essentially the BNQ Method)

1. Uses 6mm thick absorptive geotextile fabric in bottom of the slab forms as in BNQ (we found this to have no impact on results with low w/cm mixes typically tested for scaling resistance---also the fabric sticks to the bottom of the slabs).

2. Wood trowel screed and no final finishing

3. Allows option for extended moist curing periods prior to 14d drying, until desired strength is obtained.

4. After drying period, salt water is ponded for 7 days prior to freezing cycles.

5. Mass loss and visual ratings used
<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics of the scaling surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No significant scaling observed</td>
</tr>
<tr>
<td>1</td>
<td>Slight scaling (3 mm depth, maximum, no coarse aggregate visible)</td>
</tr>
<tr>
<td>2-A</td>
<td>Slight to moderate scaling of the surface mortar (possibly a few popouts)</td>
</tr>
<tr>
<td>2-B</td>
<td>Slight to moderate scaling of the surface mortar, (several popouts)</td>
</tr>
<tr>
<td>3</td>
<td>Moderate scaling of the surface mortar (some exposed coarse aggregate)</td>
</tr>
<tr>
<td>4</td>
<td>Moderate to severe scaling (significant surface mortar loss with exposed coarse aggregate)</td>
</tr>
<tr>
<td>5</td>
<td>Severe scaling (coarse aggregate visible over entire surface)</td>
</tr>
</tbody>
</table>

*The formation of popouts may be caused by (a) the rupture of the aggregate (b) the sudden detachment of the mortar over the aggregate.*
## Recommendation for equivalent mass loss

<table>
<thead>
<tr>
<th>Equivalency Rating</th>
<th>CSA Scaling Rating</th>
<th>Mass Loss Range (kg/m²)</th>
<th>Visual Characteristics of the scaling surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0 - 50</td>
<td>No significant scaling observed</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>51 - 210</td>
<td>Very slight scaling 3mm (1/8&quot;) depth, max, no coarse aggregate visible and no popouts present</td>
</tr>
<tr>
<td></td>
<td>2A</td>
<td>211 - 500</td>
<td>Slight to moderate scaling and/or presence of a few popouts</td>
</tr>
<tr>
<td></td>
<td>2B</td>
<td>211-500</td>
<td>Slight to moderate scaling and/or presence of many popouts</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>501 - 1300</td>
<td>Moderate scaling of mortar with some exposed coarse aggregate</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1301 - 2100</td>
<td>Moderate to severe scaling: the coarse aggregate is clearly exposed and there is significant scaling of the surface mortar</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>&gt;2100</td>
<td>Severe scaling: coarse aggregates are visible over the entire surface</td>
</tr>
</tbody>
</table>
Conclusions

- ASTM C672 does not relate well to field performance and is overly severe to SCM concretes.
- The new CSA A23.2-22A scaling test method appears to relate better to field performance.
- A draft ASTM test method has been prepared and will be discussed at the June meetings.