Code Requirement and Deicer (Salt) Damage of Concrete

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Director - Technical Services (rmc)

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Overview

1. The building Code of Virginia
2. Code requirements for residential and commercial concrete.
3. Deicer (salt) damage – why it happened?
4. Rock salt and other types of deicers.
5. How to prevent/minimize deicer scaling?
The building Code of Virginia
Virginia: Code writer - DHCD
Virginia state building codes

• . . . and regulations are administered through the Virginia Uniform Statewide Building Code (USBC).

• The 2012 USBC is effective July 14, 2014.
The USBC comprised of three parts:

- 2012 Virginia Construction Code (USBC, Part I)
- 2012 Virginia Rehabilitation Code (USBC, Part II)
- 2012 Virginia Maintenance Code (USBC, Part III)
- 2012 Errata to the Virginia Building and Fire Regulations
VA USBC says: use ICC 2012
VA Construction Code

Table Of Contents
2012 VA Construction Code

Google: va construction code
Codes and Standards

Building Codes

Fairfax County is required to enforce the Virginia Uniform Statewide Building Code (USBC) and the Statewide Fire Prevention Code (SFPC). Both codes are administered by the Virginia Department of Housing and Community Development and reference the 2009 International Codes as published by the International Code Council.

Statewide Codes

- 2009 Virginia Construction Code (IBC) | USBC, Part I
- 2012 Virginia Construction Code (IBC) | USBC, Part I
- 2009 Virginia Residential Code (IRC)
- 2012 Virginia Residential Code (IRC)
- 2009 Virginia Energy Conservation Code
- 2012 Virginia Energy Conservation Code
- 2009 Virginia Mechanical Code (IMC)
- 2012 Virginia Mechanical Code (IMC)
- 2009 Virginia Plumbing Code (IPC)
- 2012 Virginia Plumbing Code (IPC)
- 2009 Virginia Fuel Gas Code (IFGC)
Code requirement on concrete
1904.2 - Concrete mixtures shall conform to the most restrictive maximum water cementitious materials ratios, maximum cementitious admixtures, minimum air entrainment and minimum specified concrete compressive strength requirements of ACI 318 based on the exposure classes assigned in Section 1904.1.
1904.2 – **Exception**: For occupancies and appurtenances thereto in Group R occupancies that are in buildings less than four stories above grade plane, normal weight aggregate concrete is permitted to comply with the requirements of Table 1904.2 based on the weathering classification (freezing and thawing) determined from Figure 1904.2 *in lieu of* the durability requirements of ACI 318.
Weathering Map

Two zones in Virginia

FIGURE 1904.2 WEATHERING PROBABILITY MAP FOR CONCRETE

a. Lines defining areas are approximate only. Local areas can be more or less severe than indicated by the region classification.
b. A “severe” classification is where weather conditions encourage or require the use of deicing chemicals or where there is potential for a continuous presence of moisture during frequent cycles of freezing and thawing. A “moderate” classification is where weather conditions occasionally expose concrete in the presence of moisture to freezing and thawing, but where deicing chemicals are not generally used. A “negligible” classification is where weather conditions rarely expose concrete in the presence of moisture to freezing and thawing.
c. Alaska and Hawaii are classified as severe and negligible, respectively.
ICC 2012 VA Construction Code
Exposure Classes

• “severe” . . . weather conditions encourage or require deicing chemicals or continuous presence of moisture during frequent cycles of freezing and thawing.

• “moderate” . . . weather conditions occasionally expose concrete in the presence of moisture to freezing and thawing, but where deicing chemicals are not generally used.
Driveways, curbs, walks, patios, porches, carport slabs, steps and other flatwork exposed to the weather, and garage floor slabs: **3500psi** for severe exposure

**TABLE 1904.2 MINIMUM SPECIFIED COMPRESSIVE STRENGTH (f'_c)**

<table>
<thead>
<tr>
<th>TYPE OR LOCATION OF CONCRETE CONSTRUCTION</th>
<th>MINIMUM SPECIFIED COMPRESSIVE STRENGTH (f'_c at 28 days, psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negligible exposure</td>
</tr>
<tr>
<td>Basement walls(^c) and foundations not exposed to the weather</td>
<td>2,500</td>
</tr>
<tr>
<td>Basement slabs and interior slabs on grade, except garage floor slabs</td>
<td>2,500</td>
</tr>
<tr>
<td>Basement walls(^c), foundation walls, exterior walls and other vertical concrete surfaces exposed to the weather</td>
<td>2,500</td>
</tr>
<tr>
<td>Driveways, curbs, walks, patios, porches, carport slabs, steps and other flatwork exposed to the weather, and garage floor slabs</td>
<td>2,500</td>
</tr>
</tbody>
</table>

For SI: 1 pound per square inch = 0.00689 MPa.

\(a\) Concrete in these locations that can be subjected to freezing and thawing during construction shall be of air-entrained concrete in accordance with Section 1904.2.

\(b\) Concrete shall be air entrained in accordance with ACI 318.

\(c\) Structural plain concrete basement walls are exempt from the requirements for exposure conditions of Section 1904.2.

\(d\) For garage floor slabs where a steel trowel finish is used, the total air content required by ACI 318 is permitted to be reduced to not less than 3 percent, provided the minimum specified compressive strength of the concrete is increased to 4,000 psi.
Driveways and walks: **NOT MENTIONED**
### Table 19.3.1.1—Exposure categories and classes

<table>
<thead>
<tr>
<th>Category</th>
<th>Class</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freezing and thawing (F)</td>
<td>F0</td>
<td>Concrete not exposed to freezing-and-thawing cycles</td>
</tr>
<tr>
<td></td>
<td>F1</td>
<td>Concrete exposed to freezing-and-thawing cycles with limited exposure to water</td>
</tr>
<tr>
<td></td>
<td>F2</td>
<td>Concrete exposed to freezing-and-thawing cycles with frequent exposure to water</td>
</tr>
<tr>
<td></td>
<td>F3</td>
<td>Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals</td>
</tr>
</tbody>
</table>

### Table 19.3.2.1—Requirements for concrete by exposure class

<table>
<thead>
<tr>
<th>Exposure class</th>
<th>Maximum $w/cm$</th>
<th>Minimum $f'_{c}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3</td>
<td>0.40</td>
<td>5000</td>
</tr>
</tbody>
</table>

[1] The maximum $w/cm$ limits in Table 19.3.2.1 do not apply to lightweight concrete.

[2] For plain concrete, the maximum $w/cm$ shall be 0.45 and the minimum $f'_{c}$ shall be 4500 psi.
b. Concrete shall be air entrained in accordance with ACI 318.

### Table 19.3.3.1—Total air content for concrete exposed to cycles of freezing and thawing

<table>
<thead>
<tr>
<th>Nominal maximum aggregate size, in.</th>
<th>Target air content, percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
</tr>
<tr>
<td>3/8</td>
<td>6</td>
</tr>
<tr>
<td>1/2</td>
<td>5.5</td>
</tr>
<tr>
<td>3/4</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>4.5</td>
</tr>
<tr>
<td>1-1/2</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
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</tr>
</tbody>
</table>
ACI 318: fly ash and slag cement limits in F3 Exposure

<table>
<thead>
<tr>
<th>Cementitious materials</th>
<th>Maximum percent of total cementitious materials by weight*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash or other pozzolans conforming to ASTM C618</td>
<td>25</td>
</tr>
<tr>
<td>Slag conforming to ASTM C989</td>
<td>50</td>
</tr>
<tr>
<td>Silica fume conforming to ASTM C1240</td>
<td>10</td>
</tr>
<tr>
<td>Total of fly ash or other pozzolans, slag, and silica fume</td>
<td>50†</td>
</tr>
<tr>
<td>Total of fly ash or other pozzolans and silica fume</td>
<td>35†</td>
</tr>
</tbody>
</table>

*The total cementitious material also includes ASTM C150, C595, C845, and C1157 cement. The maximum percentages above shall include:
(a) Fly ash or other pozzolans in Type IP, blended cement, ASTM C595, or ASTM C1157;
(b) Slag used in the manufacture of an IS blended cement, ASTM C595, or ASTM C1157;
(c) Silica fume, ASTM C1240, present in a blended cement.
†Fly ash or other pozzolans and silica fume shall constitute no more than 25 and 10 percent, respectively, of the total weight of the cementitious materials.
Deicer Damage – what is it?
Deicer Damage, a.k.a. Scaling

- Scaling is the general loss of surface mortar exposed to freezing and thawing. The aggregate is usually clearly exposed and often stands out from the concrete.

Google: concrete salt damage
Scaling: Yes or No?
My driveway – 18 years old
Deicer (salt) damage – why it happened?
Scaling – per PCA (Portland Cement Association)

- Scaling is primarily a physical action caused by hydraulic pressure from water freezing within the concrete and not usually caused by chemical corrosive action.
- When pressure exceeds the tensile strength of concrete, scaling can result if entrained-air voids are not present to act as internal pressure relief valves.
- The presence of a deicer solution in water-soaked concrete during freezing causes an additional buildup of internal pressure.

(Concrete Slab Surface Defects: Causes, Prevention, Repair, PCA)
b. Concrete shall be air entrained in accordance with ACI 318.

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<th>Nominal maximum aggregate size, in.</th>
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<td>4</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
</tr>
</tbody>
</table>
pressure relief – entrained air
Higher concrete strength

Google: air entrained concrete
Low air is due to

- Not enough air admixture
- High slump
- Over finishing the surface
- Use water as a finishing aid
The wrong kind of deicer?
Deicers can add the following:

- Thermal shock
- Pressure from osmosis
- Growth of salt crystals

# Deicer Comparison

**Deicing Chemical Comparison Chart**

The following chart compares common deicing chemicals with respect to concrete degradation, their relative effectiveness and the impact on the environment and on human health.

<table>
<thead>
<tr>
<th>Deicer</th>
<th>Concrete Degradation Impact</th>
<th>Effective* Temperature (°F / °C)</th>
<th>Cost ($ per dry lb)</th>
<th>Environmental / Health Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl Sodium Chloride</td>
<td>Amplifies freeze thaw damage</td>
<td>15 / -9</td>
<td>0.11</td>
<td>Vegetation impairment</td>
</tr>
<tr>
<td>MgCl₂ Magnesium Chloride</td>
<td>Amplifies freeze thaw damage, chemical attack</td>
<td>-8 / -22</td>
<td>0.20</td>
<td>Vegetation impairment</td>
</tr>
<tr>
<td>CaCl₂ Calcium Chloride</td>
<td>Amplifies freeze thaw damage, possible chemical attack</td>
<td>-2 / -19</td>
<td>0.20</td>
<td>Vegetation impairment, eye and skin irritant, toxic</td>
</tr>
<tr>
<td>CMA Calcium Magnesium Acetate</td>
<td>Amplifies freeze thaw if Mg ratio is high, possible chemical attack</td>
<td>19 / -7</td>
<td>2.30</td>
<td>Skin irritant, high aquatic impairment</td>
</tr>
<tr>
<td>KA Potassium Acetate</td>
<td>Amplifies freeze thaw damage</td>
<td>-11 / -24</td>
<td>1.00</td>
<td>Skin irritant, high aquatic impairment</td>
</tr>
</tbody>
</table>

*Effective temperature is lowest practical temperature of the deicer defined as the lowest temperature at which the relative melting potential (MP) is 0.7 as calculated in reference (1).  
(1) Information adapted from National Cooperative Highway Research Program Report 577 “Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts” © 2007 Transportation Research Board

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**ICPI Technical Note The Effects of Deicing Chemicals on Interlocking Concrete Pavers, WWW.ICPI.ORG (Interlocking Concrete Pavement Institute)**

**Mideast Division- RM Concrete**
Deicer: Thermal shock?

<table>
<thead>
<tr>
<th>Composition</th>
<th>Eutectic**</th>
<th>Lowest Practical Melting Temp</th>
<th>Thermodynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Chloride</td>
<td>NaCl</td>
<td>- 6°F (-21°C) at 23 wt% conc.</td>
<td>15°F (-9°C)</td>
</tr>
<tr>
<td>Mannesium Chloride</td>
<td>MgCl₂·6H₂O (46 wt% MgCl₂)</td>
<td>-28°F (-33°C) at 22 wt% conc.</td>
<td>5°F (-15°C)</td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td>CaCl₂·0.2-2H₂O (dihydrate: 75-80 wt% CaCl₂)</td>
<td>-59°F (-51°C) at 30 wt% conc.</td>
<td>-25°F (-32°C)</td>
</tr>
<tr>
<td></td>
<td>(anhydrous: 90-97 wt% CaCl₂)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Composition: NaCl
**Eutectic: NaCl at 23 wt% conc.

Deicer Comparisons - www.tetrachemicals.com
Calcium chloride generates heat

Dow Chemical:
35 lbs DOWFLAKE + 5-gal water = 45% Calcium Chloride
Chemical attack

- Sodium chloride (rock salt) – none
- Calcium chloride – calcium oxychloride and other complex salts
- Magnesium chloride – brucite (M-S-H)
- Calcium magnesium acetate (CMA) – brucite (M-S-H)

Literature review: E. Sumsion and W. Guthrie, “Physical and Chemical Effects of Deicers on Concrete Pavement: Literature Review,” *Utah Dept of Transportation*, July 2013
High concentration is bad

**Fig. 4**—Specimen subjected to 95 weeks of exposure to 1.06 molal ion concentration solution of NaCl.

**Fig. 5**—Specimen subjected to 95 weeks of exposure to 1.06 molal ion concentration solution of CaCl$_2$.

**Fig. 8**—Specimen subjected to 95 weeks of exposure to 6.04 molal ion concentration solution of NaCl.

**Fig. 9**—Specimen subjected to 10 weeks of exposure to 6.04 molal ion concentration solution of CaCl$_2$.

High concentration is bad

Fig. 7—Specimen subjected to 95 weeks of exposure to 1.06 molal ion concentration solution of CMA.

Fig. 6—Specimen subjected to 80 weeks of exposure to 1.06 molal ion concentration solution of MgCl₂.

Fig. 11—Specimen subjected to 60 weeks of exposure to 6.04 molal ion concentration solution of CMA.

Fig. 10—Specimen subjected to 10 weeks of exposure to 6.04 molal ion concentration solution of MgCl₂.

What types of deicer are available to homeowner -?
Read the label!

- Salt (NaCl); 5F

www.homedepot.com
Read the label!

- calcium chloride crystals; -25F

www.homedepot.com
Read the label!

- calcium chloride enhanced with CMA (calcium magnesium acetate); -8F

www.homedepot.com
Read the label!

- calcium chloride blend with magnesium chloride; -15F

www.homedepot.com
Read the label!

- NaCl, MgCl, Corn Steepwater; -20F

www.homedepot.com
Read the label!

- amide/glycol mixture; -2F
- Amide: ammonia compound, urea

www.homedepot.com
How to prevent or minimize deicer scaling?
If only the top 0.5” has . . .

• Good strength
  – 4500 psi, 0.45 w/cm (ACI 318)
  – No excessive job added water
  – No “holy water” when finishing
  – Good curing
  – Matured concrete

• Good air content
  – Minimum 4.5%
Questions ?