Code Requirement and Deicer (Salt) Damage of Concrete

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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

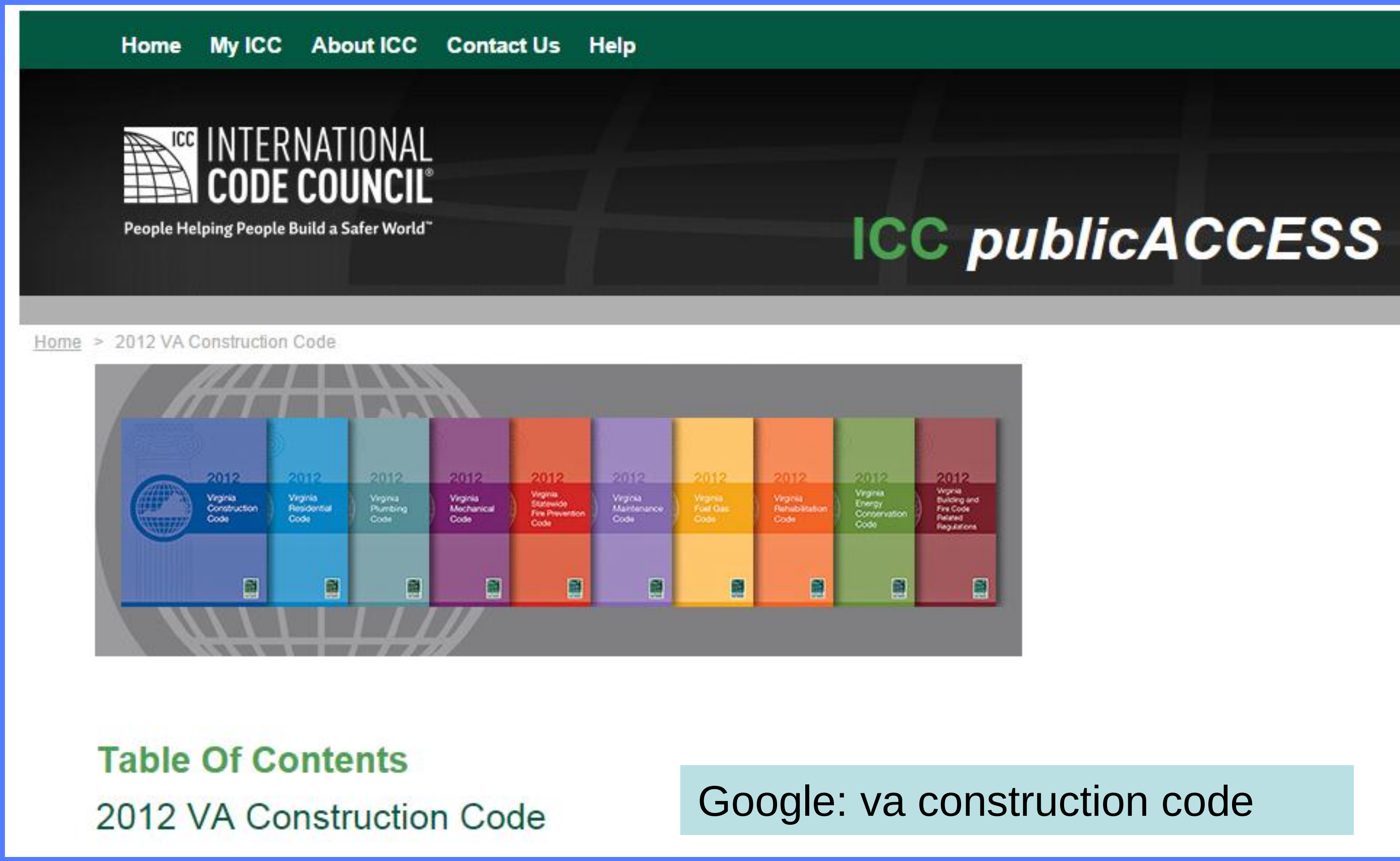
Virginia state building codes

- . . . 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



Google: va construction code

USBC Enforcer – County, City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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.

ICC 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)

Code requirement on concrete

ICC 2012 VA Construction Code, Chapter 19

- 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.

ICC 2012 VA Construction Code, Chapter 19

- 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

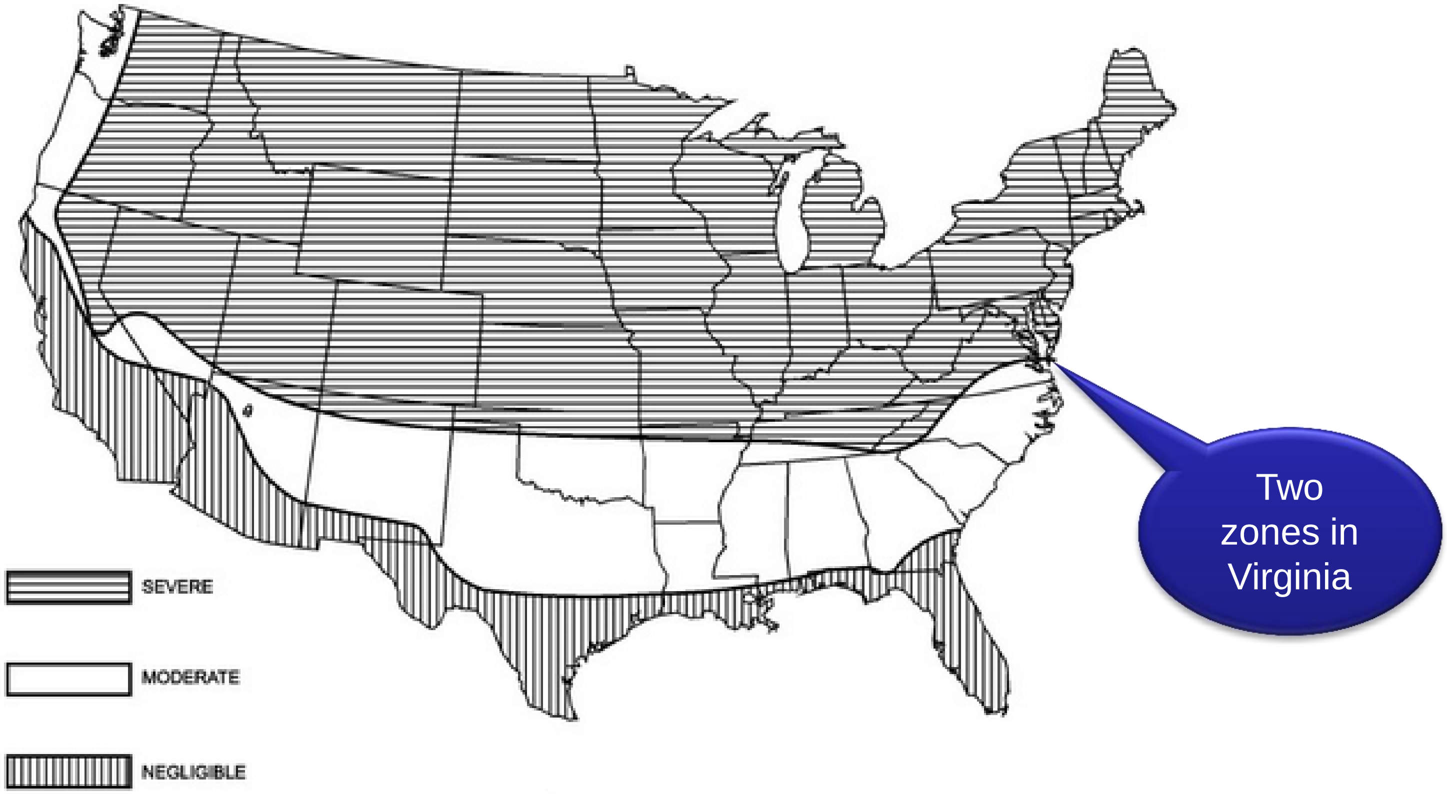

FIGURE 1904.2 WEATHERING PROBABILITY MAP FOR CONCRETE[a, b, c]

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.

ICC 2012 VA Construction Code

TABLE 1904.2 MINIMUM SPECIFIED COMPRESSIVE STRENGTH (f'_c)

TYPE OR LOCATION OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH (f'_c at 28 days, psi)		
	Negligible exposure	Moderate exposure	Severe exposure
Basement walls[c] and foundations not exposed to the weather	2,500	2,500	2,500[a]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[a]
Basement walls[c], foundation walls, exterior walls and other vertical concrete surfaces exposed to the weather	2,500	3,000[b]	3,000[b]
Driveways, curbs, walks, patios, porches, carport slabs, steps and other flatwork exposed to the weather, and garage floor slabs	2,500	3,000[b, d]	3,500[b, d]

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, curbs, walks, patios, porches, carport slabs, steps and other flatwork exposed to the weather, and garage floor slabs: ***3500psi for severe exposure***

2012 International Residential Code (IRC) – confusing!

TABLE R402.2 MINIMUM SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE

TYPE OR LOCATION OF CONCRETE CONSTRUCTION	MINIMUM SPECIFIED COMPRESSIVE STRENGTH[a] (f'_c)		
	Weathering Potential[b]		
	Negligible	Moderate	Severe
Basement walls, foundations and other concrete not exposed to the weather	2,500	2,500	2,500[c]
Basement slabs and interior slabs on grade, except garage floor slabs	2,500	2,500	2,500[c]
Basement walls, foundation walls, exterior walls and other vertical concrete work exposed to the weather	2,500	3,000[d]	3,000[d]
Porches, carport slabs and steps exposed to the weather, and garage floor slabs	2,500	3,000[d, e, f]	3,500[d, e, f]

Driveways and walks: ***<u>NOT MENTIONED</u>***

ACI 318-14

CODE

Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition
Freezing and thawing (F)	F0	Concrete not exposed to freezing-and-thawing cycles
	F1	Concrete exposed to freezing-and-thawing cycles with limited exposure to water
	F2	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water
	F3	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals

ICC severe = F2 and F3

Table 19.3.2.1—Requirements for concrete by exposure class

Exposure class	Maximum w/cm[1]	Minimum f'_c, psi	Add
F3	0.40[2]	5000[2]	

[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

Nominal maximum aggregate size, in.	Target air content, percent	
	F1	F2 and F3
3/8	6	7.5
1/2	5.5	7
3/4	5	6
1	4.5	6
1-1/2	4.5	5.5
2	4	5
3	3.5	4.5

ACI 318: fly ash and slag cement limits in F3 Exposure

TABLE 4.4.2 — REQUIREMENTS FOR CONCRETE SUBJECT TO EXPOSURE CLASS F3

Cementitious materials	Maximum percent of total cementitious materials by weight*
Fly ash or other pozzolans conforming to ASTM C618	25
Slag conforming to ASTM C989	50
Silica fume conforming to ASTM C1240	10
Total of fly ash or other pozzolans, slag, and silica fume	50†
Total of fly ash or other pozzolans and silica fume	35†

*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)

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

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1/2	5.5	7
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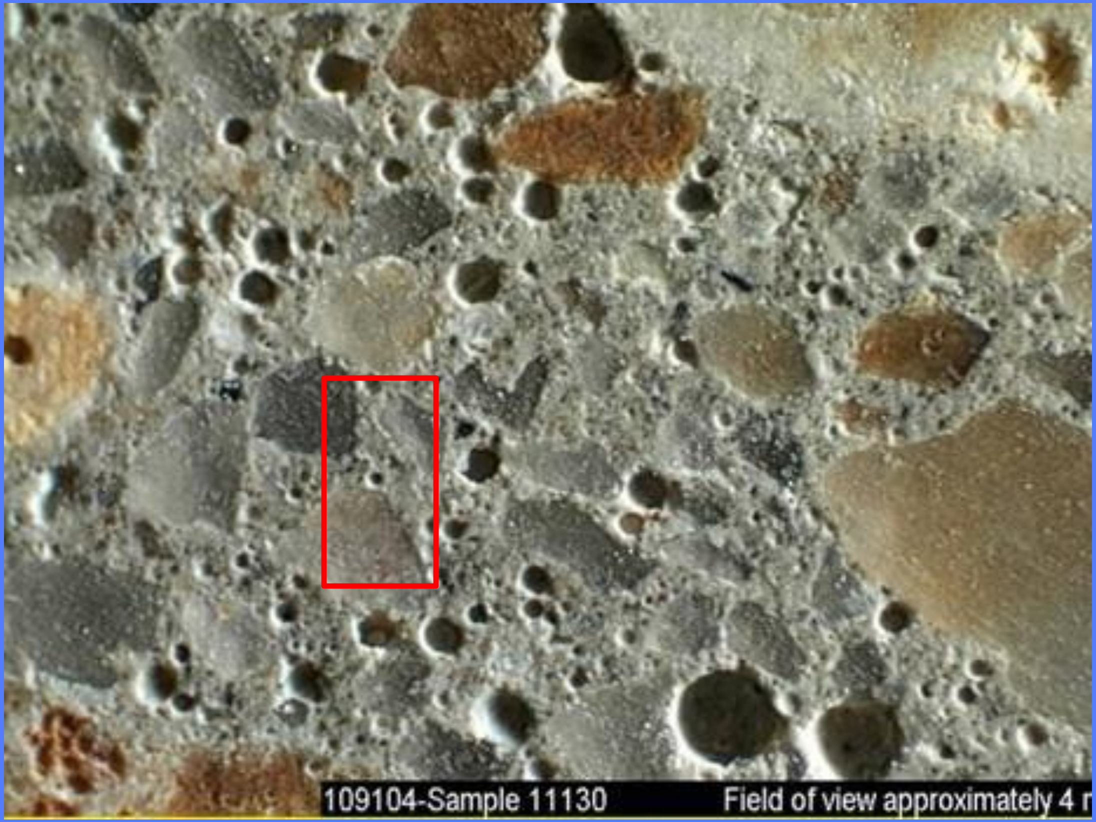
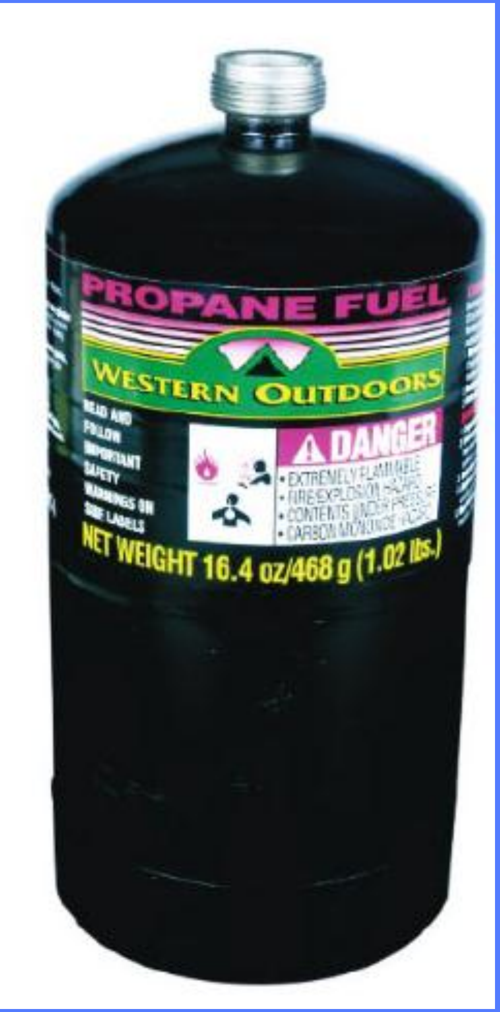
1	4.5	6
1-1/2	4.5	5.5
2	4	5
3	3.5	4.5

pressure relief – entrained air



Google: air entrained concrete

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

E. Sumsion and W. Guthrie, "Physical and Chemical Effects of Deicers on Concrete Pavement: Literature Review," **Utah Dept of Transportation**, July 2013.

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.

Deicer	Concrete Degradation Impact	Effective* Temperature (°F / °C) [1]	Cost ($ per dry lb) [1]	Environmental / Health Impact [1]
NaCl Sodium Chloride	Amplifies freeze thaw damage	15 / -9	0.11	Vegetation impairment
$MgCl_2$ Magnesium Chloride	Amplifies freeze thaw damage, chemical attack	-8 / -22	0.20	Vegetation impairment
$CaCl_2$ Calcium Chloride	Amplifies freeze thaw damage, possible chemical attack	-2 / -19	0.20	Vegetation impairment, eye and skin irritant, toxic
CMA Calcium Magnesium Acetate	Amplifies freeze thaw if Mg ratio is high, possible chemical attack	19 / -7	2.30	Skin irritant, high aquatic impairment
KA Potassium Acetate	Amplifies freeze thaw damage	-11 / -24	1.00	Skin irritant, high aquatic impairment

*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

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

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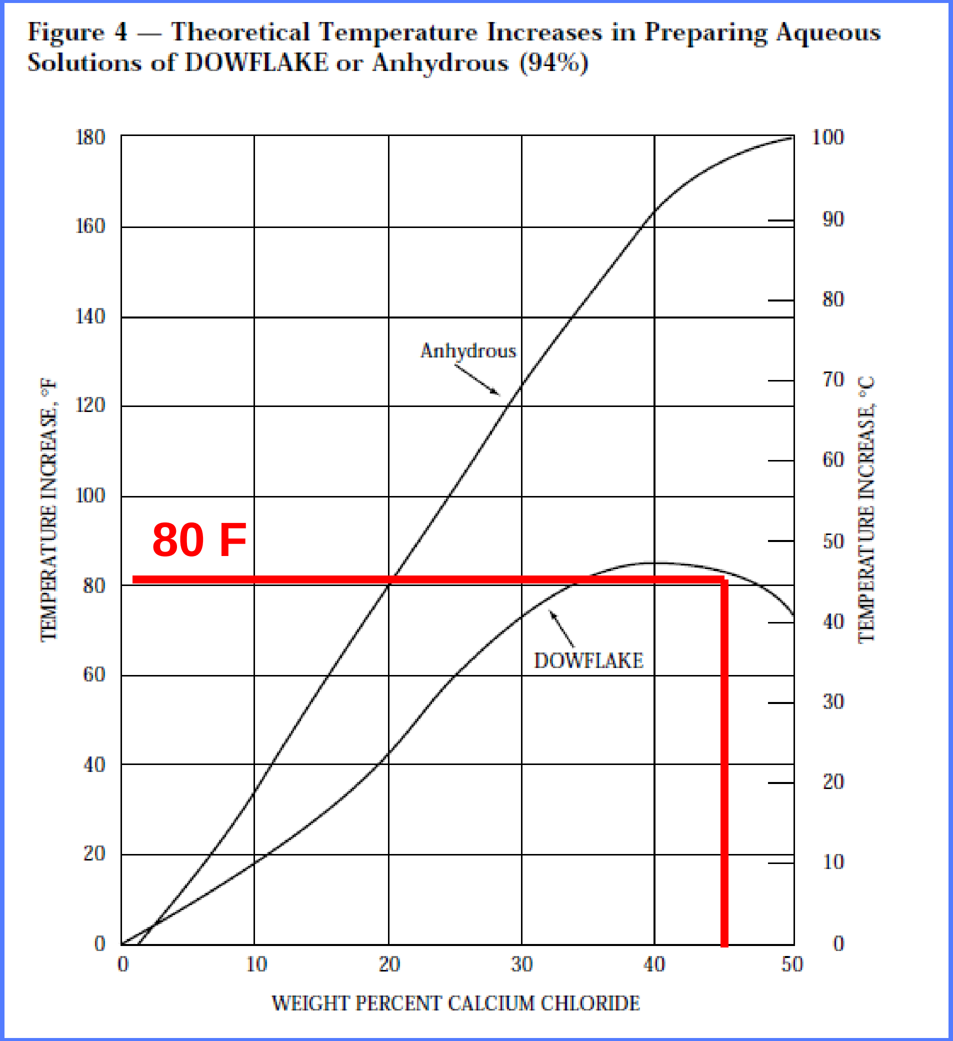
Deicer: Thermal shock?

	Composition*	Eutectic**	Lowest Practical Melting Temp	Thermodynamics
Sodium Chloride	NaCl	- 6°F (- 21°C) at 23 wt% conc.	15°F (-9°C)	Endothermic (Absorbs heat when in contact with snow and ice)
Mannesium Chloride	$MgCl_2.6H_2O$ (46 wt% $MgCl_2$)	-28°F (- 33°C) at 22 wt% conc.	5°F (-15°C)	Exothermic (Releases heat when in contact with snow and ice)
Calcium Chloride	$CaCl_2.0.2\text{-}2H_2O$ (dihyrdate: 75-80 wt% $CaCl_2$) (anhydrous: 90-97 wt% $CaCl_2$)	-59°F (- 51°C) at 30 wt% conc.	-25°F (-32°C)	Exothermic (Releases heat when in contact with snow and ice)

Deicer Comparisons - www.tetrachemicals.com

Calcium chloride generates heat



Dow Chemical:

35 lbs DOWFLAKE
+ 5-gal water
= 45% Calcium Chloride

Calcium Chloride Handbook, www.dowcalciumchloride.com

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.

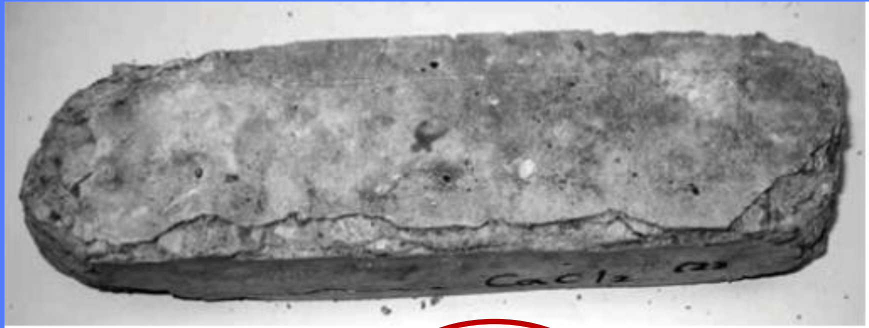


Fig. 9—Specimen subjected to 10 weeks of exposure to 6.04 molal ion concentration solution of $CaCl_2$.

Literature review: D. Darwin et al., "Effects of Deicers on Concrete Deterioration," *ACI Materials Journal*, November-December 2008, pp 622-627.

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 $MgCl_2$.

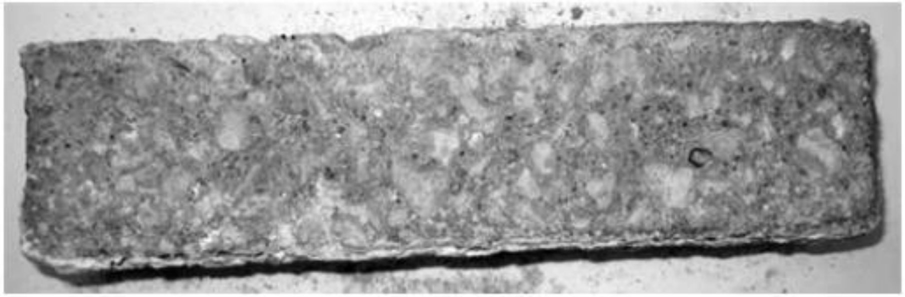


Fig. 11—Specimen subjected to 60 weeks of exposure to 6.04 molal ion concentration solution of CMA.

Fig. 10—Specimen subjected to 10 weeks of exposure to 6.04 molal ion concentration solution of $MgCl_2$.

Literature review: D. Darwin et al., "Effects of Deicers on Concrete Deterioration," *ACI Materials Journal*, November-December 2008, pp 622-627.

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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 ?