De-Icing Agent Performance Evaluation

National Concrete Pavement Technology Center

Final Report
May 2013

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Technical Report Documentation Page

1. Report No.	**2. Government Accession No.**	**3. Recipient's Catalog No.**

4. Title and Subtitle
De-Icing Agent Performance Evaluation

5. Report Date
May 2013

6. Performing Organization Code

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8. Performing Organization Report No.

9. Performing Organization Name and Address
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10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Organization Name and Address

Iowa Center for Industrial Research and Service (CIRAS)	Iowa State University Extension and Outreach
2272 Howe Hall Suite 2620	2150 Beardshear Hall
Iowa State University	Iowa State University
Ames, Iowa, 50011-2272	Ames, Iowa, 50011-2046

13. Type of Report and Period Covered
Final Report

14. Sponsoring Agency Code

15. Supplementary Notes
Visit www.intrans.iastate.edu for color pdfs of this and other research reports.

16. Abstract

The presence of snow and ice during winter in northern states, including Iowa, leads to many problems related to public safety and transportation efficiency. Therefore, selecting a deicing product to solve these problems is important. There is a continuous search for the ideal product that is effective against ice, and not harmful to pavement and environment at the same time.

A laboratory program was carried out to investigate the effects of the de-icing product, named Ossian Season One, on a portland cement concrete pavement mixture. The assessment includes the following:

- Damage to concrete
- Effect on skid resistance
- Sealing effect on concrete

Based on the findings of this work, the data collected indicate that, in all cases, the effects of Ossian Season One are either acceptable, neutral, or beneficial.

17. Key Words
concrete damage—concrete sealing—deicing PCC—Ossian Season One—skid resistance—winter pavements

18. Distribution Statement
No restrictions.

19. Security Classification (of this report)	**20. Security Classification (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified.	Unclassified.	20	NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

DE-ICING AGENT PERFORMANCE EVALUATION

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ACKNOWLEDGMENTS

The authors would like to thank Iowa Center for Industrial Research and Service (CIRAS) at Iowa State University and Iowa State University Extension and Outreach for sponsoring this research.

EXECUTIVE SUMMARY

The presence of snow and ice during winter in northern states, including Iowa, leads to many problems related to public safety and transportation efficiency. Therefore, selecting a deicing product to solve these problems is important. There is a continuous search for the ideal product that is effective against ice, and not harmful to pavement and environment at the same time.

A laboratory program was carried out to investigate the effects of the de-icing product, named Ossian Season One, on a portland cement concrete pavement mixture. The assessment includes the following:

- Damage to concrete
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Based on the findings of this work, the data collected indicate that, in all cases, the effects of Ossian Season One are either acceptable, neutral, or beneficial:

- Mass loss under freezing thawing was equivalent to water and better than salt solutions
- Strength loss under freezing thawing was similar to water and better than salt solutions
- Visual rating after salt scaling was equivalent to water and better than salt solutions
- Friction was lower than the other systems tested but still considered acceptable
- Electrical resistivity was improved when immersed in Ossian Season One compared to the other systems
- Air permeability was similar when immersed in Ossian Season One compared to the other systems
- Water sorption was improved when immersed in Ossian Season One compared to the other systems

SCOPE

The presence of snow and ice during winter in northern states, including Iowa, leads to many problems related to public safety and transportation efficiency. Therefore, selecting an effective deicing product to solve these problems is important. The traditional material used for ice melting, sodium chloride, is cheap but it has a relatively high freezing point and can damage concrete pavement. One of the common deterioration mechanisms associated with this damage is scaling. Concrete slabs exposed to freezing and thawing or wetting and drying cycles with chloride salts will show a peeling or pitting of the surface. Moreover, salt based products may harm plant life near the pavement. There is a continuous search for the ideal product.

The study aims to assess the suitability of a liquid product manufactured by Ossian, Inc. as a de-icing agent for use on concrete pavements. A laboratory program was carried out to investigate the effects of the de-icing product, named Ossian Season One, on a portland cement concrete pavement mixture. The assessment includes the following:

- Damage to concrete
- Effect on skid resistance
- Sealing effect on concrete

EXPERIMENTAL WORK

The effects of the deicing product, Ossian Season One, were evaluated in comparison to plain water and two other commonly used deicing chemicals—sodium chloride and calcium chloride.

Mixture

A concrete batch was prepared that represents a typical pavement mixture. Control parameters include the following:

- Binder type—Type I portland cement
- Cement content—565 lbs/yd^3
- Water-to-cement ratio—0.45
- Coarse aggregate—1inch maximum aggregate size limestone
- Fine Aggregate—siliceous river sand
- Target air content—5%

Specimens for all concrete tests were prepared from this mixture as described below.

Damage to New Concrete

Two tests were included in the study to evaluate the effect that the deicing product may have on concrete longevity:

- Modified ASTM C666/SHRP 2 H-205.8: evaluation of the effect of chemical deicer on the structural integrity of concrete under freeze-cycling conditions.
- Modified ASM C672/SHRP 2 H-205.9: evaluation of the effect of chemical deicer on concrete surface

The SHRP 2 205.8 tests were conducted on 2 in. mortar cubes. The method is intended for use in quantitatively evaluating the damage by measurement of test specimen mass loss. Specimens were cured for 28 days (1 day in the mold + 13 days in moist room at 73°F + 14 days at 50% relative humidity and 73°F). At the end of the curing period another set of eight cubes were tested in compression. Four samples were then put on sponges that were soaked with plain water or deicing solutions and subjected to 10 freezing-thawing cycles. The test solutions included 3% sodium chloride, 4% calcium chloride, and Ossian Season One. The test cell is illustrated in Figure 1. Each cycle comprised 16-18 hrs at 0°F and 6-8 hrs at 73°F. The mass of each sample was recorded at the end of 5th and 10th cycles. Compressive strength of the tested specimens was measured after 10 freezing-thawing cycles.

Figure 1. Test cells for cyclic freezing and thawing

The SHRP 2 205.9 tests were conducted on 12×12×4 in. concrete slabs (Figure 2). The slabs were cured for 28 days (1 day in the mold + 13 days in moist room at 73°F + 14 days at 50% relative humidity and 73°F); then transferred to environmental chamber for freezing-thawing cycles. Each cycle comprised 16-18 hrs at 0°F and 6-8 hrs at 73°F. Specimen surfaces were ponded with plain water or test solution as above. Two slabs were tested under for each solution.

Figure 2. Concrete slab for scaling evaluation

Skid Resistance

Skid resistance testing (SHRP 2 H205.10 / ASTM E 303) was carried out using a British Pendulum as shown in Figure 3. In this test, the pendulum is released from the horizontal position, and the rubber slider at the bottom of the pendulum slides across the coated surface for a fixed previously set length. All of the solutions were tested using two test surfaces—a single typical concrete surface and custom-manufactured sandblasted glass as recommended in SHRP 2 H205.10.

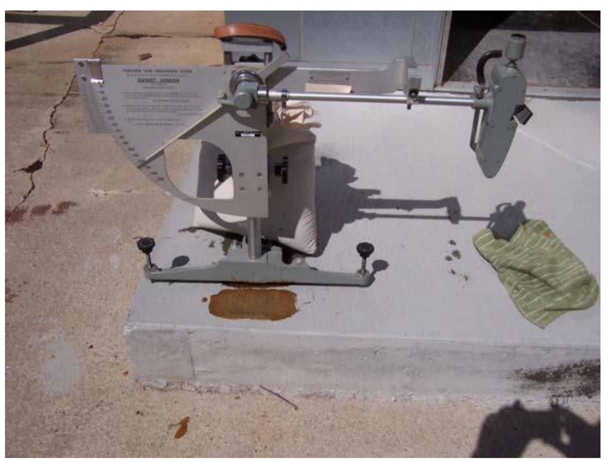

Figure 3. British Pendulum for skid resistance

Sealing Effect of De-Icing Liquid on Concrete

Three different tests were carried out in order to investigate the effect of deicing solutions on the permeability (e.g., surface penetration) of concrete mixes.

4×8 in. cylinders were cast and moist cured for 14 days, then, immersed in each testing solution. After 14 days of conditioning compressive strength of cylinders was determined in order to see any effect of different solutions. In this test compressive load is applied on unconfined cylindrical specimens.

The electrical resistivity of surfaces was measured using a Wenner array probe (Figure 4) after 28 days curing (i.e., 14 days moist curing followed by 14 days immersion in liquid). Resistivity is considered as a reasonable, albeit indirect, indicator of concrete permeability. Interpretation of the data must take into account that penetration of ionic solutions into the concrete may bias the conductivity upwards.

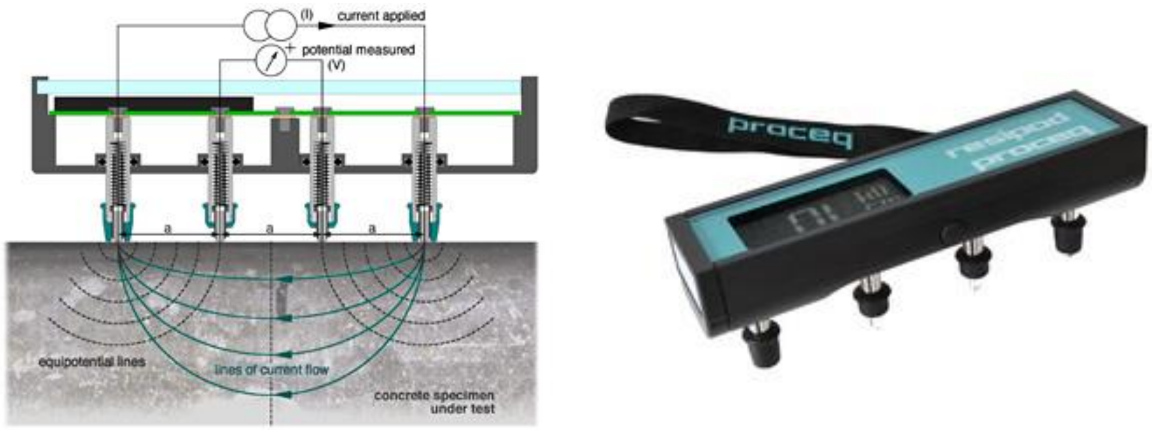

Figure 4. Wenner array probe for electrical resistivity measurement

Gas permeability was determined using 1 in. thick slices cut from cylinders that were conditioned in the same way. The specimens were then dried in air for seven days. In this University of Cape Town test, pressurized air is forced through concrete and the coefficient of permeability is measured from the pressure drop in a fixed volume container over six hours. The test apparatus and specimens are shown in Figure 5.

Figure 5. Air permeability apparatus and test specimens sealed tight at the perimeter

Water sorption was determined using 2 in. thick disks cut from cylinders and tested in accordance with ASTM C 1581. The test specimens were dried and sealed on three surfaces before being placed on a thin film of water (Figure 6). Water intake was recorded as mass change periodically and used to calculate initial (1 minute to 6 hours) and secondary (1 to 6 days) rates of water absorption.

Figure 6. Water absorption specimens

RESULTS AND DISCUSSION

Damage to New Concrete

The mass loss data due to freezing and thawing obtained from 2 in. cubes are given in Table 1.

Table 1. Mass loss after cyclic freeze thaw test

	Mass loss, %	
	5 cycles	**10 cycles**
Plain water	0.48 ± 0.06	0.51 ± 0.04
3% sodium chloride	6.90 ± 1.38	8.90 ± 1.13
4% calcium chloride	2.48 ± 1.37	4.71 ± 2.07
Ossian Season One	0.36 ± 0.11	0.61 ± 0.14

The values represent the average of four specimens. The results shows that the cubes exposed to chloride solutions (i.e., NaCl and $CaCl_2$) demonstrates significant deterioration as compared to plain water and Ossian Season One. Visual examination is in agreement with the mass loss findings. Figure 7 illustrates the amount of distress after 10 freezing-thawing cycles in typical samples. There is no sign of distress in the specimens that are treated either with Ossian Season One or with plain water.

Figure 7. Condition of cubes after 10 freezing-thawing cycles: a) plain water, b) 3% sodium chloride, c) 4% calcium chloride, d) Ossian Season One

Compressive strength of cubes was determined before and after freezing-thawing cycles. The results are given in Table 2.

Table 2. Compressive strength of cubes

	Compressive strength (psi)
	Before conditioning
	7,460 ± 351
	After 10 freeze-thaw cycles
Plain water	6,792 ± 2,469
3% sodium chloride	3,996 ± 550
4% calcium chloride	5,275 ± 1,603
Ossian Season One	7,973 ± 1,571

The standard deviations are relatively high since freezing-thawing deterioration is not the same for all the specimens and surface scaling will significantly affect the test result due to differences in cross sectional areas. Nonetheless, the results are in agreement with the visual examination. Plain water and Ossian Season One treated specimens have higher compressive strengths compared to sodium chloride and calcium chloride specimens. In this test, a lower compressive strength value compared to the one determined before conditioning shows that the specimen has deteriorated as a result of freezing-thawing action. The compressive strength of the mortar exposed to Ossian Season One is well comparable to initial values, which suggests no damage to concrete due to Ossian Season One application.

Visual ratings of the concrete slab surfaces after 50 daily freeze-thaw cycles are shown in Table 3.

Table 3. Concrete surface scaling after 50 freezing-thawing cycles

	Cumulative Mass Loss g/m^2 ($oz./ft^2$)	**Numerical Scaling Rating**	**Visual Rating**
Plain water	28 (0.1)	0	0
3% sodium chloride	1,926 (6.3)	4	4
4% calcium chloride	1,057 (3.5)	3	4
Ossian Season One	17 (0.1)	0	0

Sodium chloride and calcium chloride result in significant scaling of the surfaces whereas the slab with Ossian Season One does not show any sign of scaling, with both visual and numerical ratings being the same as plain water. The ratings are given in Table 4.

Table 4. Surface condition rating given in SHRP 2 H-205.9 and ASTM C 672

Rating	**Surface Condition**
0	No scaling
1	Very slight scaling (3 mm [1⁄8 in.] depth, max, no coarse aggregate visible)
2	Slight to moderate scaling
3	Moderate scaling (some coarse aggregate visible)
4	Moderate to severe scaling
5	Severe scaling (coarse aggregate visible over entire surface)

The table provides three values—the amount of mass (per unit area) scaled from the surface as a result of the deicing application, corresponding rating based on this mass loss, and a subjective visual rating in accordance with SHRP 2 H-205.9 and ASTM C 672 (Figure 8). Ossian Season One performed very well in surface scaling testing.

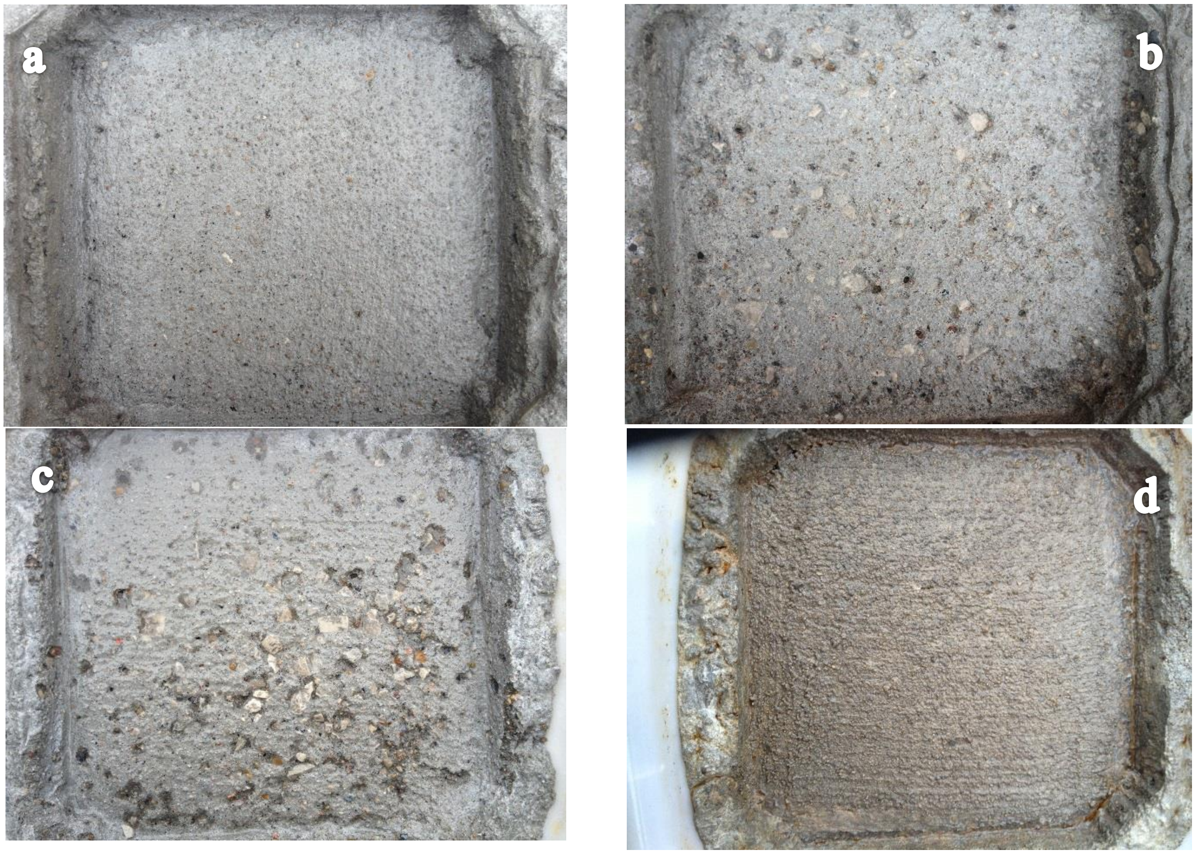

Figure 8. Surface scaling after 50 freezing-thawing cycles: a) plain water, b) 3% sodium chloride, c) 4% calcium chloride, d) Ossian Season One

Skid Resistance

Skid resistance test results (i.e., expressed as British Pendulum Number) on the two different surfaces are given in Table 5.

Table 5. Skid resistance at room temperature (British Pendulum)

	BPN	
	Sandblasted glass	**PCC**
Plain water	79.6 ± 0.5	70.4 ± 0.5
3% sodium chloride	77.4 ± 0.5	68.8 ± 0.4
4% calcium chloride	76.8 ± 0.4	69.6 ± 0.5
Ossian Season One	46.8 ± 0.4	59.6 ± 0.5
Ossian Season One 1 hour after initial testing	-	65.2 ± 0.4

Results are based on five measurements. A higher BPN value indicates greater skid resistance. For the standard sandblasted glass surface Ossian Season One shows a lower BPN number, an average of 46.8. However, the European standard EN 1436 specifies a minimum BPN value of 45.The values are improved on the concrete surface. Ossian Season One achieves 85% of the skid resistance of plain water and the value is well above 45. These tests were carried out at an ambient temperature of 73 to 75°F.

A second series of skid resistance testing was carried out at lower temperatures in order to see the effect of temperature with sodium chloride and Ossian Season One. Drying time is also included as a variable in this series. The results are given in Table 6. Ossian Season One showed lower friction than sodium chloride but the values still appear acceptable. Drying time seems to have little effect on skid resistance.

Table 6. Skid resistance at low temperatures

	Site 1		Site 2	
	BPN	**Temp.* (°F)**	**BPN**	**Temp.* (°F)**
Ossian Season One at 0 hour	55 – 56	35.5 – 37.4	59 – 60	34.7 – 36.2
Ossian Season One at 2 hours	54 – 55	41.9 – 44.6	55 – 56	41.8 – 44.5
Ossian Season One at 4 hours	51 – 52	24.3 – 28.6	54 – 55	21.6 – 27.4
3% sodium chloride at 0 hour	71 – 72	33.2 – 38.6	72 – 73	33.8 – 37.8
3% sodium chloride at 2 hours	72 – 73	42.9 – 45.3	72 – 73	41.9 – 43.8
3% sodium chloride at 4 hours	75 – 76	21.5 – 24.9	72 – 73	22.9 – 25.7

*Temperature of testing surface

Sealing Effect of Ossian Season One

Indirect permeability tests were conducted in order to evaluate the effect of Ossian Season One on concrete permeability in comparison to plain water, sodium chloride and calcium chloride.

Compressive strength of concretes that are cured 14 days in a moist room followed by another 14 days in testing solutions are given in Table 7. The results indicate there is no effect of curing concrete in different deicing solutions compared to standard water curing. Ossian Season One has no negative impact on concrete strength gaining during the period the specimens are immersed.

Table 7 summarizes the results of the indirect permeability tests. The chloride-based compounds appeared to have had little effect on resistivity when compared to the water cured concrete. On the other hand, the results indicate Ossian improves the electrical resistivity of concrete.

Table 7. Permeability test data

	Electrical resistivity (kΩ-cm)	Air permeability index	Water absorption rate×10^{-4} (mm/$s^{1/2}$)		Compressive strength (psi)
			Initial	Secondary	
Plain water	11.8 ± 0.1	8.0 ± 0.1	6.22	3.74	6,407 ± 242
3% sodium chloride	11.4 ± 0.1	8.1 ± 0.2	5.47	3.05	6,238 ± 196
4% calcium chloride	12.0 ± 0.5	7.8 ± 0.1	5.59	4.42	6,422 ± 95
Ossian Season One	16.9 ± 1.9	7.9 ± 0.1	4.21	2.80	6,615 ± 173

The air permeability results show little effect of Ossian Season One.

The sorption results suggest Ossian Season One slows the water absorption rate. Both initial and secondary water absorption rates for the specimens cured in Ossian Season One are lower than the plain water cured specimens. This might indicate Ossian Season One improves the internal structure of concrete by creating an impermeable barrier at the concrete skin.

CONCLUSION

Three types of properties were investigated in this study to assess the effect of Ossian Season One on concrete properties—damage to concrete, effect on skid resistance, and sealing effect on concrete.

In all cases, the data collected indicate that the effects of Ossian Season One are either acceptable, neutral, or beneficial:

- Mass loss under freezing thawing was equivalent to water and better than salt solutions
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