Warnock Hersey

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50244-C7-416600

Concretech Inc.

Attention: Ms. Lisa K. Cvet
Tehnical Sales Manager

SUBJECT: Laboratory Testing and Evaluation of
Concrete Sealer, Radcon Formula #7

Dear Ms. Cvet:

1.0 INTRODUCTION

On July 16, 1988 Warnock Hersey Professional Services Ltd. was commissioned by Concretech Inc. to conduct a complete series of tests as outlined in the subsequent parts of this report. This report is intended to convey testing and evaluation results of Radcon Formula #7 conducted in our Mississauga laboratory since July 1988.

2.0 TESTING PROGRAM

The testing program included the following tests:

1.1	Depth of Penetration
1.2	Water Absortion
1.3	Moisture Vapour Permeability
1.4	Chloride Ion Penetration
1.5	Freeze-Thaw Test in the Presence of Deicing Salt
1.6	Chemical Resistance (2 acidic, 2 alkalis, 1 solvent) Resistance to Oil, Gasoline and Grease
1.7	Slip Resistance
1.8	Viscosity
1.9	Non-volatile Contents
1.10	Relative Density
1.11	Ph Value
1.12	Hardness test

3.0 REFERENCE STANDARD

This report refers to the following International and Canadian Standards for Material Testing for Material Testing.

- MTC-M1-79 April 1985, Used as a general guideline
- CSA CAN43-A23. I and CAN-A23.2
- AASHT0 T259-78, Resistance of Concrete to Chloride Ion Penetration
- MTC LS-411, Method of Determination of Water Soluble Chloride Ion in Concrete
- MTC Form 1351, Salt Scaling Test
- ASTM C192, Making & Curing Concrete Samples in the Laboratory
- ASTM C672, Sealing Resistance of Concrete Surfaces Exposed to Deicing Chemicals
- ASTM 01644, Test for Non-Volatile Contents

4.0 PREPARATION OF TEST SPECIMENS

Two concrete mixes were designed and batched in accordance with MTC-M1-79 test procedures. One mix was made without an Air Entraining Agent, and designated as Normal Concrete. The other mix was made by adding an Air Entraining Agent, and designated as Air Entrained Concrete. The mix proportions and values for the slump and air content are presented in Table 1 below.

TABLE 1

MIX PROPORTIONS (BASED ON DRY MASS)

Materials	Normal Concrete Mix 1	Air Entrained Concrete Mix 2
Coarse Aggregate (kg)		
max. size 20 mm	171.0	168.0
Sand (kg)	116.5	121.0
Cement type 10 (kg)	56.2	52.2
Water (4kg)	28.2	28.3
Water reducing (ml)	247.0	243.0
Admixture (WR DA)		
Air Entraining (ml)		
Admixture (DAREX AEA)	nil	11.0
Fresh Concrete Test Results		
Slump (mm)	75.0	82.0
Air Content (%)	2.5	5.8

All the materials complied with the MTC requirements.

4.2 Test Specimen

Two different size of slabs as test specimens were cast. Fifteen small slabs (150 x 150 x 50 mm) and nine larger slabs (300 x 300 x 75 mm) were cast from each mix. Samples cast were compacted by rodding in accordance with ASTM C192-81. All the samples were moist cured for 14 days followed by 14 days laboratory curing.

4.3 Application of the Sealant

Radcon Formula #7 was applied by brushing it on to the concrete surface under strict supervision of Concretech Inc. (manufacturer).

5.0 TEST RESULTS

5.1 Depth of Penetration

Four of the 150 x 150 x 50 mm slabs after being moist cured for 14 days, were surface dried under normal laboratory conditions. Samples were lightly sandb1asted to remove the surface laitance and other residual materials. Radcon Formula #7 was applied onto the surface of the samples under the supervision of Concretech Inc. The surface treated slabs were allowed to cure for 14 days at normal laboratory air conditions before they were cut into four 75 x 15 x 50 mm blocks. The blocks were then immersed in water for approximately one minute to delineate the depth of penetration to the nearest 0.1 cm on each saw cut side of each block. Four readings were taken from each cut block, therefore a total of 16 measurements were made for each slab sample and their average was recorded as the depth of penetration. The test results are presented in Table 2 below.

TABLE 2

DEPTH OF PENETRATION

Concrete Type	No. of Sealant Coats Applied	Average Depth of Penetration (mm)
Normal	1 coat	15.80
Air Entrained	1 coat	15.50
Normal	2 coats	16.10
Air Entrained	2 coats	15.60

5.2 Water Absorption

Eight of the 150 x 150 x 50 slabs after being moist cured for 14 days, were surface dried under normal laboratory conditions. All of the eight samples were lightly sandblasted to remove the laitance and other residual materials. The samples were then oven dried at 110 ± 5°C to a constant mass, after removal of the samples from the oven they were cooled to a normal room temperature under laboratory conditions. Radcon Formula #7 was applied to all sides of each slab, under the supervision of Concretech Inc. with strict manufacturer's directions. The slabs were further cured for 14 days under normal laboratory conditions and then each slab was weighed and recorded. Then all the slabs were immersed in water, after 48 hours they were removed and surface dried by a water absorbant cloth, each slab was weighed and recorded. All the slabs weighet were recorded to the nearest 0.1g. Test

results are presented in Table 3 below.

TABLE 3

WATER ABSORBTION

ConcreteType	*No. of Sealant Coats Applied*	*Average Water Absorbtion (%)*
Normal	1 coat	2.42
Air Entrained	1 coat	2.33
Normal	2 coats	2.11
Air Entrained	2 coats	2.25
Control Sample (Normal)	-	4.07
Control Sample (Air Entrained)	-	3.18

5.3 Moisture Vapour Permeability

Eight of the 150 x 150 x 50 mm slabs after being moist cured for 14 days, were surface dried under normal laboratory conditions. All of the eight samples were lightly sandblasted to remove the laitance and other residual materials. The samples were then oven dried at 110 ± 5°C to a constant mass**,** after removal of the samples frm the oven they were cooled to a normal room temperature under laboratory conditions. Then the samples were placed in distilled water for 46 hours. After removal from the distilled water, they were surface dried with an absorbant cloth. The mass of each slab was measured and recorded to the nearest 0.1 g. Radcon Formula #7 was applied to all sides of each slab, under the direct supervision of Concretech Inc., following strict manufacturers directions. Upon drying of the sealant the mass of each slab was determined to the nearest 0.1 g and recorded. The treated slabs were stored for 14 days under laboratory conditions. Then they were placed in an oven at 110 ± 5°C until they reached a constant mass. Each slab was weighed and the mass was recorded. Tests results are presented in Table 4 below.

TABLE 4

MOISTURE VAPOUR PERMEABILITY

ConcreteType	*No. of Sealant Coats Applied*	*Average Vapour Permeability (%)*
Normal	1 coat	84.1
Air Entrained	1 coat	91.4
Normal	2 coats	81.2
Air Entrained	2 coats	83.1
Control Sample (Normal)	-	98.0
Control Sample (Air Entrained)	-	96.0

5.4 Chloride Ion Penetration

Eight of the 300 x 300 x 75 mm slabs after being moist cured for 14 days, were surface dried under normal laboratory conditions. Four of the slabs were of normal concrete and the other four samples were concrete slabs with entrained air. Two slabs of normal concrete were treated with one and two coats of Radcon Formula #7, and two slabs of air entrained concrete were also treated in the same fashion. Two of the samples, one or each type were used as control and the last two samples were used to determine background chloride ion content of each type of concrete. After 14 days of storage at normal laboratory conditions six of the slabs were ponded with a 3% sodium chloride solution. Testing was conducted in accordance with AASHTO Designation T259—78. The water soluble chloride ion contents were determined in accordance with MTC Method LS—41. An additional band was also taken and tested at the 25 mm to 38 mm depth. Test results after deduction of the background chloride ion content (as determined from the unponded samples) are presented in Table 5 below.

TABLE 5

AVERAGE WATER SOLUBLE CHLORIDE ION CONTENT

ConcreteType	*Layer Depth (mm)*	*% cl^- Contents by mass of Concrete*	*Comments*
Normal with one coat of Radcon Formula #7	2-13 13-25 25-38	0.199 0.026 0.000	3% Sodium Chloride Solution Ponding
Air Entrained with one coat of Radcon Formula #7	2-13 13-25 25-38	0.397 0.032 0.000	3% Sodium Chloride Solution Ponding
Normal with two coats of Radcon Formula #7	2-13 13-25 25-38	0.048 0.001 0.000	3% Sodium Chloride Solution Ponding
Air Entrained with two coats of Radcon Formula #7	2-13 13-25 25-38	0.127 0.002 0.000	3% Sodium Chloride Solution Ponding
Normal (untreated)	2-13 13-25 25-38	0.459 0.048 0.003	3% Sodium Chloride Solution Ponding
Air Entrained (untreated)	2-13 13-25 25-38	0.697 0.065 0.001	3% Sodium Chloride Solution Ponding

5.5 Chemical Resistance & Resistance to Oil, Gasoline & Grease

Procedure

The surface effects of various reagents on the concrete samples with ASTM T308-79, Spot Test Open. Two uncoated concrete slabs, one normal concrete and one entrained air concrete were used as the control; two similar slabs with the coating applied, as the test surface. Each surface was divided into six equal areas and the test reagents applied in drop form (or equivalent) of approximately 1 ml and exposed to the surface for 15 minutes. The surfaces were then wiped with a dry paper towel. Where the change appeared to be permanent, the surface was further wiped with a water-dampened towel. All tests were conducted under ambient laboratory conditions (20°C). Observations were made to determine objectionable alterations to the applied surface.

Reagent	*Normal Concrete*		*Air Entrained Concrete*	
	Control	*Coated*	*Control*	*Coated*
Hydrochloric Acid 31% Industrial	Retained drop shape Very rapid reaction Yellow foam appeared Final surface very porous, deep pits No permanent discolouring	Spread out on surface Less rapid reaction Yellow foam appeared Less porous surface evenly eroded No permanent discolouring	Reactions were more intense and faster with low air. Other observations as per normal concrete samples.	
Sulfuric Acid 15% Industrial	Retained drop shape Slow reaction Small bubble formation White foam result Final surface slightly porous No permanent discolouring	Spread rapidly Slight reaction Very few bubbles Faint white foam result Slight surface erosion No permanent discolouring	Reactions slightly more intense, otherwise the surface responses were identical to those of the normal concrete samples.	
Sodium Hydroxide 34% Solution	Wet surface, spread rapidly No reaction Final surface unaffected No discolouration	Wet surface, spread rapidly No reaction Final surface unaffected No discolouration	See observations for normal concrete samples.	
Ammonia Hydroxide 34% Solution	Wet surface, spread rapidly No reaction Final surface unaffected No discolouration	Wet surface, spread rapidly No reaction Final surface unaffected No discolouration	See observations for normal concrete samples.	

Reagent	*Normal Concrete*		*Air Entrained Concrete*	
	Control	*Coated*	*Control*	*Coated*
Orange Dye (liquid)	Local surface penetration. Permanent stain	Local surface penetration. Dye wipes away with damp towel No permanent stain	See observations for normal concrete samples.	
Blue Dye (gel blobs in liquid)	Local surface penetration. Permanent stain	Local surface penetration. Dye wipes away with damp towel No permanent stain	See observations for normal concrete samples.	
Gasoline (unleaded)	Spread slowly Wet surface No reaction Evaporated completely No stain	Spread rapidly Wet surface No reaction Evaporated completely No stain	See observations for normal concrete samples.	
Grease (heavy duty)	Surface wet after wiping Permanent stain	Surface wet after wiping No stain	See observations for normal concrete samples.	
Motor Oil (10W40)	Retained drop shape, spread slowly Surface wetted Wipes away, residual surface wet No stain	Spread rapidly Surface wetted Wipes away, residual surface slightly wet No stain	See observations for normal concrete samples.	
Penetrating oil	Spread slowly Wet surface No reaction Wipes away, residual surface wet Permanent stain	Spread slowly Wet surface No reaction Wipes away, residual surface slightly wet No stain	See observations for normal concrete samples.	
Carbon Tetrachloride	Spread slowly Wet surface No reaction Evaporated completely No stain	Spread rapidly Wet surface No reaction Evaporated completely No stain	See observations for normal concrete samples.	
Varsol	Retained drop shape Wiped dry No stain	Spread readily Wiped dry No stain	See observations for normal concrete samples.	

5.6 Freeze - Thaw Test in the Presence of Deicing Salt

Ten of the 300 x 300 x 75 mm slabs were prepared in the same manner as those tested for chloride ion test. All the samples were ponded with 3% sodium chloride solution and tested in accordance with ASTM-C672 and MTC Form 1351 for 50 cycles of freeze-thaw. Test results are presented in Table 6 below. Also photographic recordings were made, and are presented in Photographs No. 1 to 38.

TABLE 6

RESULTS OF 50 CYCLES FREEZE-THAW TESTS

Concrete Type & No of Sealant Coats Applied	**Cumulative Mass Loss after 5 cycles (gr.)**										**Mass Loss per m^2 at 50 Cycles (kg/m^2)**
	5^{th}	10^{th}	15^{th}	20^{th}	25^{th}	30^{th}	35^{th}	40^{th}	45^{th}	50^{th}	
Normal Concrete 1 coat	0.3	0.8	1.8	2.6	3.9	5.4	6.9	7.9	9.3	10.5	0.182
Visual rating	0	0	0	0	0	1	1	2	2	2	
Normal Concrete 1 coat	0.7	1.5	2.3	4.7	5.8	6.9	7.5	8.1	9.2	11.2	0.194
Visual rating	0	0	0	0	0	0	0	1	2	2	
Normal Concrete 2 coats	0.8	1.5	2.8	3.8	4.9	6.0	7.5	11.6	13.4	14.6	0.254
Visual rating	0	0	0	0	1	1	1	2	2	3	

Concrete Type & No of Sealant Coats Applied	Cumulative Mass Loss after 5 cycles (gr.)										Mass Loss per m^2 at 50 Cycles (kg/m^2)
	5th	10th	15th	20th	25th	30th	35th	40th	45th	50th	
Normal Concrete 2 coats	0.4	1.0	2.2	3.8	5.2	6.7	7.8	8.6	9.5	10.3	0.179
Visual rating	0	0	0	0	0	0	0	0	1	1	
Air Entrained Concrete 1 coat	0.1	0.5	2.2	3.6	4.8	7.0	8.1	9.2	10.8	12.1	0.210
Visual rating	0	0	0	0	1	2	2	2	3	3	
Air Entrained Concrete 1 coat	0.8	1.8	3.6	5.0	7.1	8.2	9.6	10.9	12.5	13.5	0.234
Visual rating	0	0	0	1	1	2	2	2	2	3	
Air Entrained Concrete 2 coats	1.1	1.8	3.0	3.8	4.8	6.0	7.2	8.5	10.1	11.0	0.191
Visual rating	0	0	0	0	1	1	1	1	2	3	
Air Entrained Concrete 2 coats	0.8	1.0	1.9	2.6	3.5	4.5	5.6	6.9	8.0	9.2	0.160
Visual rating	0	0	0	0	0	1	1	1	2	2	
Normal (Control) Concrete	0.6	2.9	13.4	24.7	29.9	32.7	42.0	53.0	63.0	74.3	1.290
Visual rating	0	0	2	3	4	5	5	5	5	5	
Normal (Control) Concrete	0.6	2.3	13.8	21.1	36.1	40.4	46.0	50.1	53.6	59.5	1.033
Visual rating	0	0	1	2	3	4	5	5	5	5	

Visual Rating Scale	**Concrete Surface Condition**
0	No scaling
1	Very light scaling
2	Slight to moderate scaling
3	Moderate scaling
4	Moderate to severe scaling (some coarse aggregate visible)
5	Severe scaling (coarse aggregate visible over the entire surface)

Summary of Freeze-Thaw Test Results

ConcreteType and No. of Sealant Coats Applied	*Average Cumulative Mass Loss after 50 cycles (gr.)*	*Average Mass Loss per m^2 at 50 Cycles (kg/m^2)*
Normal Concrete 1 coat	10.85	0.188
Normal Concrete 2 coats	12.45	0.217
Air Entrained Concrete 1 coat	12.80	0.222
Air Entrained Concrete 2 coats	10.10	0.176
Normal Concrete Control	74.30	1.290
Air Entrained Concrete Control	59.50	1.033

5.7 Slip Resistance Test

The surfaces of the samples treated with Radcon Formula #7 and those not treated were tested for slip resistance in wet and dry conditions. Testing was conducted in accordance with CAN2-75.1-M77. Test results are presented in Table 7 below.

TABLE 7

RESULTS OF SLIP RESISTANCE TEST
(CAN2-75.1-M77**)**

Panel With Sealant

Trial	Rubber (Dry) (N)	Rubber (Wet) (N)	Leather (Dry) (N)	Leather (Wet) (N)
1	110	120	83	114
2	110	126	77	125
3	108	115	70	128
Average	109.3	120.3	76.7	122.3
Friction (Ave Resistance 150)	0.73	0.80	0.51	0.81
Specification	0.70	0.65	0.50	0.60

Control Panel

Trial	Rubber (Dry) (N)	Rubber (Wet) (N)	Leather (Dry) (N)	Leather (Wet) (N)
1	105	117	95	97
2	107	112	96	99
3	104	113	93	103
Average	105.3	114.0	94.7	99.7
Friction (Ave Resistance 150)	0.70	0.76	0.63	0.66
Specification	0.70	0.65	0.50	0.60

5.8 Viscosity
The viscosity of Radcon Formula #7 was determined in accordance with Stoke's Law. The value for the viscosity of Radcon Formula #7 was found to be 0.1172 Stoke.

5.9 Non-volatile Contents
Testing was carried out in accordance with ASTM D-1644 and the value for the non-volatile content of Radcon Formula #7 was 27.7%.

5.10 Relative Density
The relative density of Radcon Formula #7 was determined to be 1.218 g/cm^3.

5.11 Ph-Value
The Ph-value of Radcon Formula #7 was found to be 12.

5.12 Hardness Test (Moh's Hardness)
The results of the hardness test are as follows:

Type of Concrete	**Moh's Hardness Prior to Application of Radcon Formula #7**	**Moh's Hardness After Application of Radcon Formula #7**
Normal	**6**	**8**
Air Entrained	**6**	**7**

6.0 DISCUSSION
Radcon Formula #7 is a clear penetrating liquid concrete sealer, which does not discolour or change the appearance of the concrete surface. As presented in the previous sections various tests were conducted, in order to determine and evaluate it's performance under each test. From the individual test results a summarized evaluation is made and presented in the following with a subsequent overall rating of Radcon Formula #7.

Depth of Penetration: The average depth of penetration was greater than 15 mm, although this is an average value it is important to note that across the sections in some areas the depth of penetration was about 20 mm. Therefore Radcon Formula #7 can be classified as a penetrating sealer. This depth is sufficient to prevent migration of chloride ion to the surface of the reinforcement with a minimum cover of 15 mm. This fact is clearly supported by the results of the chloride ion tests.

Water absorbtion: Test results presented in Table 3 clearly indicate that the samples treated with Radcon Formula #7 absorb about 50% less water than those samples untreated. Part of the water absorbed by the treated sample is used to reactivate the sealer. Our subsequent tests of the treated samples showed much lower values of water absorbtion.

Moisture Vapour Permeability: The moisture loss varied between 81 to 91%, again this is mainly due to the fact that part of the moisture absorbed is used by the sealer to reactivate it.

Chloride Ion Penetration: Test results are presented in section 5.5 and it is seen from the results that Radcon Formula #7 provides a better protection to the concrete.

Chemical Resistance: Test results are presented in section 5.5 and it is seen from the results that Radcon Formula #7 provides a better protection to the concrete.

Freeze-Thaw Test: All of the treated samples after 50 cycles of freeze-thaw test showed very good performance. The maximum mass loss on the treated samples ranged from 0.160 to 0.254 kg/m^2 which are far below the 0.80 kg/m^2 threshold by MTC Form 1351 and 1352. For comparison, the values for control (untreated) samples for normal and air entrained concrete were 1.290 and 1.033 kg/m^2 respectively.

Hardness Test: Our test results show that Radcon Formula #7 improves the surface hardness of the concrete. Also, our supplemental tests indicate that the compresive strength of the concrete is improved by the application of Radcon Formula #7. Therefore, Radcon Formula #7 acts as consolidant.

Slip Resistance: Radcon Formula #7 improved the slip resistance of concrete surface, except in the dry condition under leather.

Overall Performance: From our test results it can be concluded that Radcon Formula #7 improves the quality of the concrete, provides excellent protection to the chloride ion penetration, freeze-thaw cycling, moisture penetration and permeability. It is a clear, penetrating sealer that does not discolour the concrete.

7.0 CONCLUSION

We trust the above report meets your current requirements, sample remnants not distroyed during the course of testing will be retained in our laboratory for 30 days pending your decision. This concludes our commision to conduct the above tests, should you have any questions please contact the undersigned.

Respectfully submitted,

WARNOCK HERSEY PROFFESIONAL SERVICES LTD.

M.J. Amini, Ph.D., P. Eng.
Manager
Materials Engineering Services

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