Improving the long-term performance of concrete bridge decks using deck and crack sealers

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NEVADA DOT

Introduction

- Chlorides ingress into the concrete cause a corrosion in the reinforcement steel.
- More cracks in concrete due to the corrosion of the steel.
- More chlorides penetrates into the cracks cause deterioration in the concrete and additional corrosion in the steel.

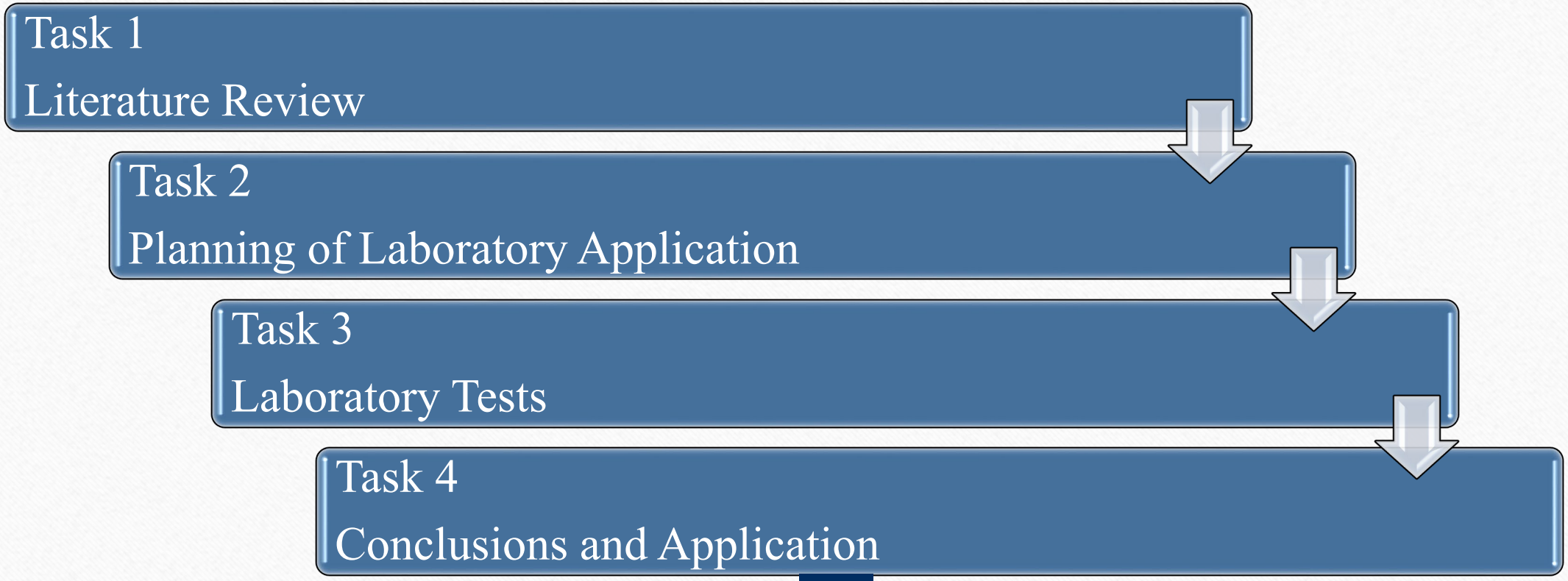
Introduction

- The use of deck and crack sealers is one method to reduce chloride ion intrusion and the subsequent deterioration of the deck or the substructure.
- Sealers are applied on the surface of the bridge deck.
- Reducing these chlorides ingress into the concrete decrease the corrosion of the steel and the deterioration of the concrete.

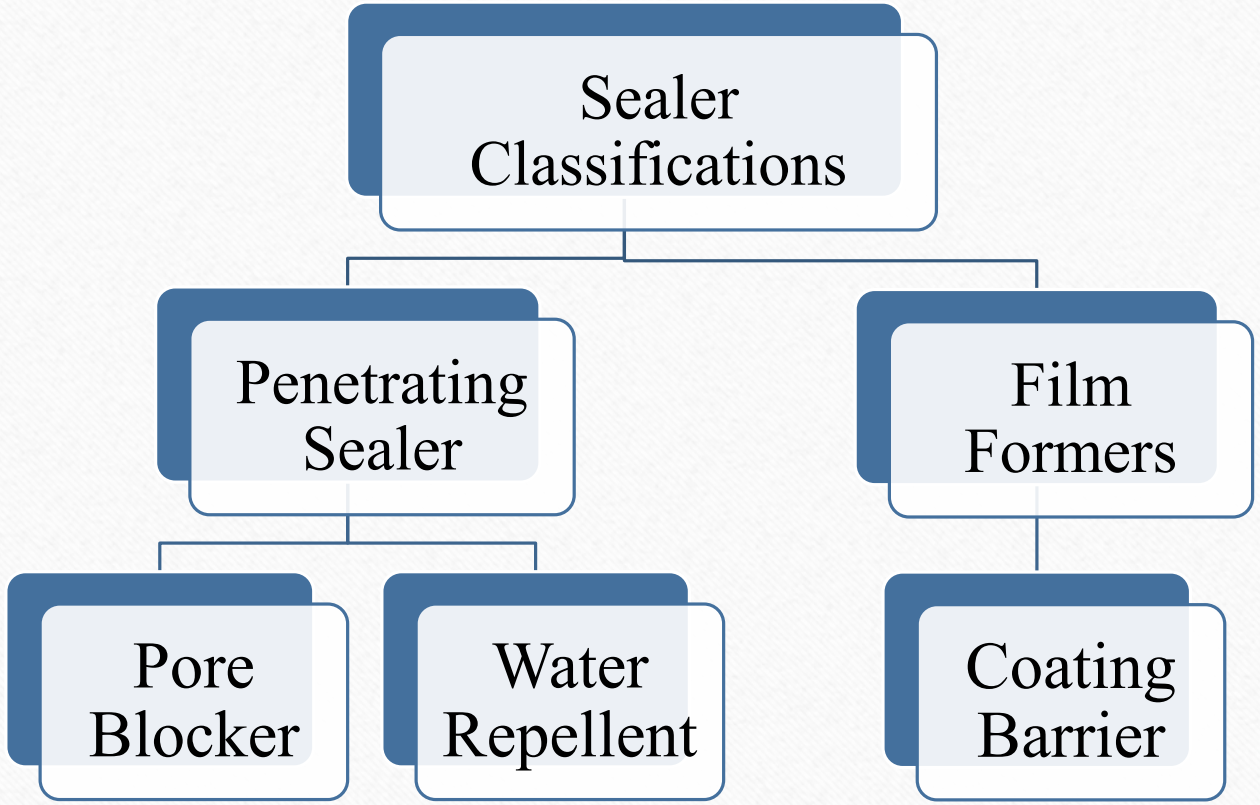
Research Objectives

- NDOT currently utilizes overlays; but effective use of sealants and deck treatments can replace overlays, save costs, and extend bridge deck life.
- Develop guide for using deck and crack sealers for bridge decks with focus on southwest desert weather conditions.
- Assess the effectiveness and performance of selected commercially available deck and crack sealers.

Research Plan



Sealer Background



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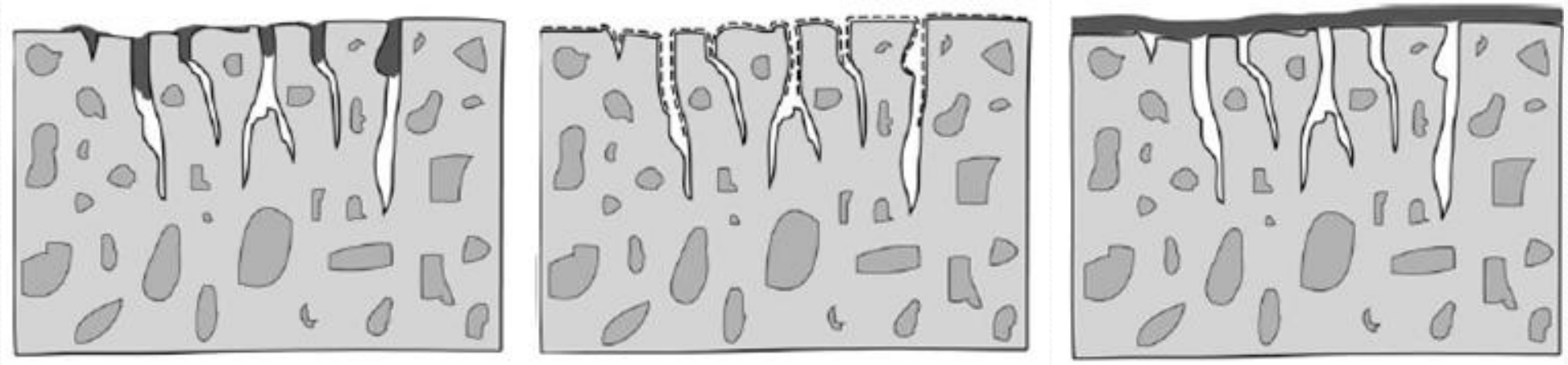


Pore Blocker

Water Repellent

Film Former Coating Barrier

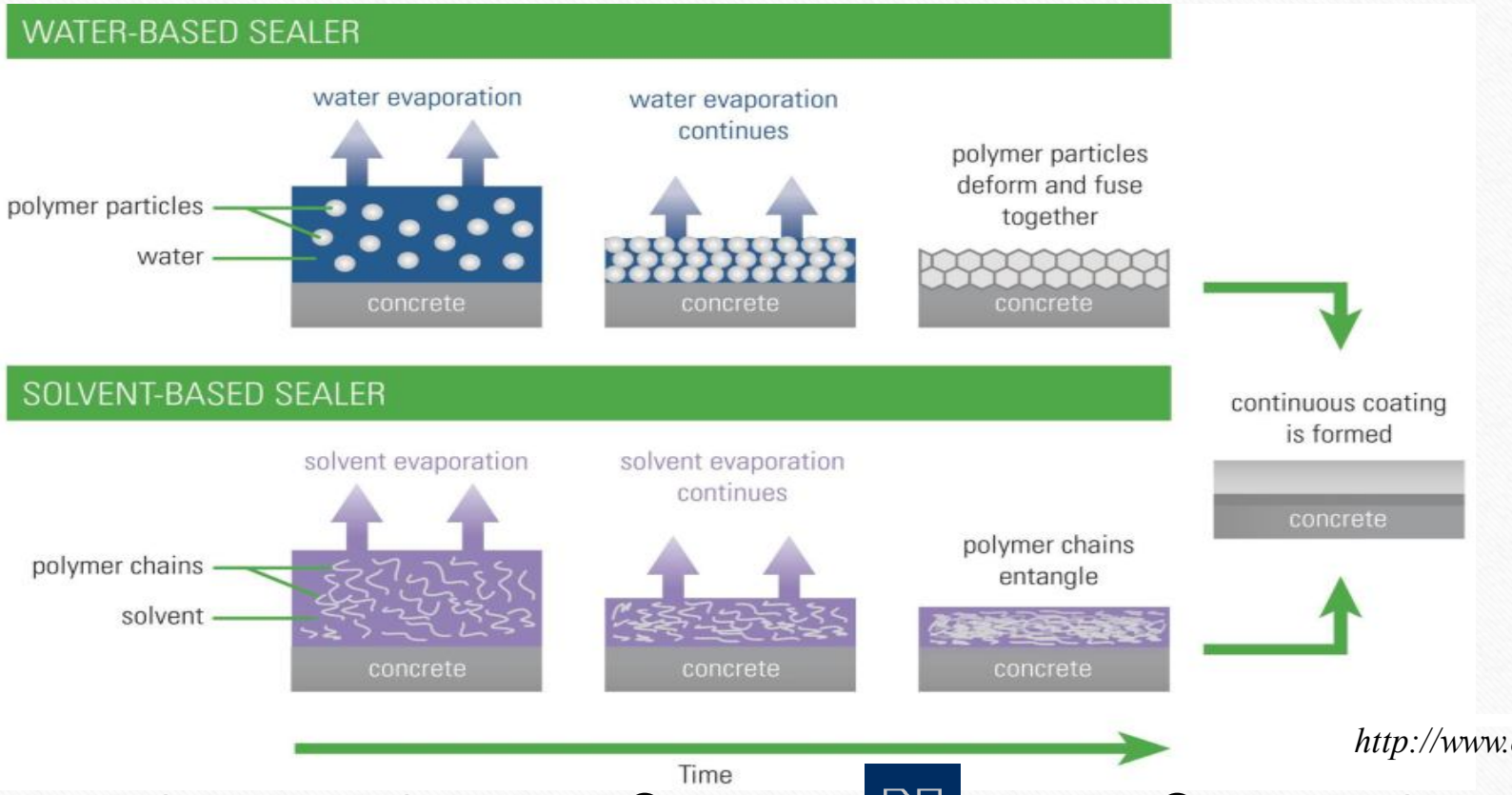
(Nielsen, J., Murgel, G., & Farid, A., 2011)

Sealer Background

Water-based sealer: the polymer particles are dispersed in water. When the sealer is applied to concrete, the water evaporates and the polymer particles move closer together. As the evaporation of water continues, the polymer particles begin to deform and fuse together, eventually forming a continuous clear coating.

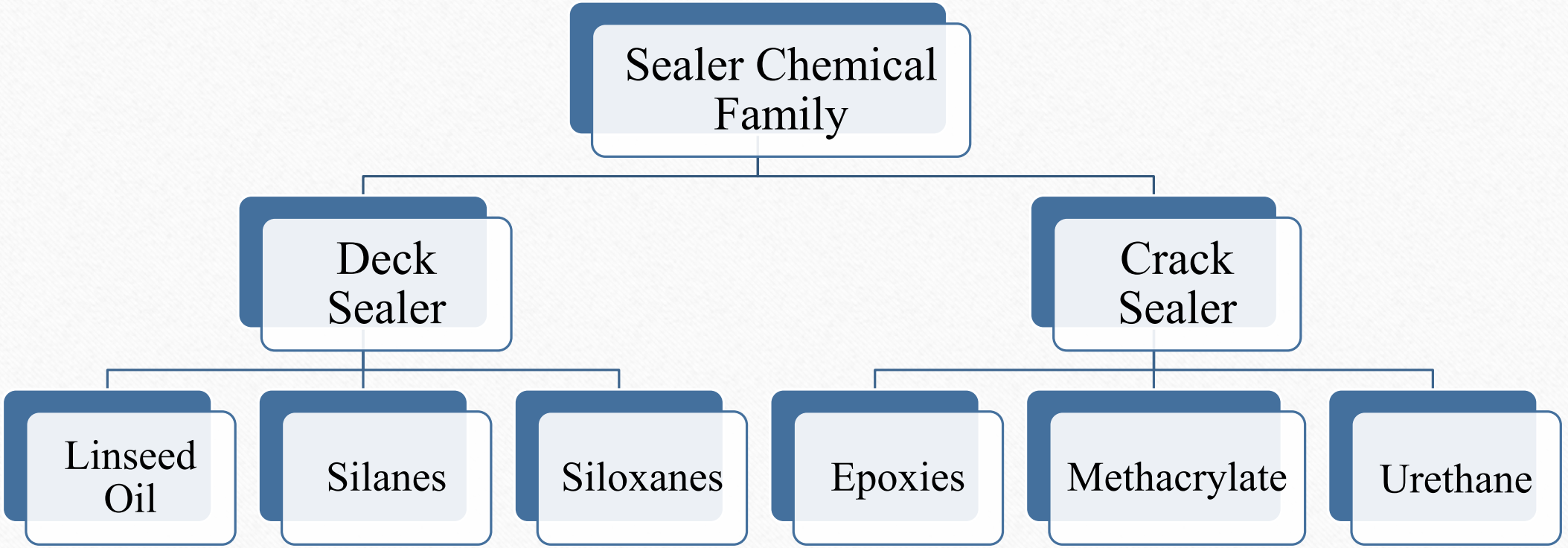
Solvent-based sealer: polymers are not present as separate particles. Instead, the polymer and solvent form a continuous, clear polymer solution. When solvent evaporates from a solvent-based sealer, the polymer chains are drawn closer together and eventually entangle.

Sealer Background



http://www.concreteconstruction.net

Sealer Background



Sealer Background

Application of the sealers:

- Before applying the sealers on the deck surface, the surface have to be cleaned either by sand/shot blasting or high pressure water.
- Deck sealers are applied by spraying the sealers on the deck with low pressure sprayer, or using a roller, or wheel cart to spread the sealers over the deck.
- Crack sealers are applied as gravity fed, or pressure injection for small number of cracks, or spread over the entire deck for case of many cracks in the same area.
- Sealers are applied in temperature ranges from 40°F to 100°F.

Sealer Background

Coverage rate:

- Coverage rate for deck sealers are typically given in square foot of coverage per gallon.
- Coverage rate of crack sealers are typically given as the volume in cubic inch that could be filled by one gallon.

Expected durability:

- Durability for deck sealers typically ranges from five to fifteen years.
- Durability for crack sealers expected to remain efficient up to the life of the structure.

Sealer Background

General properties for sealers:

- Viscosity
- Depth of penetration
- Volatile organic compound (VOC), Environmental Protection Agency (EPA) imposed VOC content limits to 5 pounds per gallon or 600 grams per liter
- Chloride reduction %
- Bond strength

Sealer Background

Main findings from previous research:

- Silanes and siloxanes are more effective in reducing chlorides than linseed oil. Silanes gave best performance.
- Linseed oil is a membrane sealer than a penetrating sealer due high molecular size and viscosity.
- Crack and deck sealers with viscosity less than 15 centipoise appear to achieve good penetration into cracks and deck surface.
- Deck sealers should be conducted within three to six months after construction and reapplied after five years.

Sealer Background

Main findings from previous research:

- Illinois DOT introduced high performance concrete mix design contain coal fly ash, blast furnace slag to improve density and porosity of concrete, and hence reduce chlorides.
- Sealers with larger penetration doesn't slow the ingress of the chlorides, but they perform better through time.
- Sealers with shallow penetration depth are removed more quickly from the surface of the bridge due to vehicle abrasion.

Experimental Program

- Two types of concrete were used for both deck sealers and crack sealers.
- Concrete used: American Ready-Mix and 3D Ready-Mix.
- For deck sealers, five sealers were applied on both concrete, and four laboratory tests were conducted.
- For crack sealers, six sealers were applied on both concrete, and two laboratory tests were conducted.

Experimental Program

- **Tests for assessing the quality of concrete:**
  - ✓ Slump Test: ASTM C143
  - ✓ Compressive Strength: ASTM D4832
  - ✓ Air Content: ASTM C231
- Slump values for both concrete were about 3.6 inch.
- Air content percentage of both concrete ranges from 5.5% to 6.5%

Experimental Program

Deck Sealers

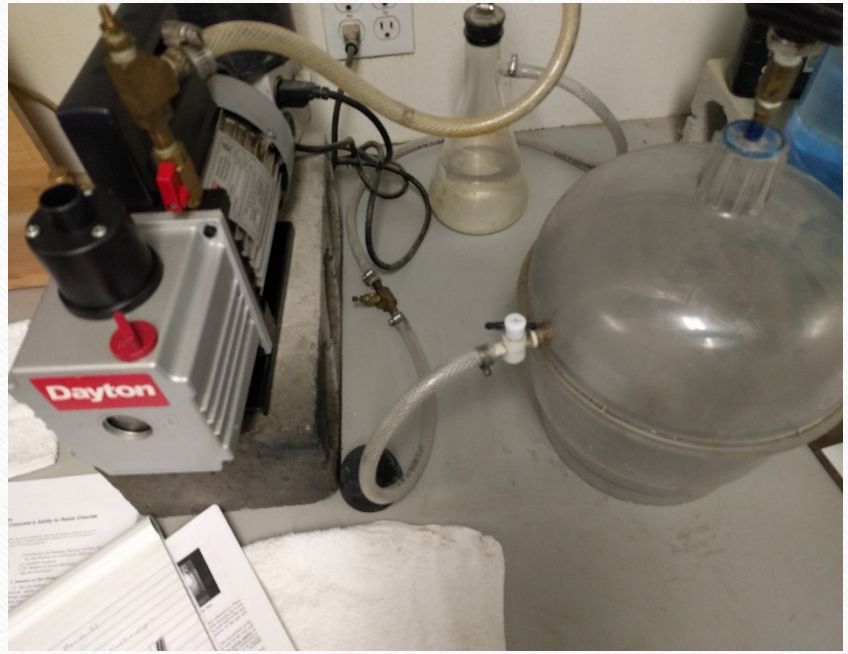
1. Rapid Chloride Permeability test "ASTM C1202"
2. Saltwater Absorption test "NCHRP report 244 series II"
3. Chloride Ion Intrusion 90 days Ponding "AASHTO T259/T260"
4. Freeze/Thaw test "ASTM C666"

Crack Sealers

5. Depth of Penetration "Visual Inspection"
6. Bond Strength "ASTM C496"

1. Rapid Permeability Test

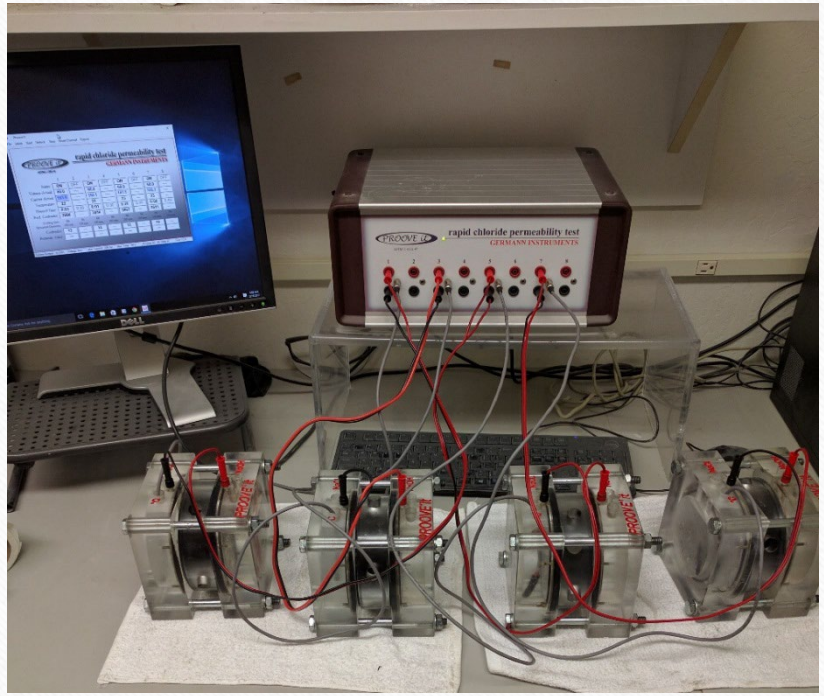
- Specimens used were cylinders 4 in. × 2 in.
- This test for determining the amount of charge passed through the specimens and hence assigned them to a certain permeability class.
- Test was performed twice, first after 30 days of age, and second after 120 days.
- Samples were put in vacuum desiccator for four hours.



Vacuum desiccator and a pump

1. Rapid Permeability Test

- Samples were clamped from both sides with two cells.
- One cell was filled with NaCl solution and connected to the negative terminal of the power supply.
- The other one was filled with NaOH and connected to the positive terminal of the power supply.
- The test starts and terminated automatically after 6 hours, and the amount of charge passed was recorded.



Rapid permeability test setup

1. Rapid Permeability Test

Both Concrete specimens after **30** days:

Sealer	American Ready-Mix		3D Ready-Mix	
	Average Charge Passed	Permeability Class	Average Charge Passed	Permeability Class
Control	5508	High	4289	High
Sikagard 705 L	3147	Moderate	2221	Moderate
Saltguard WB	3092	Moderate	2136	Moderate
ATS-100	2528	Moderate	1107	Low
MasterProtect H400	2320	Moderate	1757	Low
Aquanil Plus 40	1947	Low	1115	Low

1. Rapid Permeability Test

Both Concrete specimens after **120** days:

Sealer	American Ready-Mix		3D Ready-Mix	
	Average Charge Passed	Permeability Class	Average Charge Passed	Permeability Class
Control	4200	High	3918	High
Sikagard 705 L	135	Very Low	143	Very Low
Saltguard WB	331	Very Low	474	Very Low
ATS-100	152	Very Low	261	Very Low
MasterProtect H400	181	Very Low	NA	NA
Aquanil Plus 40	NA	NA	150	Very Low

2. Saltwater Absorption Test

- Specimens used were slabs 12×12×3 inches
- This test for calculating the change in weight occurs due to the chlorides ingress into the specimens.
- Specimens were weighed before immersion in sodium chloride solution (15% by weight).
- After calculating the weight, the saltwater absorption Ratio "SAR" could be calculated.

Two specimens were immersed in sodium chloride solution

2. Saltwater Absorption Test

- Specimens remained in the solution for 7, 14, and 21 days, then removed and weighted.
- The equation below was used to calculate the SAR% for each specimen

$$SAR\% = \frac{\Delta W_{treated}}{\Delta W_{untreated}} = \frac{W_{treated(7,14,21)} - W_{treated\ (0)}}{W_{untreated\ (7,14,21)} - W_{untreated\ (0)}} \times 100$$

- Treated specimens are specimens applied with sealers.
- Untreated specimen is the control specimen without any sealers.

2. Saltwater Absorption Test

American Ready-Mix Concrete specimens:

Sealer	SAR7 %	SAR14 %	SAR21 %
Control	100	100	100
Sikagard 705 L	35.6	32.0	34.2
Saltguard WB	56.3	58.9	63.9
ATS-100	45.4	45.3	49.8
MasterProtect H400	35.8	36.4	39.2
Aquanil Plus 40	48.9	52.6	55.2

2. Saltwater Absorption Test

3D Ready-Mix Concrete specimens:

Sealer	SAR7 %	SAR14 %	SAR21 %
Control	100	100	100
Sikagard 705 L	49.1	52.4	51.2
Saltguard WB	65.9	67.4	69.7
ATS-100	43.7	45.5	48.6
MasterProtect H400	45.3	47.7	54.3
Aquanil Plus 40	50.4	52.5	54.8

3. Chloride Ion Intrusion Test

- Specimens used were 12×12×3 inches
- This test for determining the amount of chlorides that penetrate through the concrete.
- This test was conducted twice with and without exposing to freeze/thaw cycles.
- Specimens covered for 90 days with sodium chloride solution (3% by weight): 0.5 in. depth then covered with plastic tarpaulin to prevent solution evaporation.

Specimens covered with plastic tarpaulin

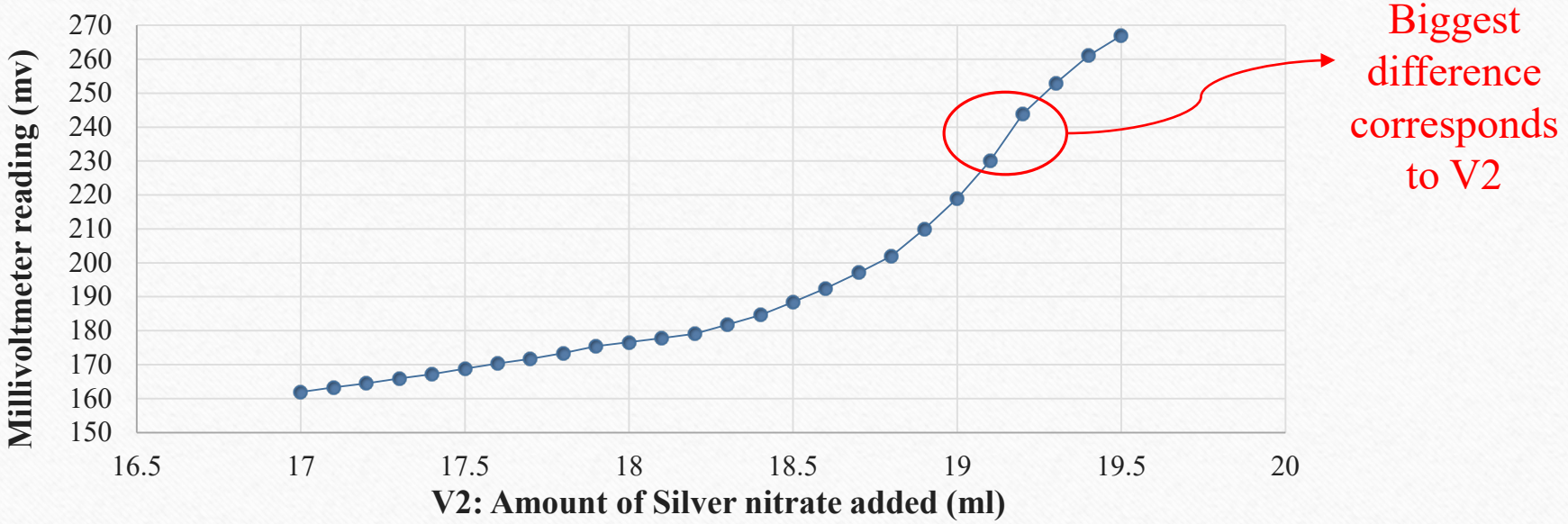
3. Chloride Ion Intrusion Test

- After 90 days, the chloride solution was removed, and the specimens were brushed from the salts.
- Concrete powders from three holes were extracted from each specimen by rotary hammer to be tested.
- Some chemical procedures were done on the concrete powder to be ready for titration.
- Electrode is calibrated and titration curve was drawn for each sample by using millivoltmeter.

Three holes where concrete powder was extracted

3. Chloride Ion Intrusion Test

- A curve was drawn and the inflection point is corresponding to the amount of silver nitrate that used in calculating the chloride %.



3. Chloride Ion Intrusion Test

- The equation used in calculating the amount of chloride is:
  - N1: normality of sodium chloride =0.01
  - V1: volume of sodium chloride added = 4ml
  - N2: normality of silver nitrate =0.01
  - V2: volume of silver nitrate
  - W: weight of sample = 3.0 gm

??

$$Cl^-, \% = \frac{\left(3.5453\left(V_1N_1 - V_2N_2\right)\right)}{W}$$

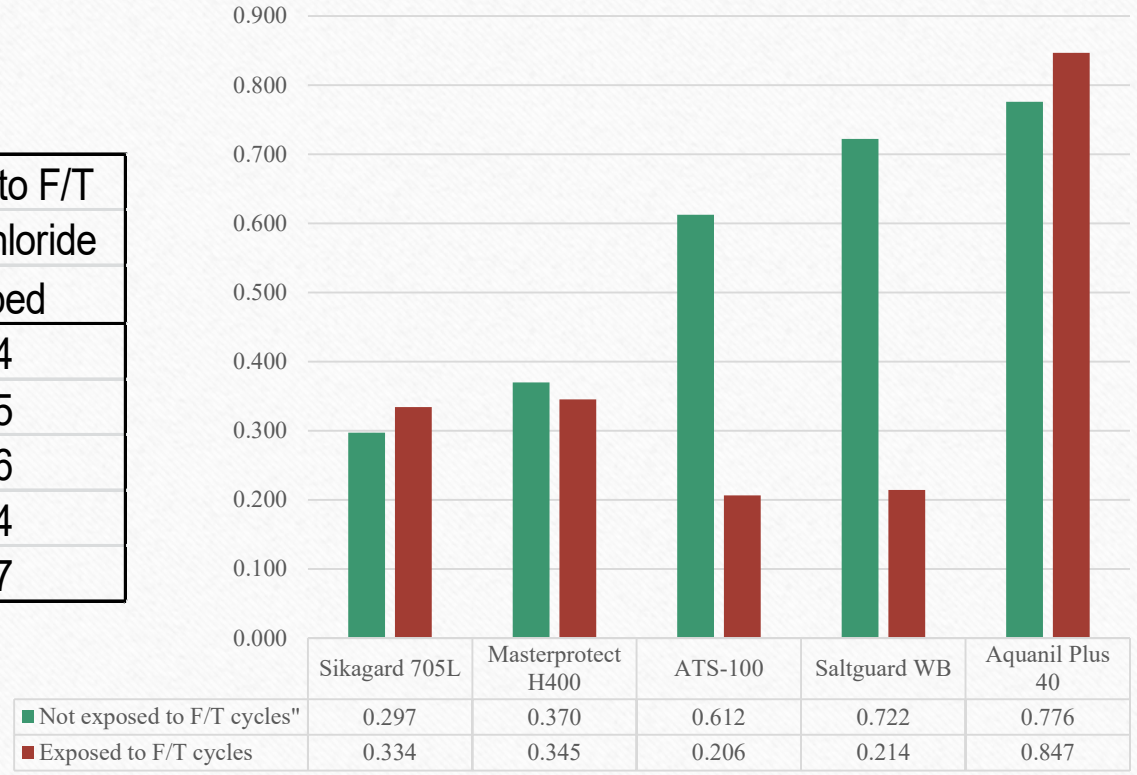
4. Freeze/Thaw (F/T) Test

- Specimens used were cubes 3×4×16 inches
- Specimens were tested in Denver, Colorado under 300 freeze and thaw cycles, and sent back to UNR for chloride ion intrusion test.
- The specimens were tested for chloride ion intrusion to assess the performance of the sealers after exposing them to freeze/thaw cycles.
- The test procedure for the chloride ion intrusion was the same as stated before for specimens not subjected to freeze/thaw.

Chloride Ion Intrusion w/ & w/o F/T

American Ready-Mix Concrete:

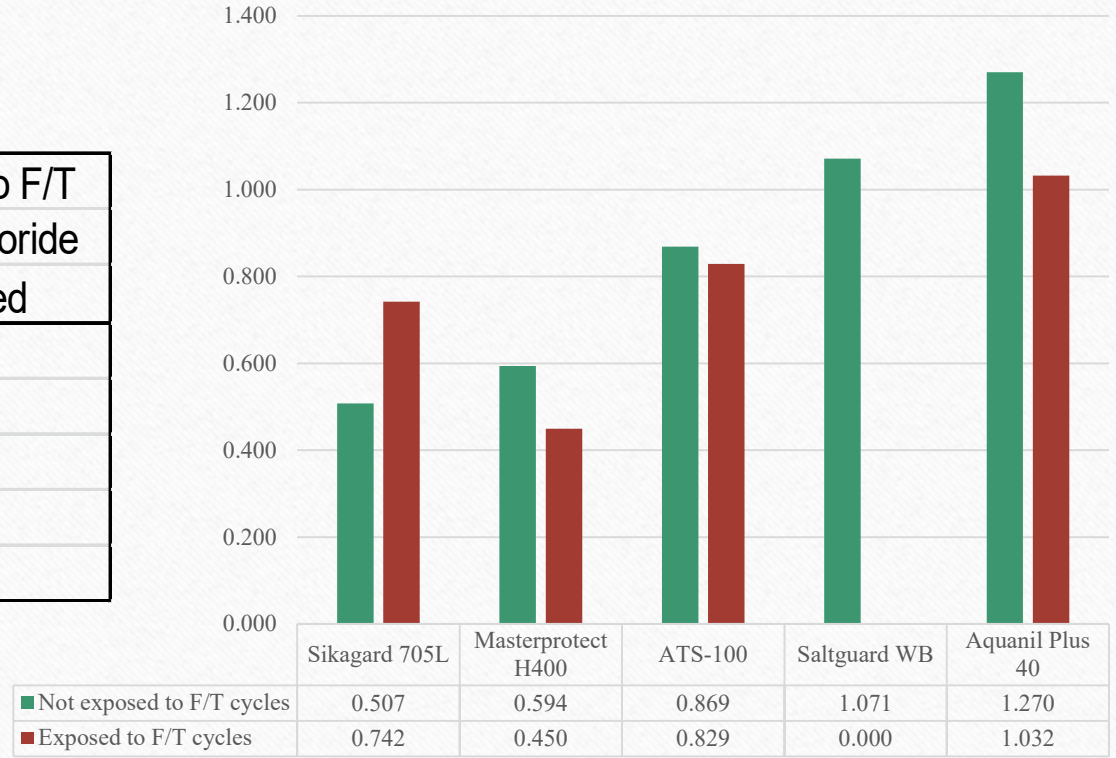
Sealer	Not exposed to F/T Ratio of chloride absorbed	Exposed to F/T Ratio of chloride absorbed
Sikagard 705L	0.297	0.334
Masterprotect H400	0.370	0.345
ATS-100	0.612	0.206
Saltguard WB	0.722	0.214
Aquanil Plus 40	0.776	0.847



Chloride Ion Intrusion w/ & w/o F/T

3D Ready-Mix Concrete:

Sealer	Not exposed to F/T Ratio of chloride absorbed	Exposed to F/T Ratio of chloride absorbed
Sikagard 705L	0.507	0.742
Masterprotect H400	0.594	0.450
ATS-100	0.869	0.829
Saltguard WB	1.071	N/A
Aquanil Plus 40	1.270	1.032



Experimental Program

Deck Sealers

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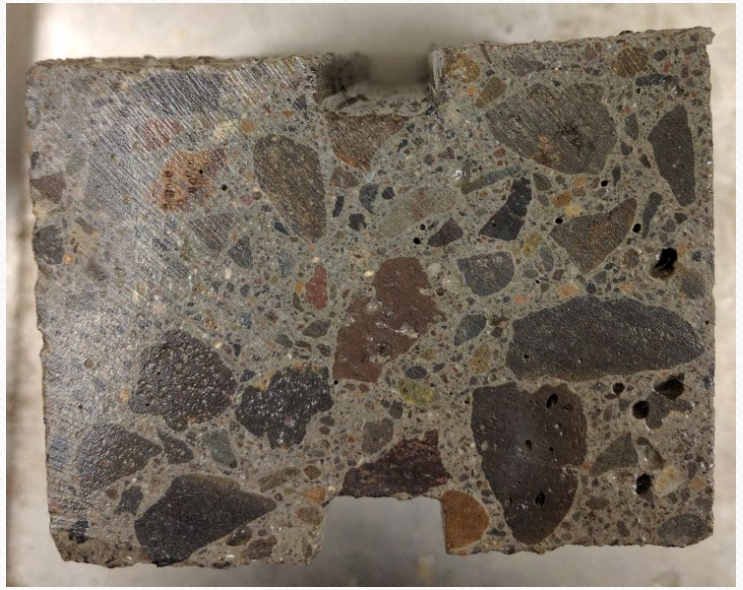
Crack Sealers

5. Depth of Penetration "Visual Inspection"
6. Bond Strength "ASTM C496"

Crack Sealers

- Specimens used were 8×4×3 inches.
- Formation of a notch in the upper and lower face of the specimens.
- Formation of cracks in the specimens using steel rods.



Notches in the specimens

Formation of cracks

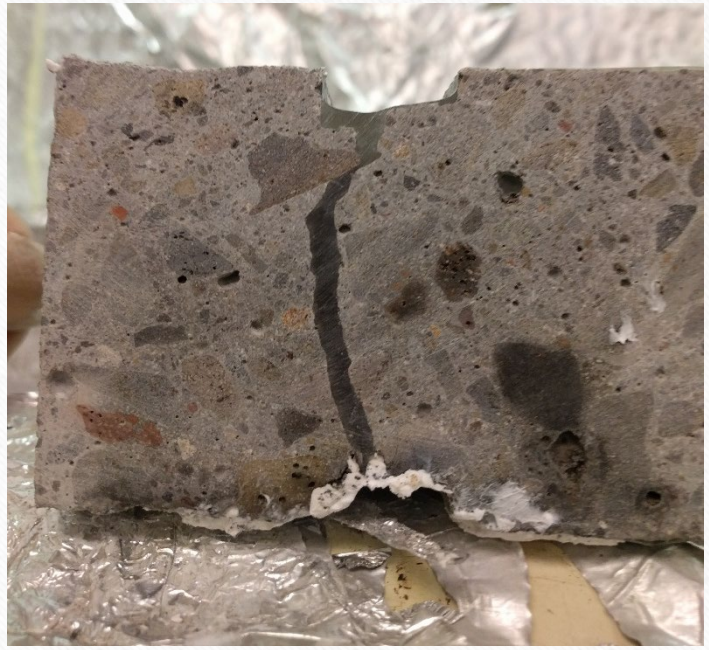
Crack Sealers

- Formation of two different crack width to be tested (0.09 in. and 0.15 in.) using C-clamps.
- Applying the sealer into the crack and left for 14 days.
- Two inches were cut from the end of each specimen for depth of penetration test.
- The remaining 4×4×3 inches from each specimen were used for bond strength test.

Formation of required crack width

5. Depth of Penetration Test

- All the six sealers were able to penetrate through the whole depth of the crack for both crack width, the 0.09 inch and 0.15 inch.
- The viscosity of some sealers ranges from 10 to 100 cps and viscosity of other ranges around 2500 cps.
- *Note:* Viscosity of water is 1 cps, and for honey is 10,000 cps.



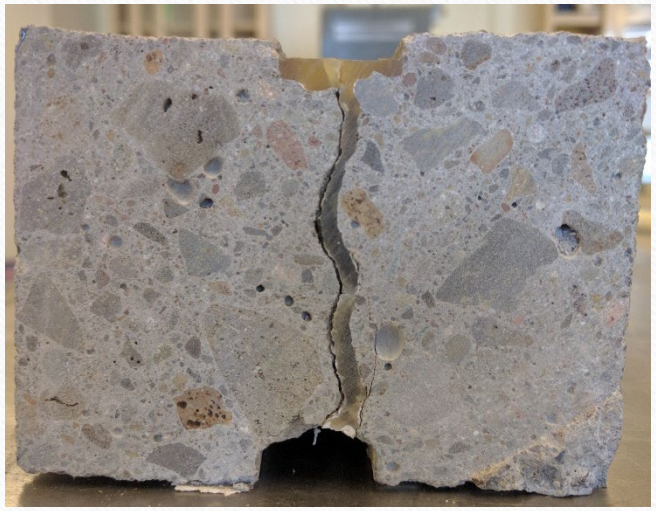
Penetration of a sealer in a crack

6. Bond Strength Test

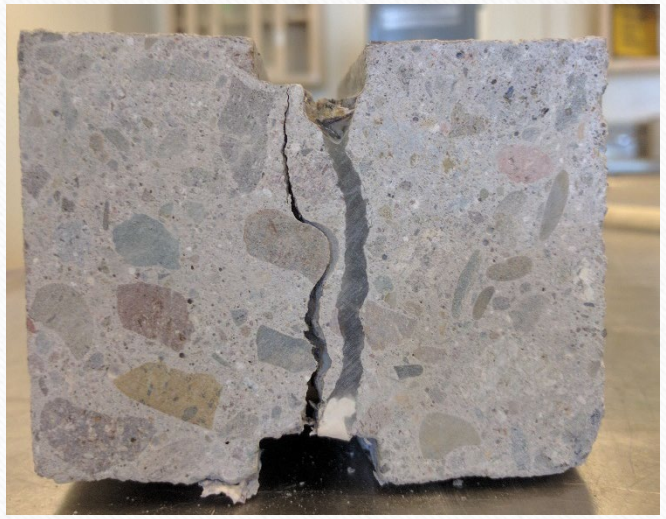
- Specimens 4×4×3 inches were broken under compression for calculating the bond strength.
- Force was applied to the specimens by load control equal to 550 lb/10 sec.
- The bond strength of each sealer is corresponding to the force which the specimens were broken.
- Load decreased after breaking until the load reach to 20% of the bond strength, then the mode of failure was observed.

6. Bond Strength Test

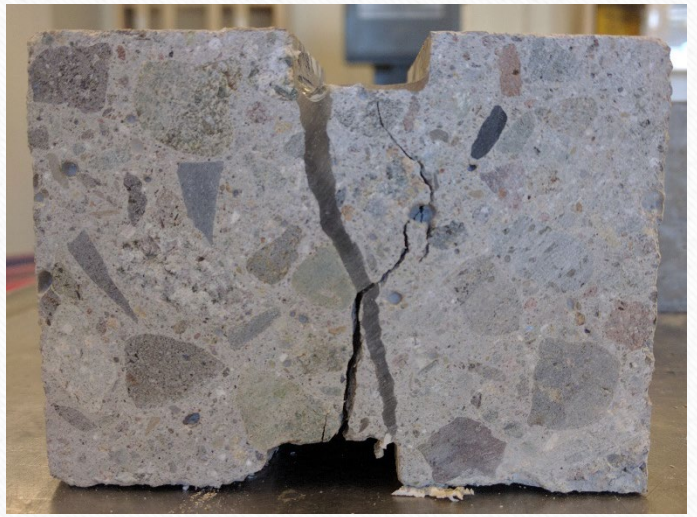
Modes of Failure:



Interface Failure



Concrete Failure



Concrete and Sealer Failure

6. Bond Strength Test

American Ready-Mix Concrete specimens:

Sealer	Bond Strength for 0.15 in. [lb]	Failure Mode	Bond Strength for 0.09 in. [lb]	Failure Mode
Duraguard HM Sealer	6980	Concrete	6545	Concrete
Sikadur 55 SLV	5815	Concrete	8155	Concrete & Interface
Sikadur 22, LO-Mod	4580	Concrete & Interface	4320	Concrete
MasterSeal 630	2825	Interface	7715	Interface
KBP 204	2210	Interface	5205	Concrete & Interface
T-78 Polymer	1485	Concrete & Interface	680	Interface

6. Bond Strength Test

3D Ready-Mix Concrete specimens:

Sealer	Bond Strength for 0.15 in. [lb]	Failure Mode	Bond Strength for 0.09 in. [lb]	Failure Mode
Duraguard HM Sealer	5480	Concrete	4145	Concrete
Sikadur 55 SLV	3545	Concrete	7130	Concrete
Sikadur 22, LO-Mod	3315	Concrete & Sealer	4680	Concrete & Interface
MasterSeal 630	2135	Interface	2570	Concrete
KBP 204	1580	Interface	2040	Interface
T-78 Polymer	905	Interface	5065	Concrete

Discussions: Deck Sealers

American Ready-Mix

Test	Sealer	Performance Category	Score
Rapid chloride permeability 30 days	Aquanil plus 40	I	30
	Sikagard 705 L	II	20
	MasterProtect H400		
	ATS-100		
	Saltguard WB		
Rapid chloride permeability 120 days	Sikagard 705 L	I	45
	MasterProtect H400		
	ATS-100		
	Saltguard WB	II	30
	Aquanil plus 40	NA	NA
Saltwater absorption 21 days	Sikagard 705 L	I	45
	MasterProtect H400		
	ATS-100	II	30
	Aquanil plus 40		
	Saltguard WB	III	15

3D Ready-Mix

Test	Sealer	Performance Category	Score
Rapid chloride permeability 30 days	Aquanil plus 40	I	30
	MasterProtect H400		
	ATS-100		
	Saltguard WB	II	20
	Sikagard 705 L		
Rapid chloride permeability 120 days	Sikagard 705 L	I	45
	MasterProtect H400		
	ATS-100		
	Saltguard WB	II	30
	Aquanil plus 40	NA	NA
Saltwater absorption 21 days	Sikagard 705 L	I	45
	Aquanil plus 40		
	ATS-100	II	30
	MasterProtect H400		
	Saltguard WB	III	15

Discussions: Deck Sealers

American Ready-Mix

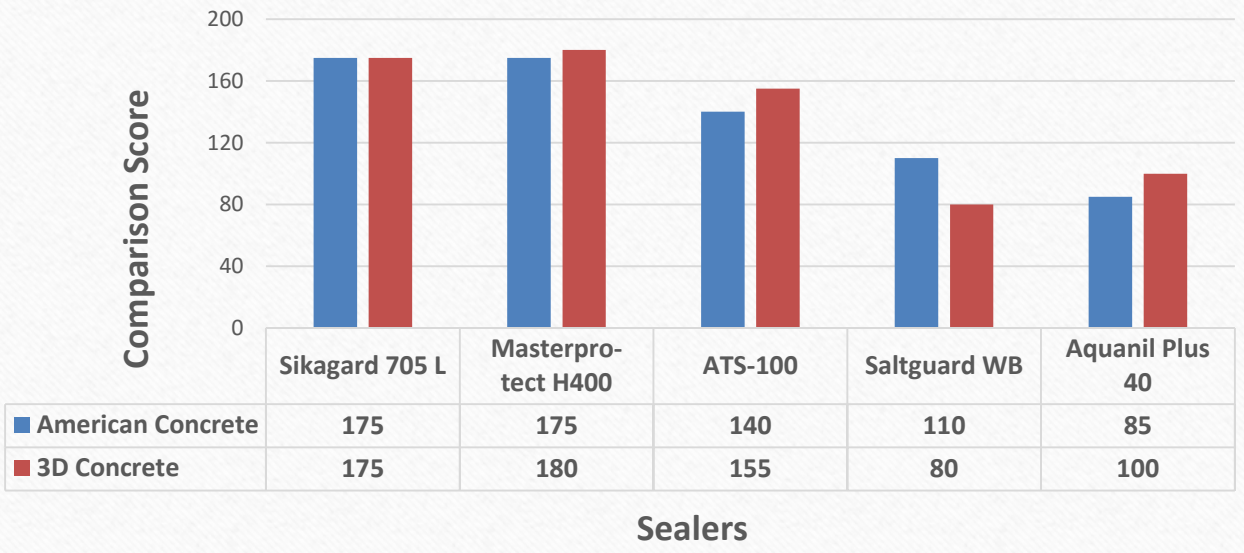
Test	Sealer	Performance Category	Score
Chloride ion intrusion Without exposed to F/T	Sikagard 705 L	I	45
	MasterProtect H400		
	ATS-100	II	30
	Saltguard WB	III	15
	Aquanil plus 40		
Chloride ion intrusion exposed to F/T	ATS-100	I	30
	Saltguard WB		
	Sikagard 705 L	II	20
	MasterProtect H400		
	Aquanil plus 40	III	10

3D Ready-Mix

Test	Sealer	Performance Category	Score
Chloride ion intrusion Without exposed to F/T	Sikagard 705 L	I	45
	MasterProtect H400		
	ATS-100	II	30
	Saltguard WB	III	15
	Aquanil plus 40		
Chloride ion intrusion exposed to F/T	MasterProtect H400	I	30
	ATS-100	II	20
	Sikagard 705 L		
	Aquanil plus 40	III	10
	Saltguard WB	NA	NA

Discussions: Deck Sealers

Concrete	Sealer	Total Score
American Ready-Mix	Sikagard 705 L	175
	Masterprotect H400	175
	ATS-100	140
	Saltguard WB	110
	Aquanil Plus 40	85
3D Ready-Mix	Sikagard 705 L	175
	Masterprotect H400	180
	ATS-100	155
	Saltguard WB	80
	Aquanil Plus 40	100



Discussions: Deck Sealers

- The chemical families are arranged from higher performance to lower one.

Chemical Family	Sealers
Alkylalkoxy Silane, water based	Sikagard 705 L & MasterProtect H 400
Alkyltrialkoxy Silane, water-based	ATS-100
Alkyltrialkoxy Silane, solvent based	Aquanil Plus 40
silane/siloxane, water based sealer	Saltguard WB

Discussions: Deck Sealers

- Sealers cost per 10,000 ft^2

Sealers	Coverage rate (ft^2 / gal)	Cost per 5 gallon (Material)	Labor & Equipment cost	Total cost (per 10,000 ft^2)
Sikagard 705L	240 to 360	$330	About 40 cents per ft^2	$6310
Masterprotect H400	100 to 200	$135		$5755
Saltguard WB	200 to 300	$150		$5875
ATS-100	200 to 300	$165		$5200
Aquanil plus 40	100 to 150	$250		$7500

Discussions: Crack Sealers

American Ready-Mix Concrete specimens:

Narrow crack (0.09")			Wide crack (0.15")		
Sealer	**Concrete type**	**Performance**	**Sealer**	**Concrete type**	**Performance**
Sikadur 55 SLV	American Ready-Mix	A	Duraguard HM Sealer	American Ready-Mix	A
MasterSeal 630			Sikadur 55 SLV		
Duraguard HM Sealer		B	Sikadur22,LO-MOD		B
KBP 204			MasterSeal 630		
Sikadur22,LO-MOD			KBP 204		
T-78 Polymer		C	T-78 Polymer		C

Discussions: Crack Sealers

3D Ready-Mix Concrete specimens:

Narrow crack (0.09")			Wide crack (0.15")		
Sealer	**Concrete type**	**Performance**	**Sealer**	**Concrete type**	**Performance**
Sikadur 55 SLV	3D Ready-Mix	A	Duraguard HM Sealer	3D Ready-Mix	A
Sikadur22,LO-MOD		B	Sikadur 55 SLV		B
Duraguard HM Sealer			Sikadur22,LO-MOD		
T-78 Polymer			MasterSeal 630		
MasterSeal 630		C	T-78 Polymer		C
KBP 204			KBP 204		

Discussions: Crack Sealers

- The main two families studied in crack sealers are epoxies and high molecular weight methacrylate.

Chemical Family	Sealers
Epoxy	• Duraguard HM Sealer • Sikadur 55 SLV • Sikadur 22, LO-MOD
High Molecular Weight Methacrylate (HMWM)	• T-78 Polymer • MasterSeal 630 • KBP 204

Conclusions

1. All the sealers were effective in reducing the amount of chlorides penetrated into the concrete compared to the control specimens
2. Sealers of a chemical family of Alkylalkoxy silane gave the highest performance.
3. Water based sealers gave higher performance than solvent based sealers and they are more friendly to the environment.
4. Bigger depth of penetration enhances the performance of the sealer, and its ability to reduce the penetration of chlorides.

Conclusions

5. Sealers made of epoxies gave higher performance in bond strength test than methacrylate.
6. Sealers made of methacrylate gave bigger depth of penetration than epoxies.
7. Sealers with lower viscosity as methacrylate are more efficient in hairline cracks because they could penetrate more.
8. HMWM, High Molecular Weight Methacrylate, product are typically applied in a flood coat due to its very low viscosity, while epoxy products are generally applied to individual crack.

Recommendations

1. Water-based sealers (Alkylalkoxy Silane) → deck sealers.
2. Sealers with viscosity lower than 3,000 cps → large penetration depth.
3. Epoxies sealers → maintenance of bridges with wide cracks (bond strength is more important than depth of penetration)
4. HMWM, High Molecular Weight Methacrylate, sealers → very narrow crack (depth of penetration is more important than bond strength)
5. Use sealer with high bond strength to prevent sealer failure or interface failure (concrete failure instead).

Chloride Ion Intrusion Test

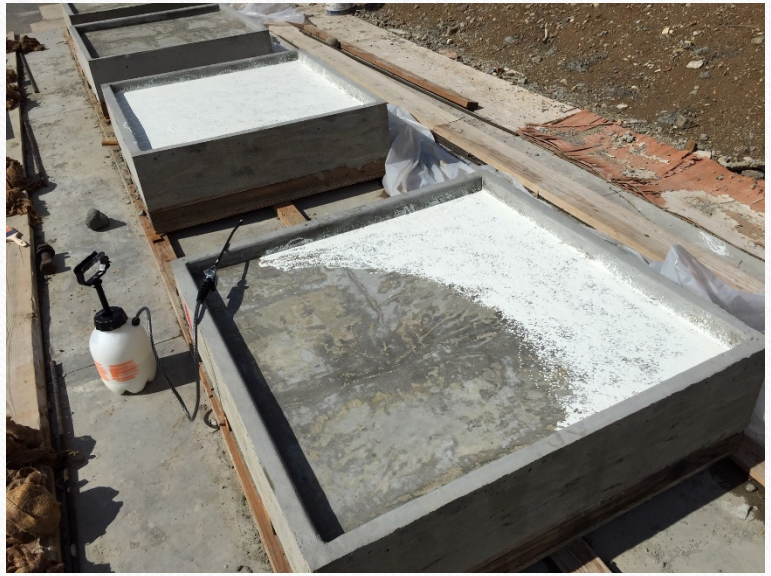
- Four slabs (4×4 feet) were used as specimens
- Conducted the test to determine the amount of chlorides that penetrate through the concrete.
- All four slabs were wet cured for 7 days.
- Then sealers and curing compound were applied on the slabs
- The slabs were divided into three. In each segment, one sealer was applied.

Casting the specimens

Chloride Ion Intrusion Test

Sealer and curing compound applying schedule:

	7th day	28th day
Slab 1:	-	Three sealers
Slab 2:	Three sealers	-
Slab 3:	Curing compound*	-
Slab 4:	Curing compound*	Three sealers



Applying the curing compound

* curing compound was removed at 28th day

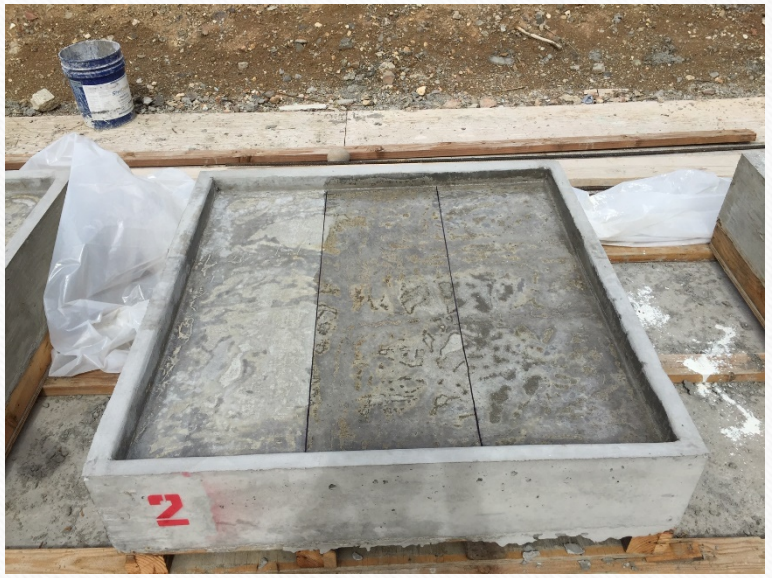
Chloride Ion Intrusion Test

- *Sealers:*

1. Sikagard 705L (Sika Corporation)
2. MasterProtect H 400 (BASF Corporation)
3. SIL-ACT- ATS-100 (Advanced Chemical Technologies)

- *Curing compound:*

  2250 White from WR Meadows



Applying the Sealers

Chloride Ion Intrusion Test

- Specimens covered for 90 days with sodium chloride solution (3% by weight): 1 in. depth then covered with plastic tarpaulin to prevent solution evaporation.
- After 90 days, the chloride solution was removed, and the specimens were brushed from the salts.

Pouring salt water on the slabs

Chloride Ion Intrusion Test

- Concrete powders from two holes were extracted from each specimen for each sealer by rotary hammer to be tested.
- Took two samples with different depth from each hole (0.0-0.5” and 0.5-1.0”)
- Some chemical procedures will be done on the concrete powder to be ready for titration.
- Electrode is calibrated and titration curve was drawn for each sample by using millivolt meter.

Taking concrete powder samples

Stay Tuned!

THANK YOU!

Test Discussion: Rapid Chloride Permeability

- The amount of charge that passed through 3D Ready-Mix specimens was less than American Ready-Mix specimens
- The aggregate used in 3D Ready-Mix and American Ready-Mix same size but different supplier.
- Concrete become more mature “denser” with time and that decrease the number of pores, and the amount of charge passed as well.
- Master Protect H400 & Aquanil plus 40 gave the highest performance.

Test Discussion: Saltwater Absorption Test

- Sikagard 705L & Master Protect H400 provide the lowest SAR ratio in American Ready-Mix specimens.
- Sikagard 705L, Master Protect H400, and ATS-100 gave the lowest SAR ratio in 3D Ready-Mix specimens.

Test Discussion: Chloride Ion Intrusion Test

- For both American Ready-Mix and 3D Ready-Mix the best performing sealers were Sikagard 705L and Masterprotect H400.
- Sikagard 705L gave lower performance when exposed to freeze/thaw cycles, unlike the other sealers.
- Aquanil plus 40 gave the lowest performance with and without exposure to freeze/thaw in both American Ready-Mix and 3D Ready-Mix.

Test Discussion: Depth of Penetration Test

- All the sealers penetrated through the whole depth of both the 0.15 in. and 0.09 in. cracks, that means that the sealers viscosity didn't affect the penetration through the crack.
- Sealers with viscosity below 3,000 cps were good in penetrating the whole depth for both crack width 0.09 in. and 0.15 in.

Test Discussion: Bond Strength Test

- Duraguard HM Sealer gave the highest bond strength for the 0.15 in. for both concrete.
- Sikadur 55 SLV gave the highest bond strength for the 0.09 in. for both concrete.
- Mode of failure for both Duraguard HM and Sikadur 55 SLV Sealer was concrete failure, indicates that the sealer perform well with the concrete.

Test Discussion: Bond Strength Test

- T-78 Polymer and KBP 204 gave the lowest bond strength and didn't perform well.
- Mode of failure for both T-78 Polymer was concrete and interface failure or interface failure, indicates that the sealer does not perform well, as well as the bonding with the concrete.
- Lowest bond strength was accompanied with interface or sealers failure.

Discussions: Deck Sealers (4/6)

- For all the tests, a statistical analysis 95% confidence interval was applied.
- The weighting score for all the sealers categories was according to the 95% confidence interval
- According to the manufacturer, the chloride reduction for Sikagard 705 L and Masterprotect H400 were the highest according to NCHRP Report 244 series II and series IV.
- On the basis of the laboratory tests Sikagard 705 L and Masterprotect H400 exhibited good performance throughout all the tests.
- On the basis of the laboratory tests, Aquanil plus 40 and Saltguard WB exhibited poor performance throughout most of the tests.

Discussions: Crack Sealers

- On the basis of laboratory tests, Duraguard HM Sealer & Sikadur 55 SLV gave the highest bond strength among all the sealers- EPOXY
- On the basis of laboratory tests, T-78 Polymer and KBP 204 gave the lower bond strength among the sealers. - Methacrylate