University of Idaho
College of Engineering

CONCRETE PERFORMANCE IN AGGRESSIVE SALT ENVIRONMENT.

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OUTLINE

- INTRODUCTION,
- PROBLEM STATEMENT;
- OBSERVATION FROM FIELD STUDIES CONDUCTED BY ITD.;
- TESTING MATRIX
- PRELIMINARY LABORATORY RESULTS;
- RESULT DISCUSSION;
- CONCLUSION.

INTRODUCTION

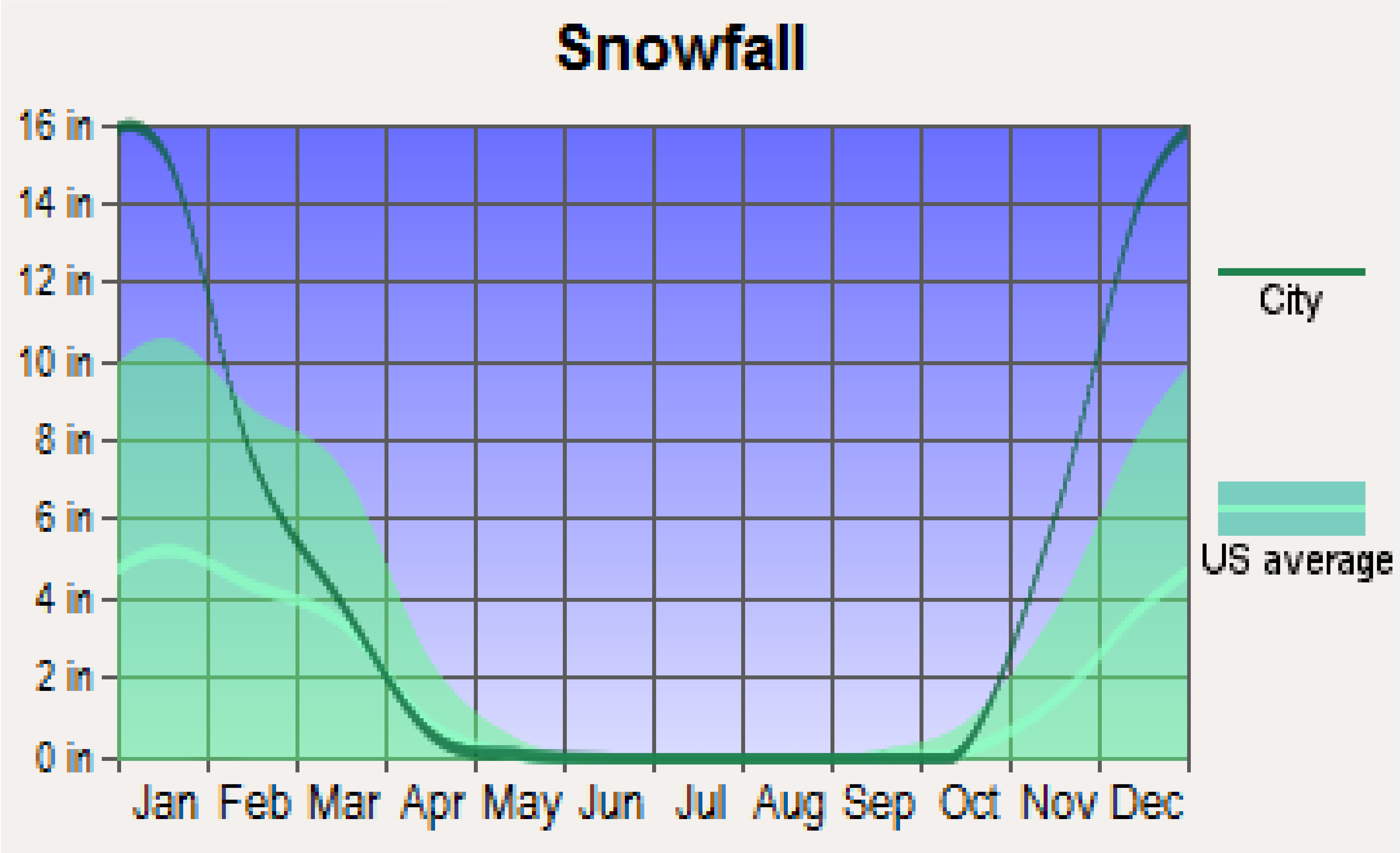
Concrete in barrier rails, parapets, and bridge decks throughout the State of Idaho are exposed to deicing chemicals. As such, signs of durability damage have manifested in some of these concrete infrastructure.

Replacement of concrete members in highway applications is not only costly for the highway agencies, but can also impose significant delays to the road users.

Spall in approach rail at SW. (ITD 2012)

Large area of patched spalls, spalls with rebar exposed and delamination at mid-span of deck.

PROBLEM STATEMENT



Coeur d’Alene Snowfall data

Major deterioration in form of scaling was observed on concrete barriers cast between June 2014-June 2015. Such deterioration called for actions on how to address the problem and prevent future recurrence.

Idaho receives substantial amount of snow every year during winter season, leading to high application of deicing chemicals on concrete pavement and high cost of maintenance after winter season.

OBJECTIVES

1. Evaluate current ITD concrete mixtures' durability against F–T and wetting–drying (W–D) exposure conditions. The proposed experimental study is focused on the evaluation of long-term mechanical degradation due to exposure to F-T cycling, W-D cycles (mass loss, scaling), to determine the performance of existing mixes (paste and concrete) used in the State of Idaho using various deicer chemicals.
2. Recommend strategies for improved durability of ITD mixtures. The study proposes:

- Whether the addition of certain amounts of Supplementary Cementitious Materials (SCMs) to the current concrete mixture designs is necessary to alleviate the prevalent durability issues.
- Also, the effect of curing and potentially sealing or coating methods on reducing the permeability and hence vulnerability to durability problems will be investigated.
- Other solutions, such as air entraining admixtures' amount and type will also be considered.

LABORATORY TESTING (MIXTURE DESIGN)

District	ID	Mixture ID	Mixture Type	Coarse Agg. Content [lbs/yd³]	Fine Agg. Content [lbs/yd³]	Nominal Max Agg. Size [in]	w/cm	Cementitious Material Content [lbs/yd³]	Supplementary cementitious material	Slump * [in]	SAM number [-]
1	M1	SH-5 Bridge Crossing, Plummer	Structural	1,850	1,081	¾	0.42	611	-	3 ½	0.2
	M2	I-90 Lookout Pass Paving Mixture 2015, Mullan	Paving	1,803	1,154	1 ½	0.38	688	20% Fly Ash	1 ½	0.1
	M7	I-90 Lookout Pass Paving Mixture 2016, Mullan	Paving	1,745	1,126	1 ½	0.40	688	20% Fly Ash	1 ½	0.02
2	M3	Thain Road Paving Mixture, Lewiston	Paving	1,721	1,246	¾	0.43	611	20% Fly Ash	4 ½	0.36
	M4	US-95 Race Creek Mixture, Lewiston	Structural	1,660	1,350	¾	0.40	625	20% Fly Ash	5 ¾	0.39
3	M5	I-84 Paving Mixture, Boise	Paving	1,751	1,167	1 ½	0.40	625	20% Fly Ash	1 ¾	0.16
5	M6	US-91 Paving Mixture, Pocatello	Paving	1,720	1,043	1 ½	0.39	729	20% Fly Ash	3 ¼	0.06
6	M8	Thornton Interchange Mixture, Idaho Falls	Structural	1,762	1,005	¾	0.39	658	25% Fly Ash	4 ¾	0.1

OBSERVATION FROM FIELD STUDIES

- Concrete mixtures do not have supplementary cementitious materials e.g., Fly Ash, etc.
- High water-cement ratio (0.43-0.55);
- Low to moderate surface resistivity values;
- Use of reactive aggregate in concrete coupled with chloride based deicing chemicals.

LABORATORY TESTING (TESTING MATRIX)

District	Type of deicer and concentration	Surface resistivity	Resistance to deicing scaling	Freeze-Thaw cycles
1	23.3% concentration of Salt brine	9	6	2
2	Mag bud converse; Freeze guard plus Magnesium Chloride; and Compass wet Salt	6	12	2
3	Mag Bud Converse	3	2	2
5	Salt brine	3	2	2
6	Salt brine	3	2	2

LABORATORY TESTING

Concrete Surface Resistivity

Figure 1- Surface resistivity testing.

Figure 2- Slabs preparation for surface ponding.

Concrete Deicing scaling

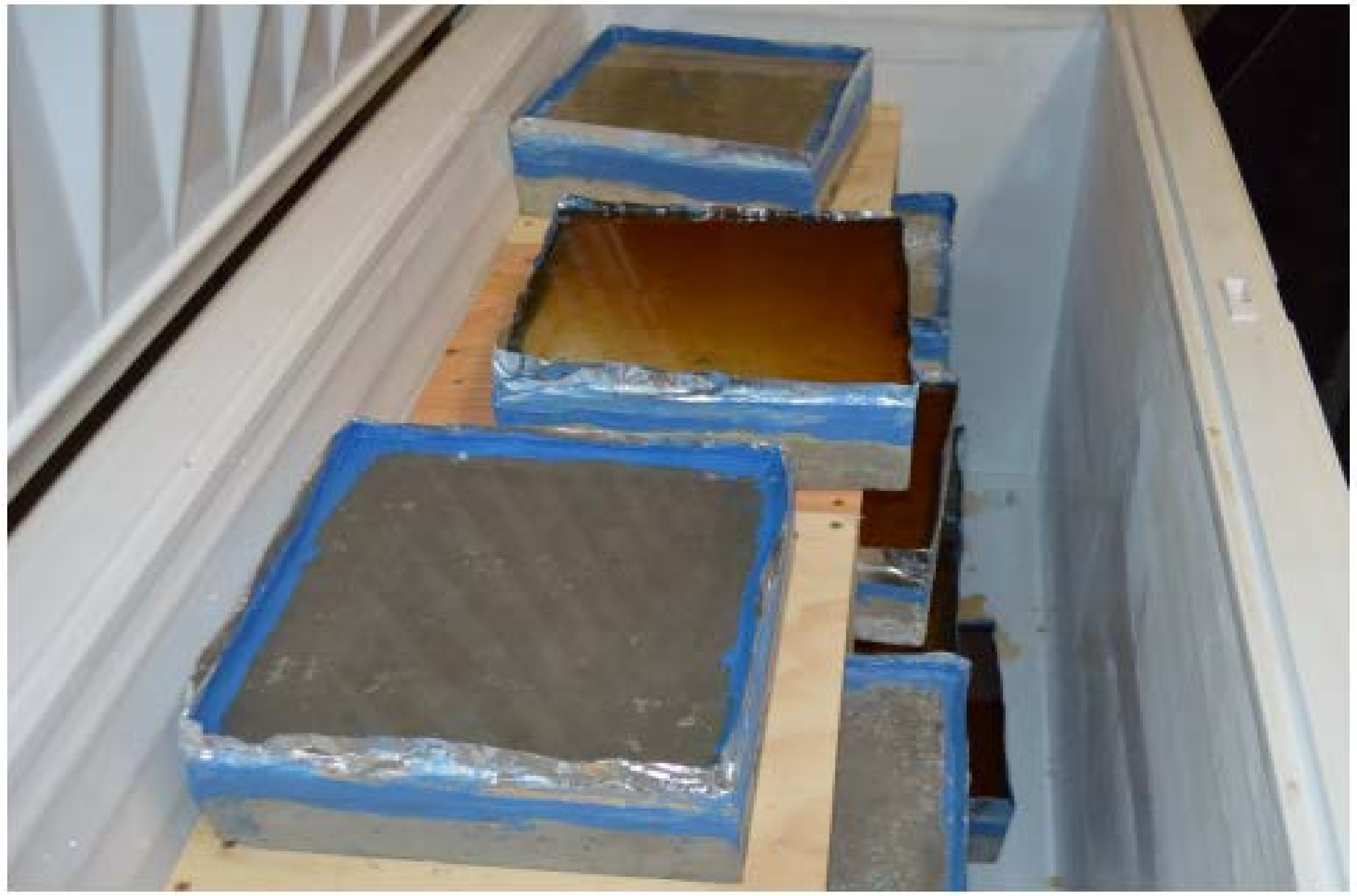


Figure 3: Slabs exposed to freezing environment during deicing scaling test.

LABORATORY TESTING

Continuous Soaking

Figure 4- Specimens under continuous soaking.

Freeze-Thaw Testing

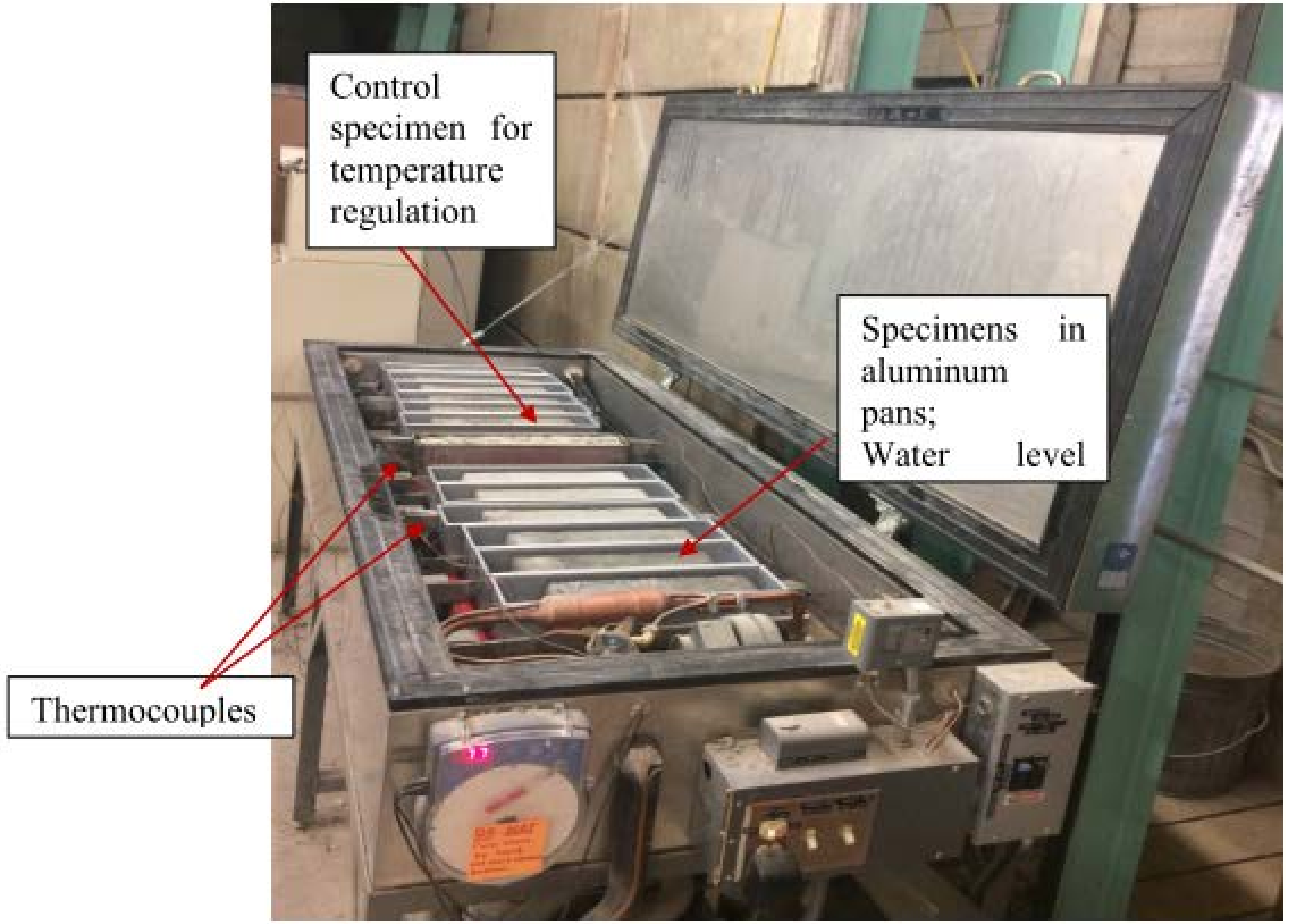


Figure 5- Freeze-Thaw (F-T) cabinet with concrete prisms subjected to F-T testing.

RESULTS OF LABORATORY TESTING

Summary of Surface Resistivity Test Results

District	Mixture ID	Application	Resistivity (Kilo-Ohms Cm)	Standard Error	Remarks
1	SH-5 Bridge Crossing, Plummer	Structural	17.9	0.4	Moderate risk
	I-90 Lookout Pass Paving Mixture 2015, Mullan	Paving	75.0	1.0	Low risk
	I-90 Lookout Pass Paving Mixture 2016, Mullan	Paving	73.2	0.5	Low Risk
2	Thain Road Paving Mixture, Lewiston	Paving	64.6	1.2	Low Risk
	US-95 Race Creek Mixture, Lewiston	Structural	93.9	5.4	Low Risk
3	I-84 Paving Mixture, Boise	Paving	90.6	0.9	Low Risk
5	US-91 Paving Mixture, Pocatello	Paving	104.0	0.3	Negligible Risk
6	Thornton Interchange Mixture, Idaho Falls	Structural	109.8	6.9	Negligible Risk

RESULTS OF LABORATORY TESTING

Figure 7: District 1 SH 5 Crossing mixture after deicing scaling test

Figure 8: I-90 Paving 2015 mixture after deicing scaling test

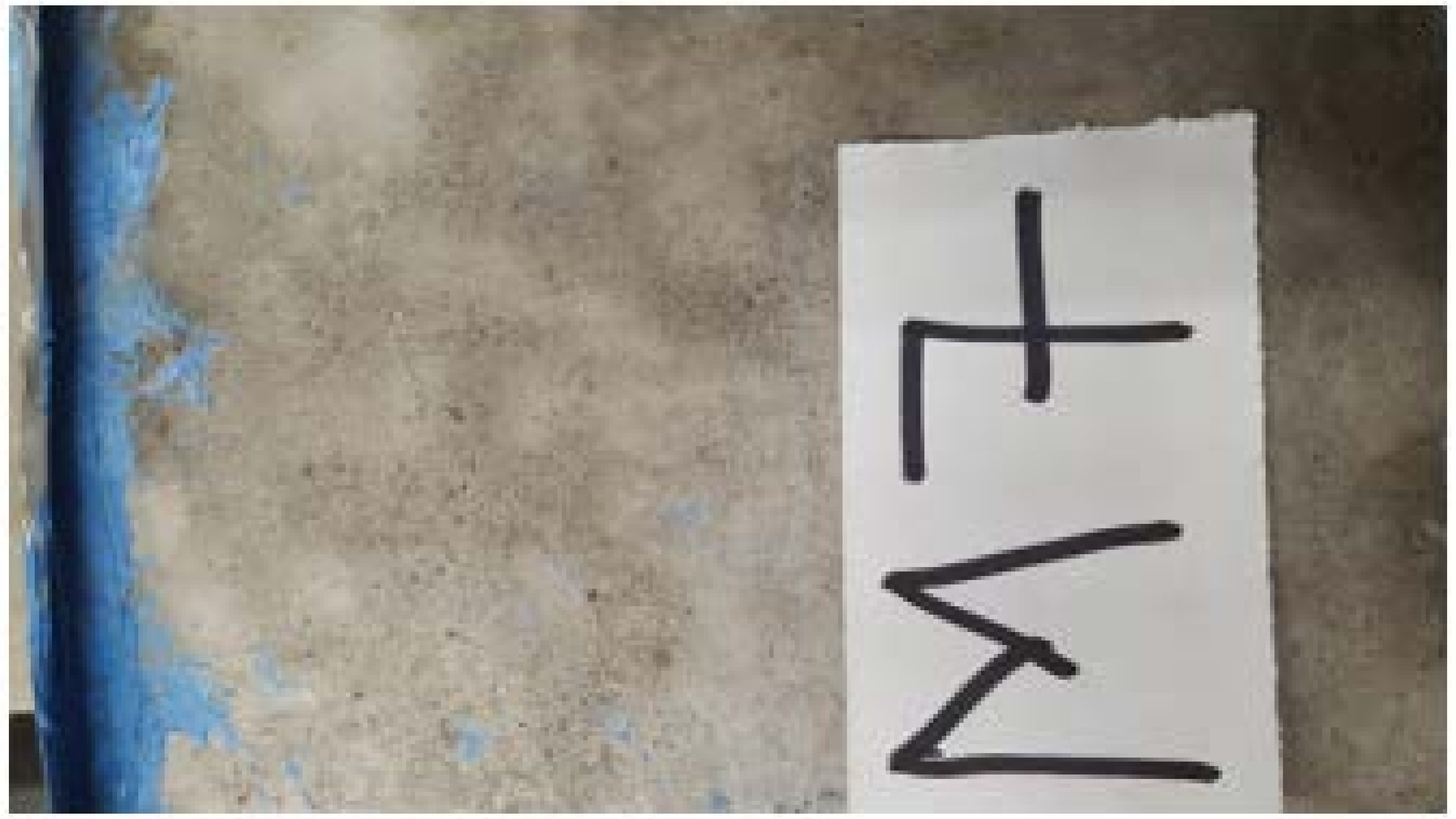


Figure 9: I-90 paving 2016 mixture after deicing scaling test

Figure 10: Thain road paving Lewiston mixture after deicing scaling test

RESULTS OF LABORATORY TESTING

Summary of Scaling Resistance of Slabs Exposed to Deicing Chemicals

District	ID	Mixture	Application	Slump, in (field value)	Water-cementitious ratio	Supplementary cementitious Materials	Type of deicer	Visual rating
1	M1	SH-5 Bridge Crossing, Plummer	Structural	3 (3 ½)	0.42	None	Salt brine	5.0 (severe)
	M2	I-90 Lookout Pass Paving Mixture 2015, Mullan	Paving	1 (1 ½)	0.38	20% Fly Ash	Salt brine	1.0
	M7	I-90 Lookout Pass Paving Mixture 2016, Mullan	Paving	1 ½ (1 ½)	0.40	Not available	Salt brine	2.0
2	M3	Thain Road Paving Mixture, Lewiston	Paving	3 (4 ½)	0.43	25% Fly Ash	Mag Bud Converse; Freeze Guard plus Mag. Chloride	2.0 and Alkali Silica Reaction
	M4	US-95 Race Creek Mixture, Lewiston	Structural	5 (5 ¾)	0.40	25% Fly Ash	Mag Bud Converse; Freeze Guard plus Mag. Chloride	2.0 and Alkali Silica Reaction
3	M5	I-84 Paving Mixture, Boise	Paving	1 ¾ (1 ¾)	0.40	25% Fly Ash	Mag Bud Converse	2.0
5	M6	US-91 Paving Mixture, Pocatello	Paving	3 ¼ (4 ¼)	0.39	25% Fly Ash	Salt brine	1.0
6	M8	Thornton Interchange Mixture, Idaho Falls	Structural	4 ½ (4 ¾)	0.39	Fly Ash (mix design did not specify %)	Salt brine	2.0

RESULTS OF LABORATORY TESTING

Concrete specimens after 90-days continuous soaking in deicing salt.

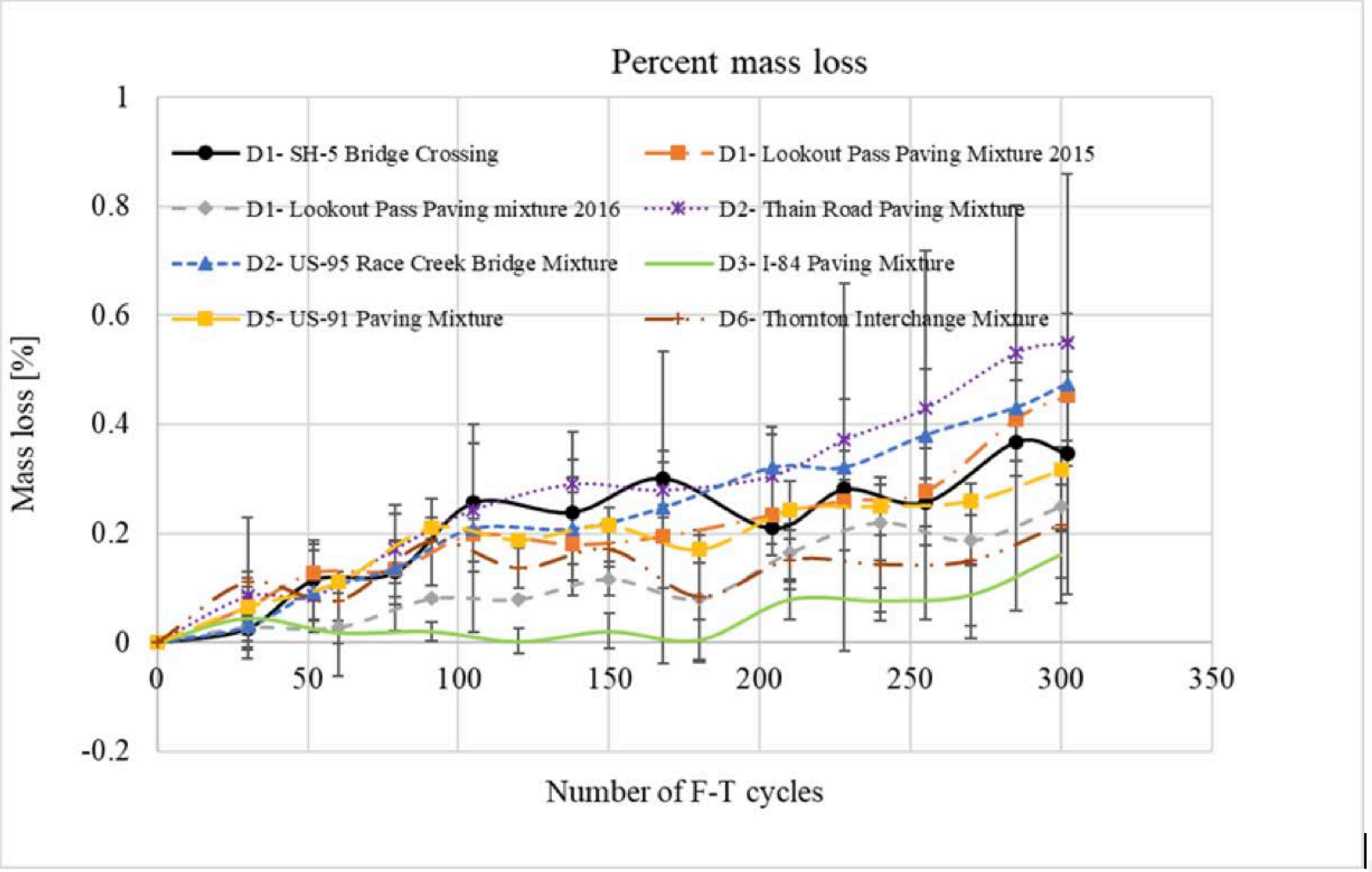
Figure 15: Concrete specimens after 90-days continuous soaking in deicing salt.

RESULTS OF LABORATORY TESTING

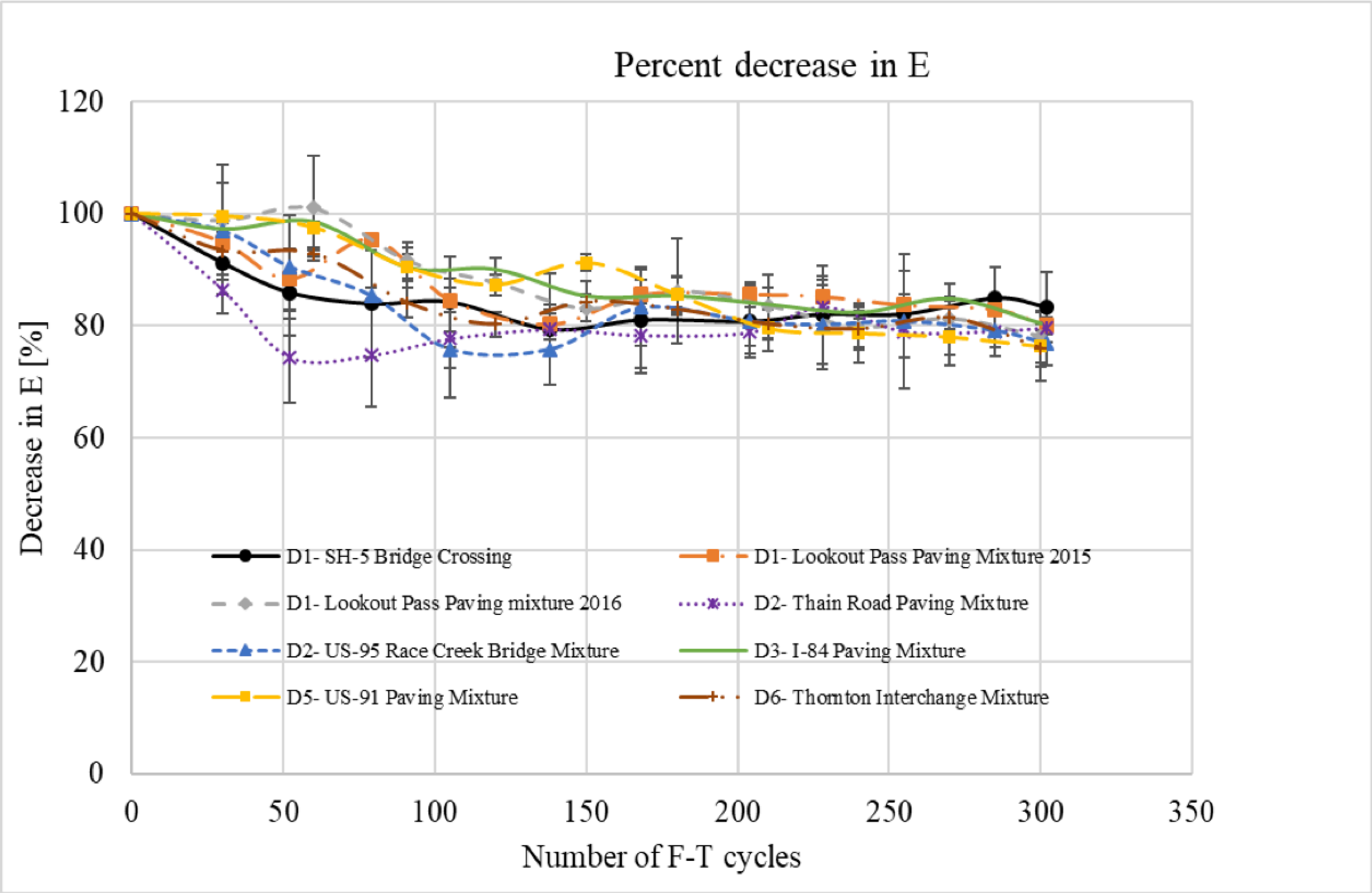
Summary of compressive strength after 90-days continuous soaking

District	ID	Mixture	Application	f'_c-28 days(Psi) (Standard deviation [psi])	f'_c- 548 days (control-without soaking) (Psi) (Standard deviation [psi])	f'_c- 548 days after soaking (Standard deviation [psi])	Type of deicer	Percentage loss %
1	M1	SH-5 Bridge Crossing, Plummer	Structural	4870 (160)	6885 (20)	6230 (35)	Salt brine	10.52
	M2	I-90 Lookout Pass Paving Mixture 2015, Mullan	Paving	5510 (240)	7790 (35)	6740 (55)	Salt brine	15.58
	M7	I-90 Lookout Pass Paving Mixture 2016, Mullan	Paving	4640 (210)	6380 (25)	5600 (25)	Salt brine	13.92
2	M3	Thain Road Paving Mixture, Lewiston	Paving	5160 (260)	7095 (50)	6970 (25)	Mag Bud Converse;	1.79
	M3	Thain Road Paving Mixture, Lewiston	Paving	5160 (260)	7095 (65)	7140 (35)	Freeze Guard plus Mag. Chloride	0.63
	M4	US-95 Race Creek Mixture, Lewiston	Structural	6900 (130)	9487 (45)	8170 (55)	Freeze Guard plus Mag. Chloride	16.12
	M4	US-95 Race Creek Mixture, Lewiston	Structural	6900 (130)	9487 (55)	7310 (60)	Salt brine	29.78
3	M5	I-84 Paving Mixture, Boise	Paving	5590 (220)	7686 (65)	4500 (45)	Mag Bud Converse	70.80
5	M6	US-91 Paving Mixture, Pocatello	Paving	5080 (120)	6985 (55)	5430 (30)	Salt brine	28.63
6	M8	Thornton Interchange Mixture, Idaho Falls	Structural	4310 (150)	5545 (75)	3620 (55)	Salt brine	53.17

RESULTS OF LABORATORY TESTING

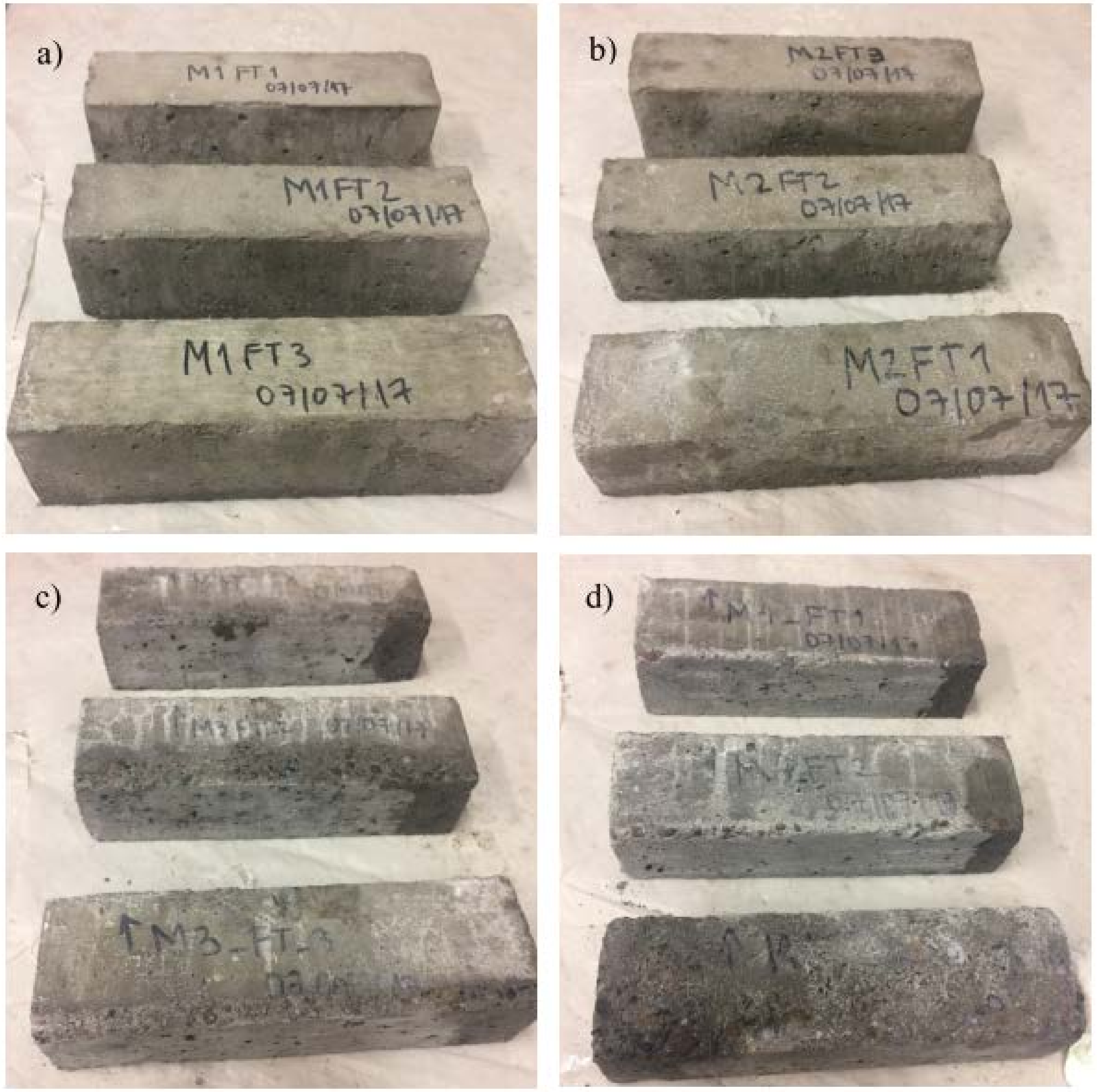


Specimen mass loss in F-T tests



Variation in elastic modulus in F-T tests

RESULTS OF LABORATORY TESTING



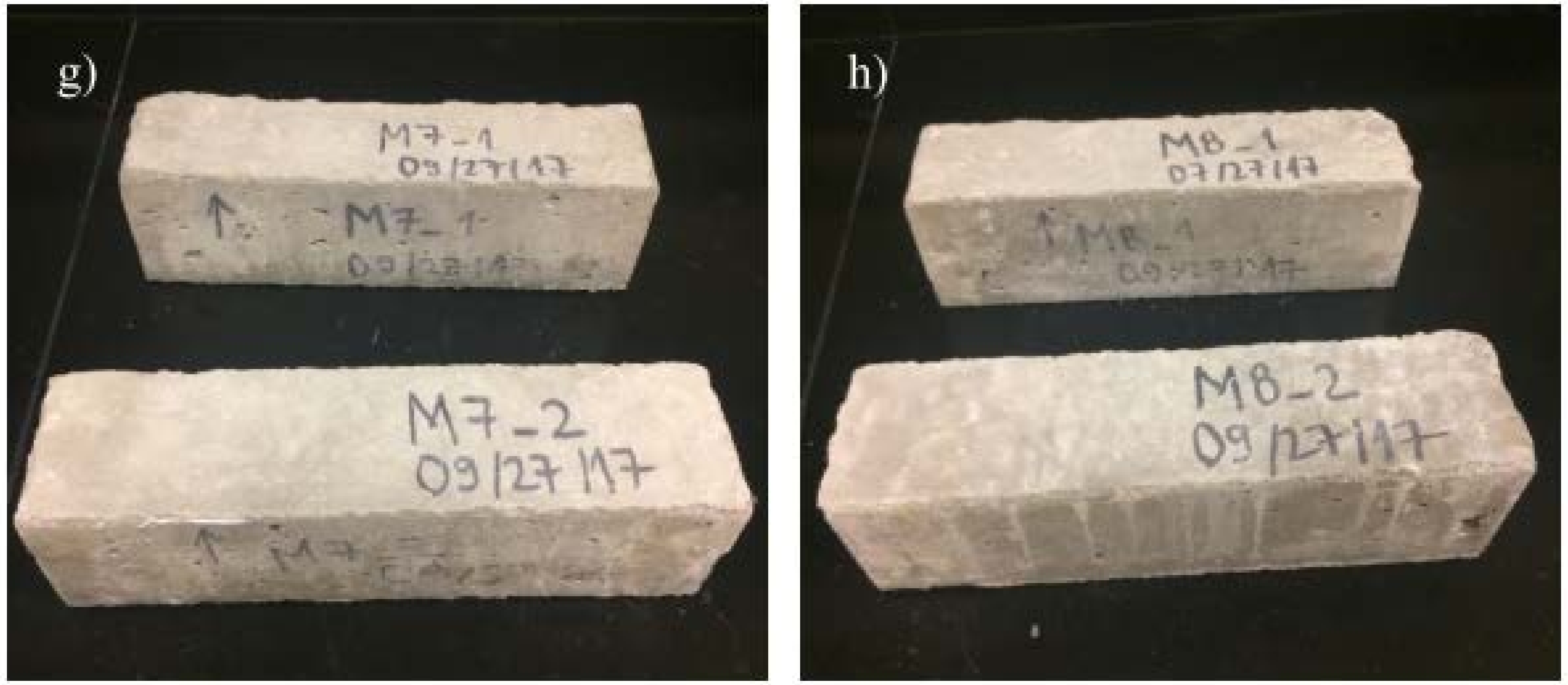


Figure 15: Tested specimens after 300 F-T cycles for the mixtures: (a) M1, (b) M2, (c) M3, (d) M4, (e) M5, (f) M6, (g) M7, (h) M8.

Tested specimens after 300 F-T cycles for the mixtures: (a) M1, (b) M2, (c) M3, (d) M4, (e) M5, (f) M6, (g) M7, (h) M8.

COMPARISON OF FIELD RESULT WITH LABORATORY RESULTS

District 1 SH5 crossing, mixture M1 after the deicing scaling laboratory test

S-10 **DESCRIPTION:** Mostly scaled front surface of the core sample as received.

District 1 SH5, mostly scaled front surface of the core sample received.

COMPARISON BETWEEN FIELD AND LABORATORY RESULTS

Table 3:Summary of Surface Resistivity Test Results.

District	Mixture ID	Application	Resistivity (Kilo-Ohms Cm)	Standard Error	Remarks
1	SH-5 Bridge Crossing, Plummer	Structural	17.9	0.4	Moderate risk

Test Results

Sample	Length	Corrected Average kΩ-cm
S-1	203 mm (8")	11.3
S-2	216 mm (8-1/2")	11.5
S-3	229 mm (9")	10.6
S-4	229 mm (9")	9.8
S-5	229 mm (9")	11.2
S-6	235 mm (9-1/4")	11.3
S-7	229 mm (9")	11.7
S-8	235 mm (9-1/4")	11.1
S-9	229 mm (9")	10.1
S-10	210 mm (8-1/4")	10.7
S-11	229 mm (9")	10.8
S-12	222 mm (8-3/4")	11.8
S-13	229 mm (9")	10.8
S-14	229 mm (9")	11.3
S-15	222 mm (8-3/4")	8.6
S-16	241 mm (9-1/2")	9.2
S-17	229 mm (9")	12.3

CONCLUSION

- The mixtures currently used by ITD perform satisfactorily under F-T cycle, as evidenced by relatively high percentage retained elastic modulus and relatively low mass losses after being subjected to a total of 300 F-T cycles.
- The structural mixture (SH-5 Bridge crossing, Plummer) suffered a severe scaling, while other mixtures showed mild to moderate scaling. The reason for the severe scaling in Mix M1, could be because of the absence of supplementary cementitious materials- Fly Ash that inhibits the formation of calcium oxychloride (CAOXY) as observed by different authors.

ACKNOWLEDGMENTS

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THANK YOU