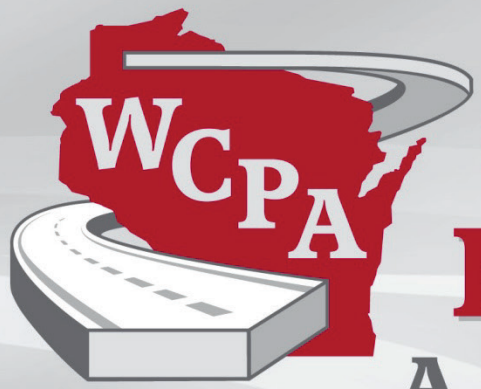


WISCONSIN CONCRETE PAVEMENT ASSOCIATION

Moving forward with concrete results

HP CURING COMPOUNDS FOR CONCRETE PAVEMENT IN WISCONSIN

Kevin W. McMullen, P.E.
President
Wisconsin Concrete Pavement Association

STUDY OF HIGH PERFORMANCE CURING COMPOUNDS FOR CONCRETE PAVEMENTS IN WISCONSIN

WisDOT/WHRP Project #0092-11-05

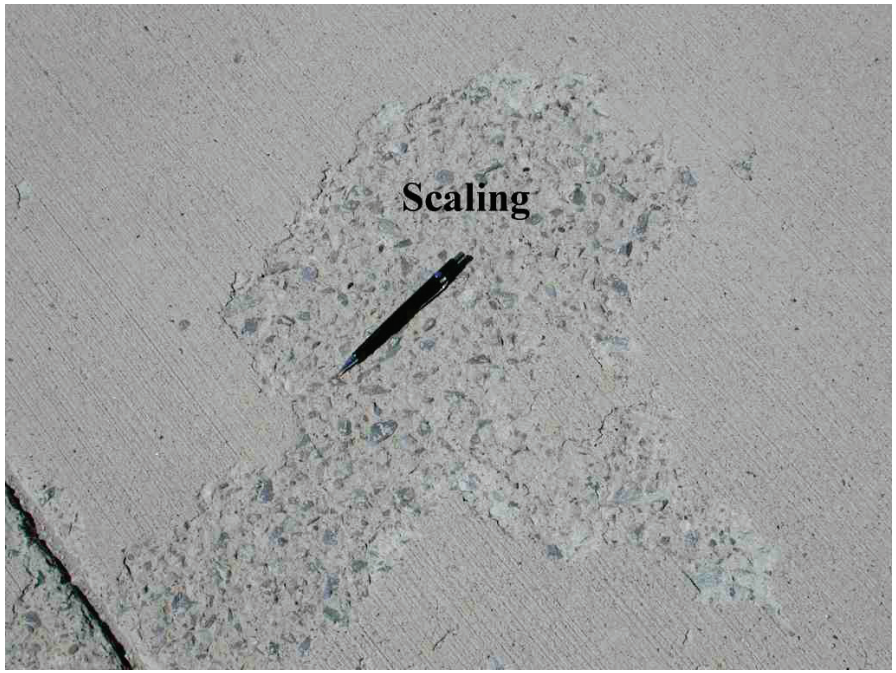
Samuel Helgeson, former graduate student
Design Engineer at Epstein in Chicago
Steven Cramer, PhD, PE

University of Wisconsin-Madison
Department of Civil and Environmental Engineering

Wisconsin Concrete Pavement Association Annual Workshop - 2015

Problem Statement

- Research project is in response to reported premature scaling damage within new Portland Cement Concrete (PCC) pavements that have been cured using membrane forming curing compounds (MFCC's)



http://nebula.wsimg.com/a3fe97072ab1155fdc32cdd5c9ce0fd3?AccessKeyId=D94D99729EAEC69E9267&disposition=0&alloworigin=1

Project Goal

- Determine the influence of MFCC application time on F/T surface durability of paving concrete specimens (ASTM C672)

  - 30 Minutes: Bleeding is occurring, with water on surface
  - 2 Hours: Bleeding progress is unknown, bleed water may be on surface
  - 4 Hours: Bleeding has terminated, bleed water is no longer present on surface

  - Emulsions: 30 Minutes, 2 Hours, and 4 Hours
  - Acrylic: 30 Minutes and 4 Hours
  - Mixes containing Fly Ash: 30 Minutes and 4 Hours

Mix Design

- Two coarse aggregate types (WISDOT #1)
  - River run glacial gravel
  - Limestone
- One fine aggregate source
- Cementitious materials
  - Ordinary Portland Cement
  - 30% mass replacement Fly Ash or Ground Granulated Blast Slag
- Madison municipal water
- Air entraining agent and water reducing admixtures
- w/cm ratio: 0.4
- Slump: 3±1 inches
- Air entrainment: 6±1%

Materials and Methods-Concrete Mixing and Specimen Manufacture

Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Limestone-OPC	Limestone-Slag	Limestone-Fly Ash	Gravel-OPC	Gravel-Slag	Gravel-Fly Ash

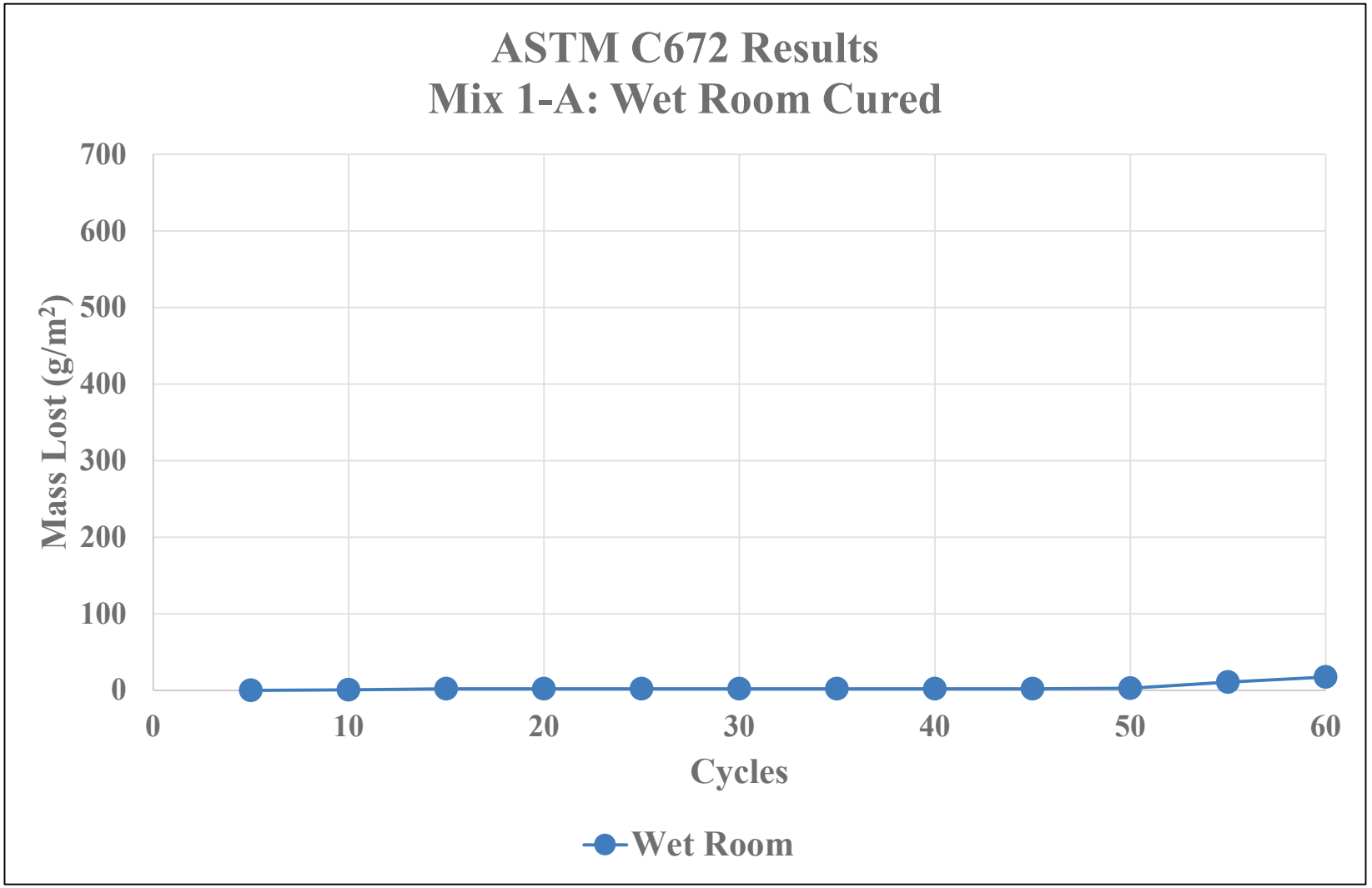
- ASTM C672 Scaling Test Specimens
  - Three replicate specimens per mix type-curing compound-application time combination
  - MFCCs applied using balance accurate to 0.1 grams
  - 3” deep by 12” diameter
  - 1” deep, 10” diameter PVC dam adhered to testing surface
  - Sealed with caulk on testing edge, epoxy around non-testing surfaces
  - Cured for 56 days prior to freeze-thaw testing

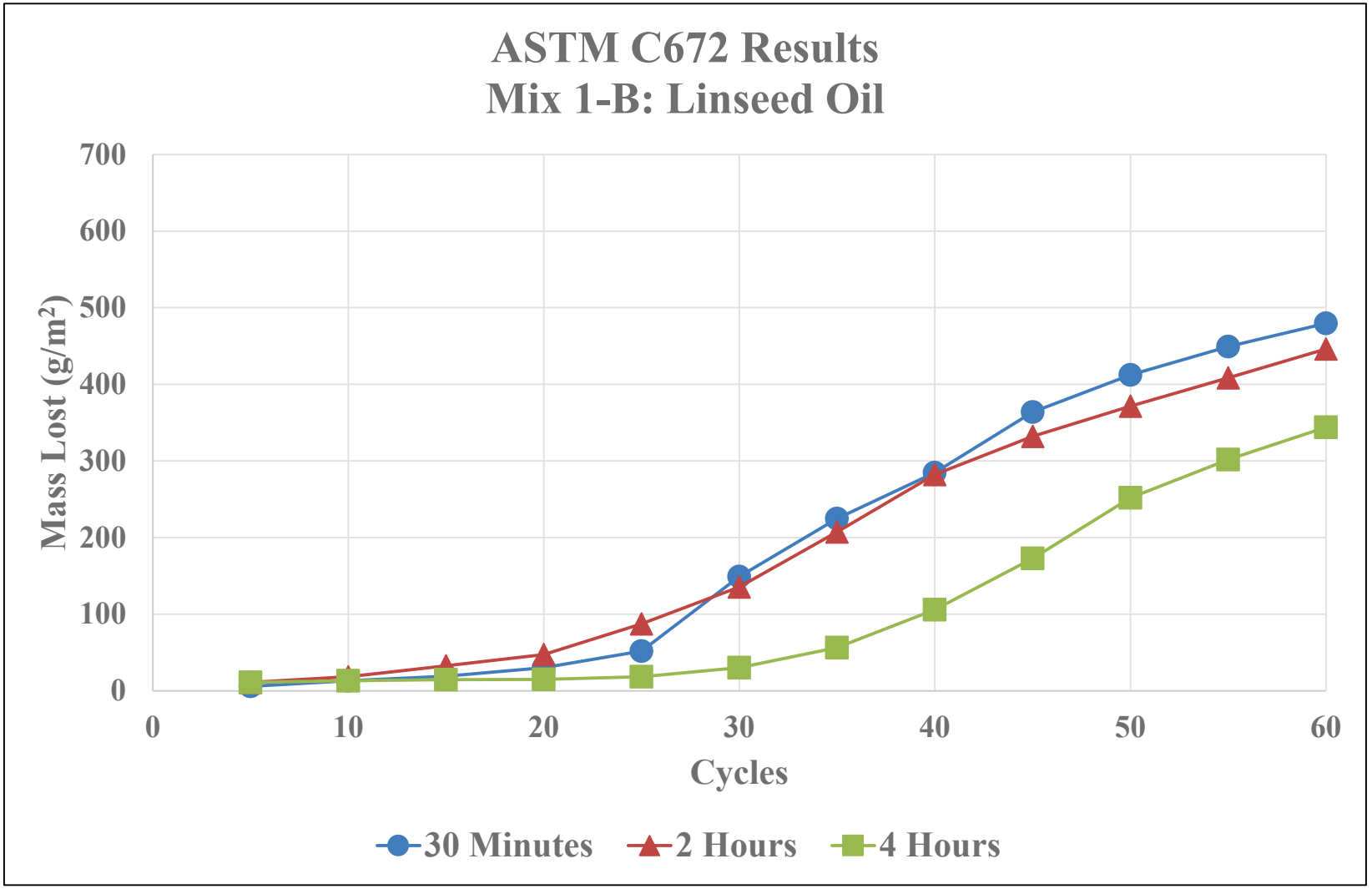
Methods and Materials-MFCC Descriptions

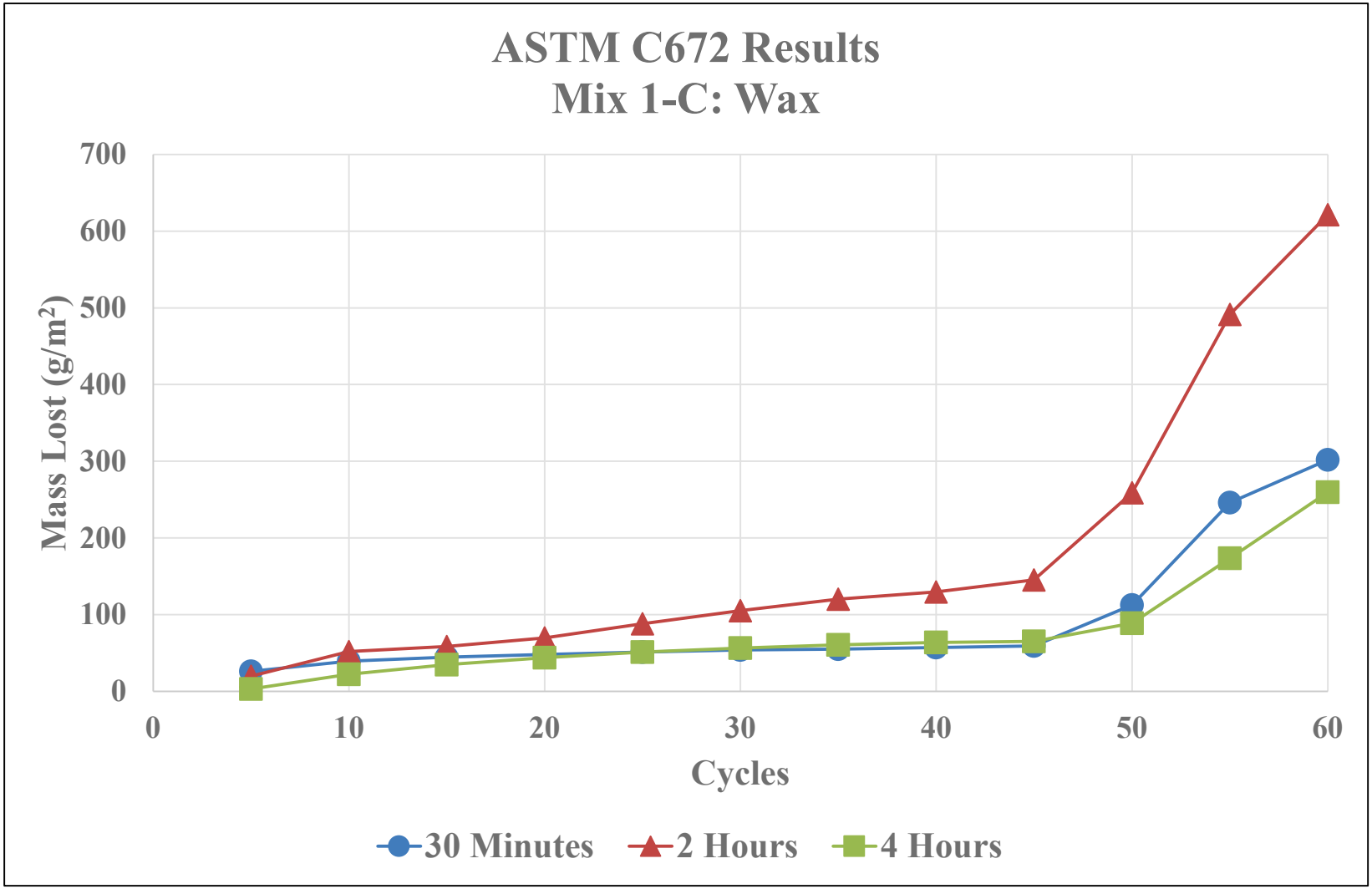
- Wet Room Curing
  - One set of specimens from each mix type, used to as representative of more traditional methods for comparison
- Water-based emulsion MFCCs (white pigmented for WISDOT use)
  - Linseed Oil
    - Application rate of 14.9 grams/specimen, solids fraction of 40-50%
  - Wax
    - Application rate of 14.9 grams/specimen, solids fraction of 15-25%
  - Poly-alpha-methylstyrene (PAMS)
    - Application rate of 14.9 grams/specimen, solids fraction of approximately 52.5%
- Sealing Compound (non-pigmented)
  - Acrylic
    - Application rate of 9.1 g/specimen, solids fraction of approximately 25%

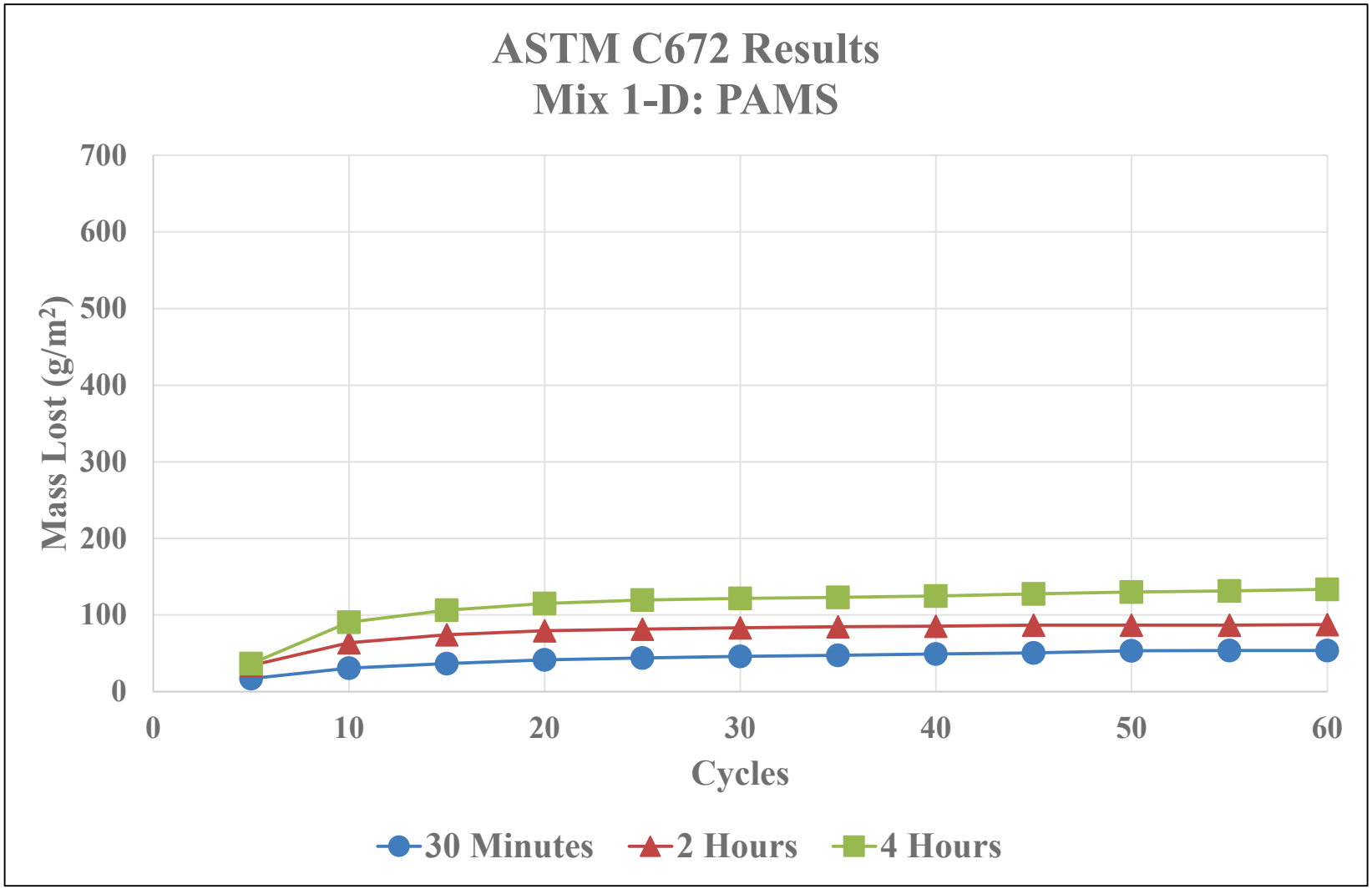
Methods and Materials-Scaling Test

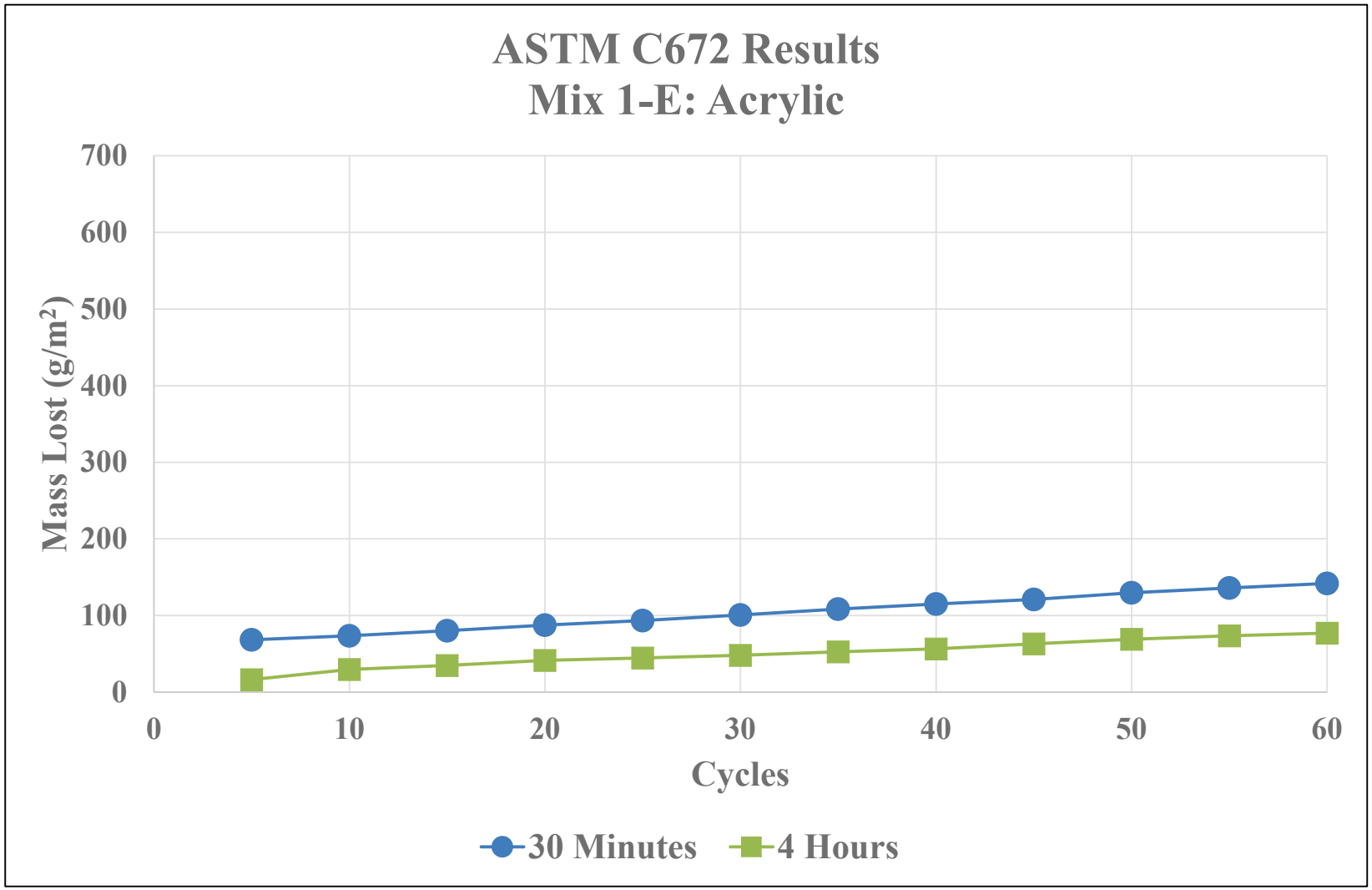
- ASTM C672
  - ¼” layer of 4% by mass NaCl in deionized water solution
  - 1 freeze-thaw cycle: 4 hours at 32°C, 20 hours at -16°C
  - Every 5 cycles, pooled water is poured over #200 sieve.
  - Specimen is gently rinsed over sieve
  - Solution replaced and put back into freeze-thaw chamber
  - Collected mass is dried for 24 hrs, weighed and recorded

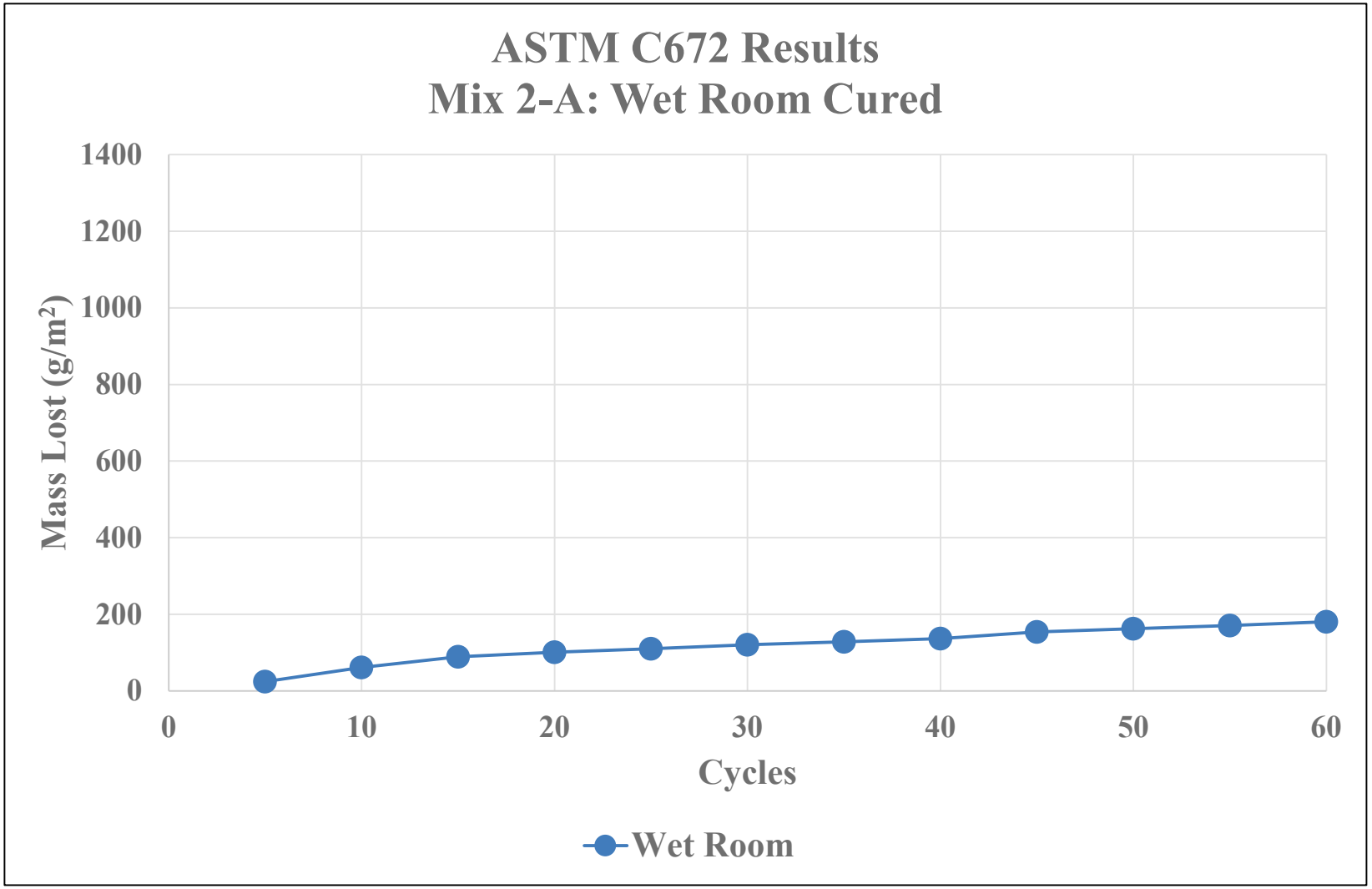

ASTM C672 Results
Mix 1-A: Wet Room Cured
Mass Lost (g/m²)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
Cycles
Wet Room

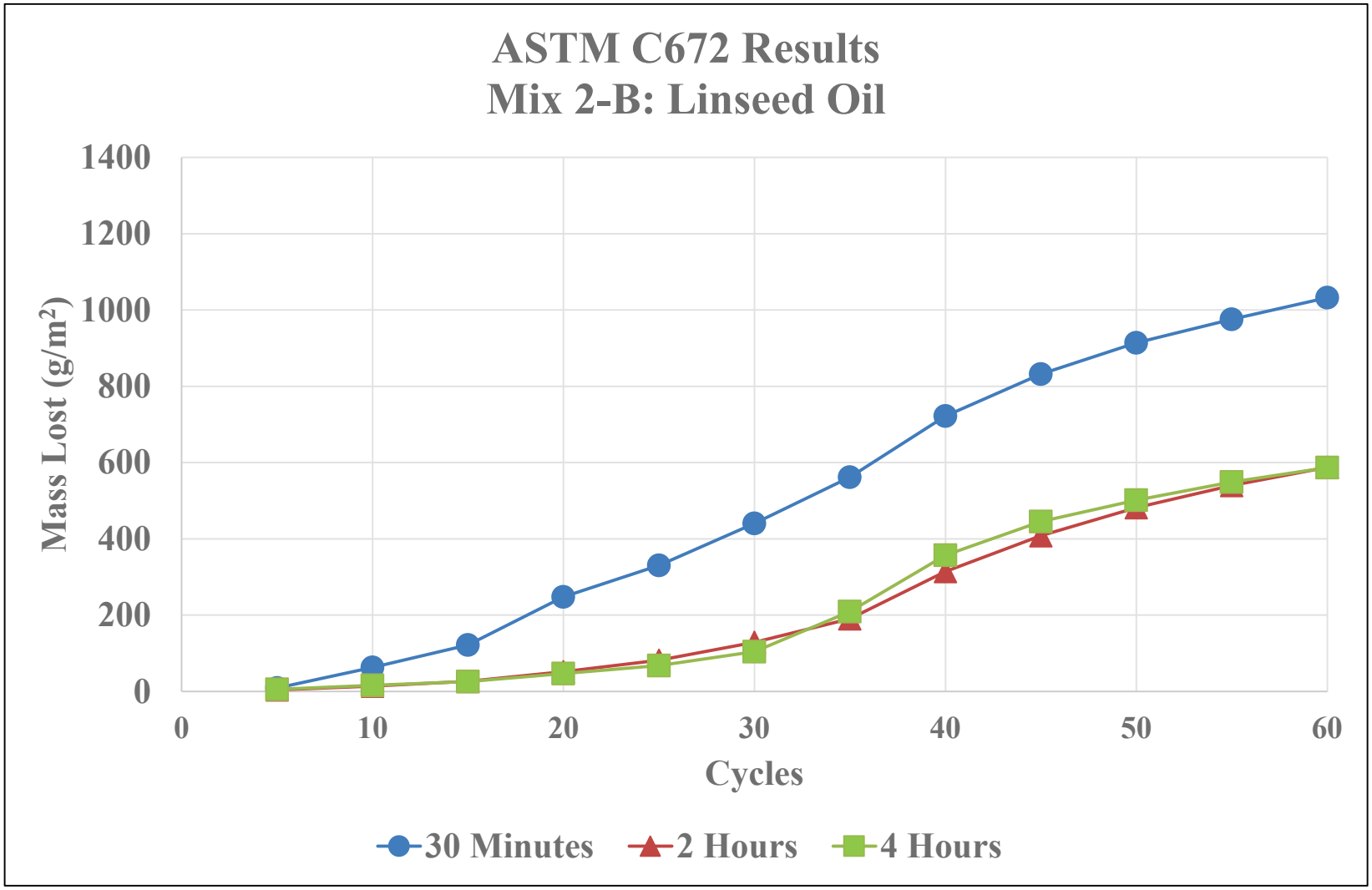

ASTM C672 Results
Mix 1-B: Linseed Oil
Mass Lost (g/m²)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
Cycles
30 Minutes
2 Hours
4 Hours

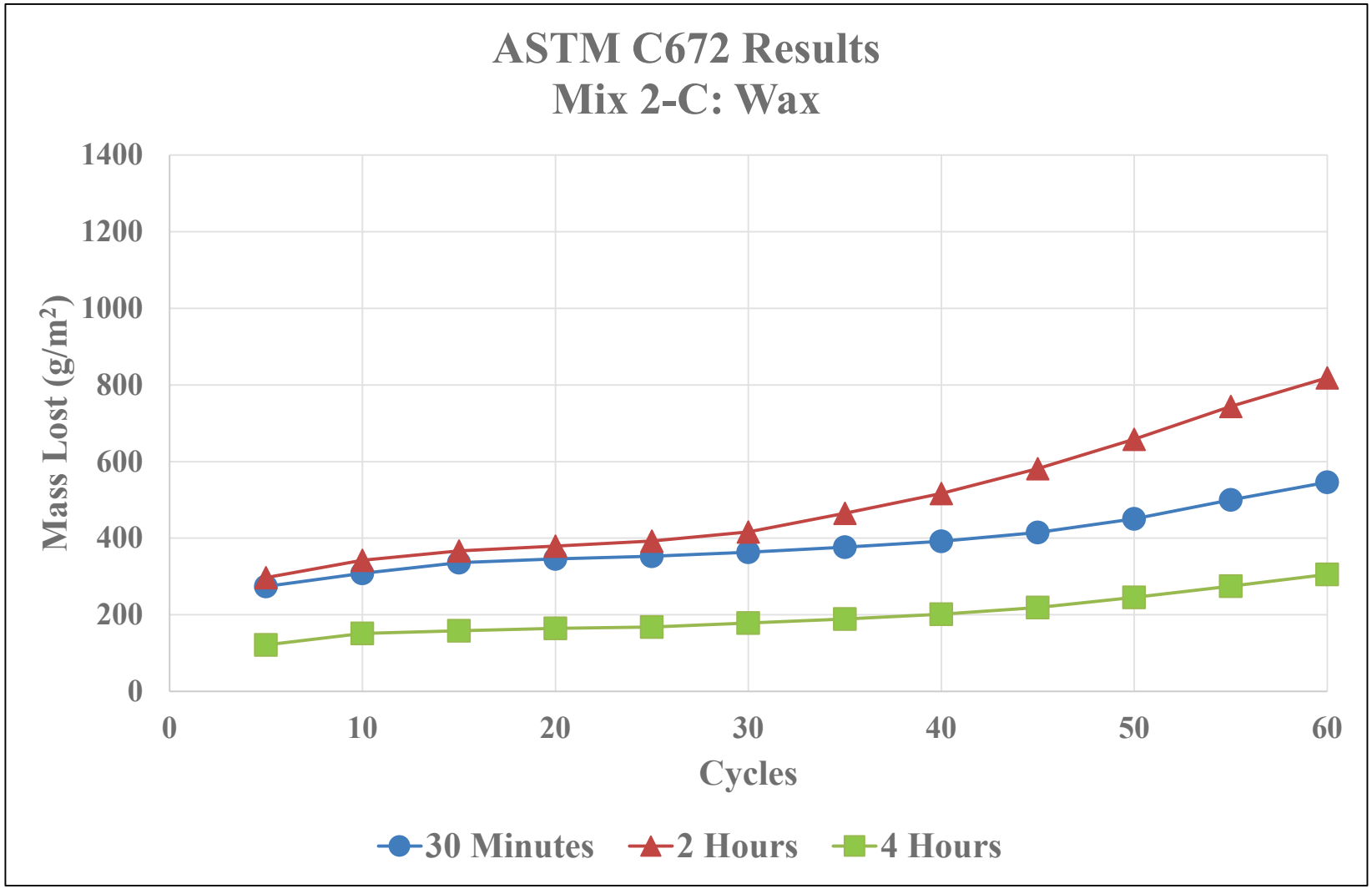

ASTM C672 Results
Mix 1-C: Wax
Mass Lost (g/m²)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
Cycles
30 Minutes
2 Hours
4 Hours

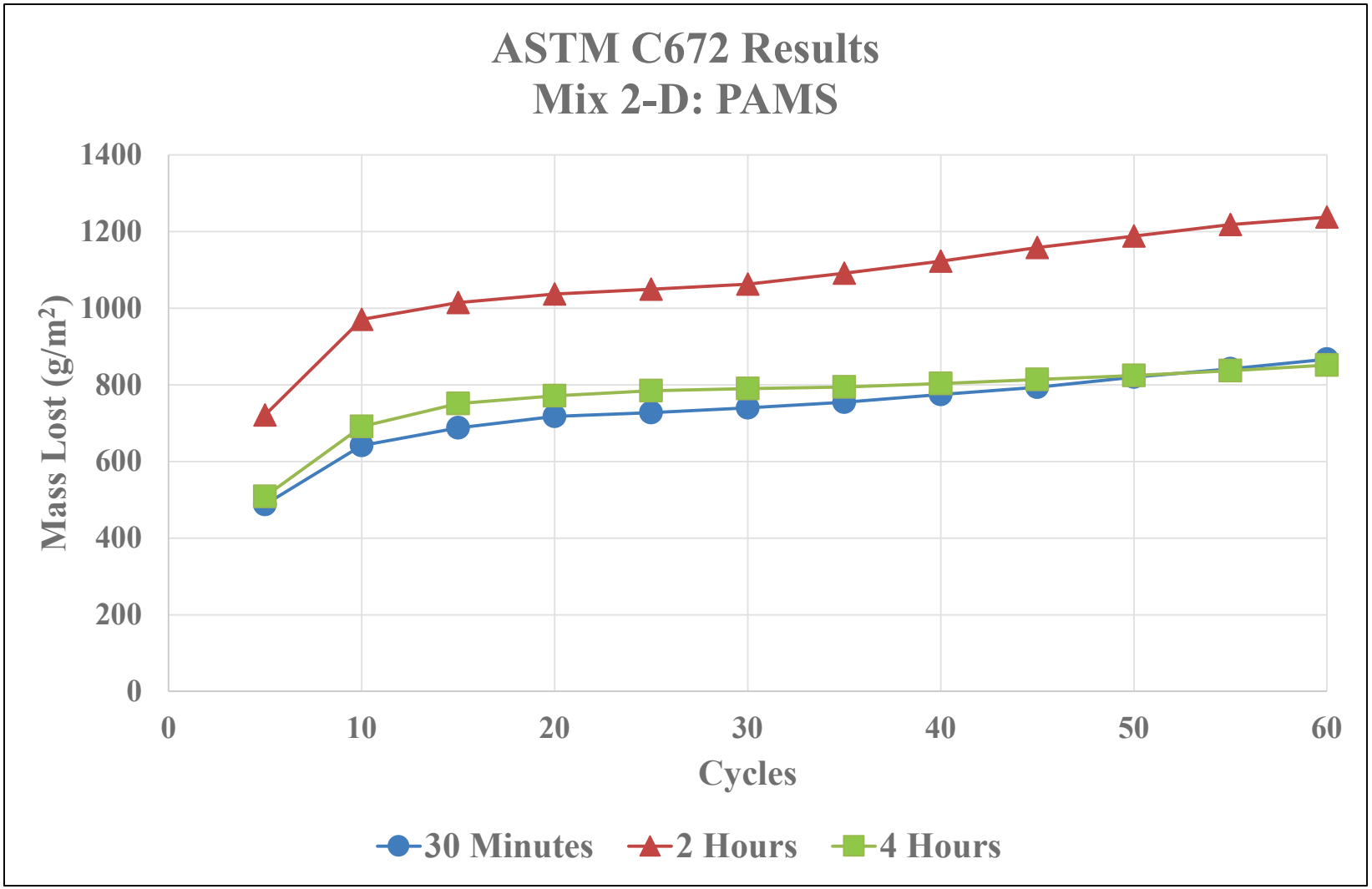

ASTM C672 Results
Mix 1-D: PAMS
Mass Lost (g/m²)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
Cycles
30 Minutes
2 Hours
4 Hours

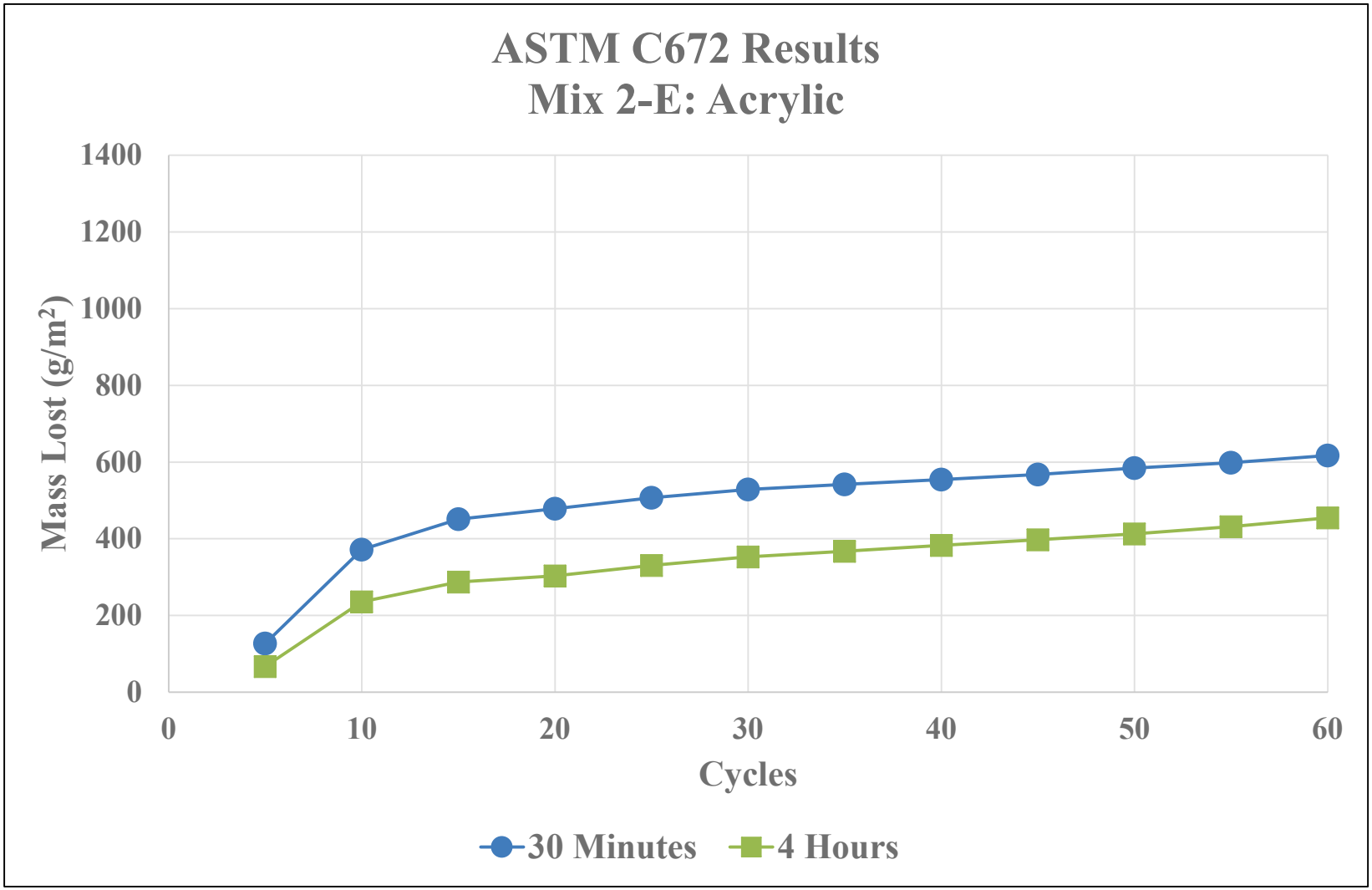

ASTM C672 Results
Mix 1-E: Acrylic
Mass Lost (g/m²)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
Cycles
30 Minutes
4 Hours


ASTM C672 Results
Mix 2-A: Wet Room Cured
Mass Lost (g/m²)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Cycles
Wet Room

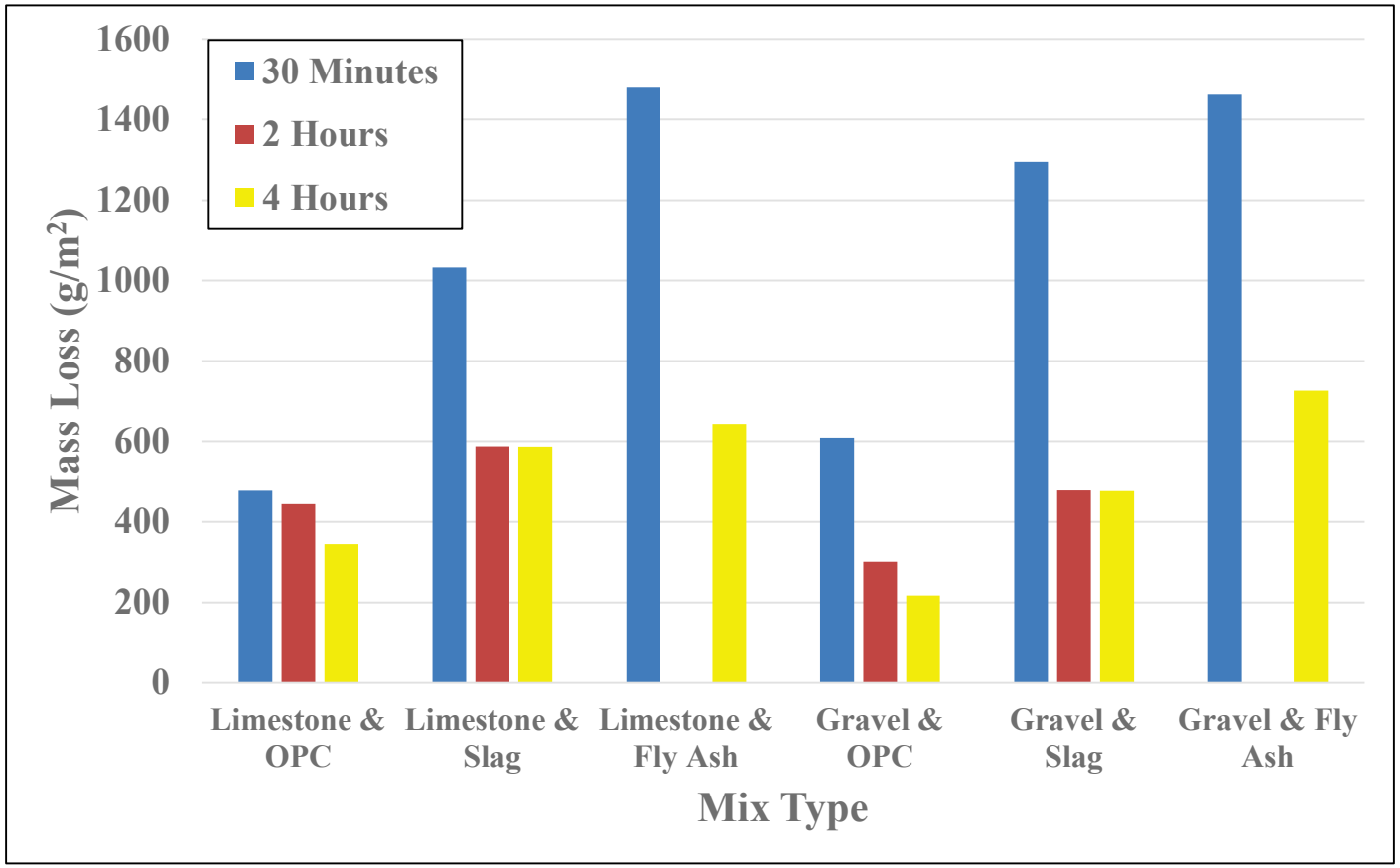

ASTM C672 Results
Mix 2-B: Linseed Oil
Mass Lost (g/m²)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Cycles
30 Minutes
2 Hours
4 Hours


ASTM C672 Results
Mix 2-C: Wax
Mass Lost (g/m²)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Cycles
30 Minutes
2 Hours
4 Hours


ASTM C672 Results
Mix 2-D: PAMS
Mass Lost (g/m²)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Cycles
30 Minutes
2 Hours
4 Hours

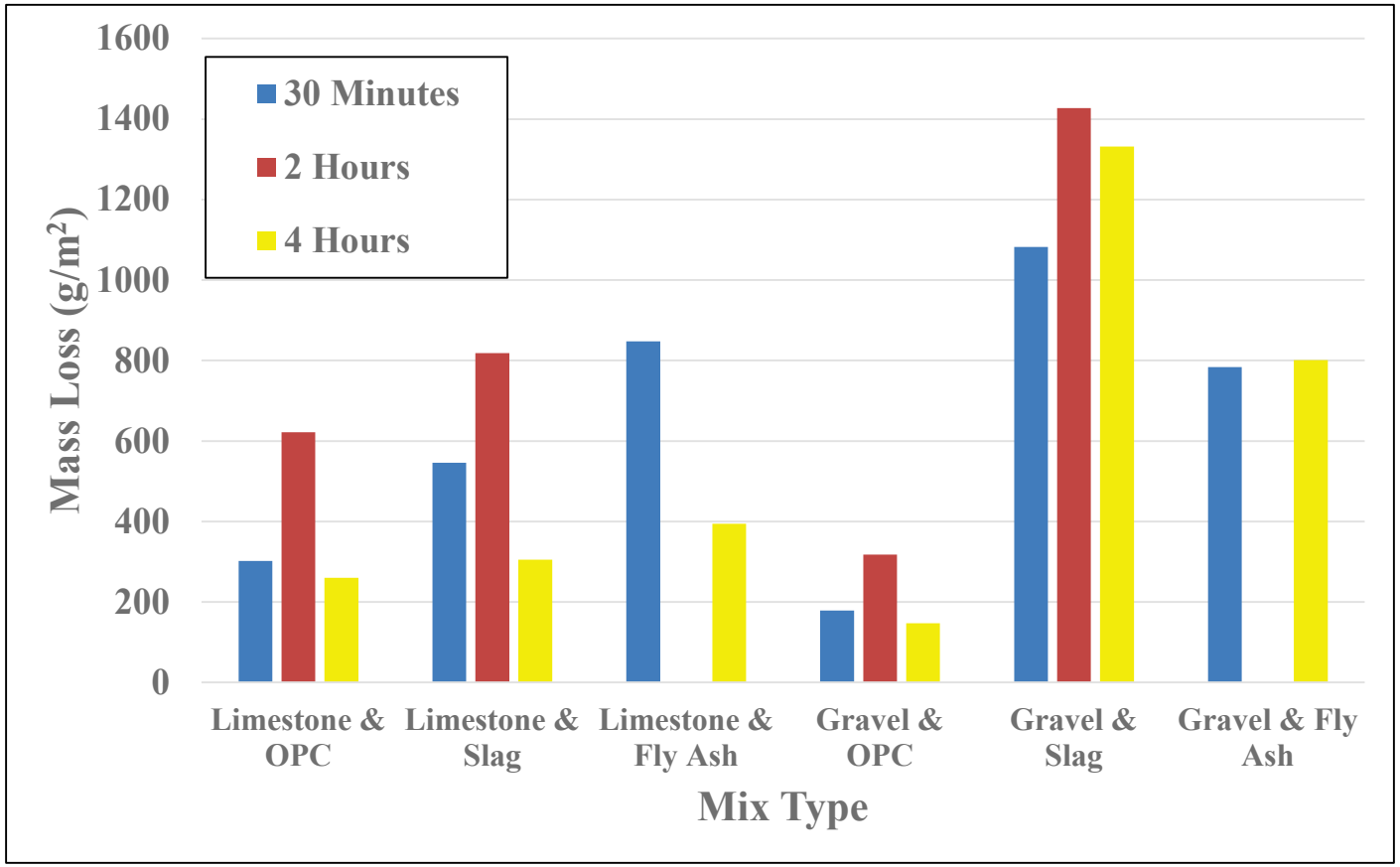

ASTM C672 Results
Mix 2-E: Acrylic
Mass Lost (g/m²)
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Cycles
30 Minutes
4 Hours

C672 Results: Linseed Oil Scaling Data Across Mix Types



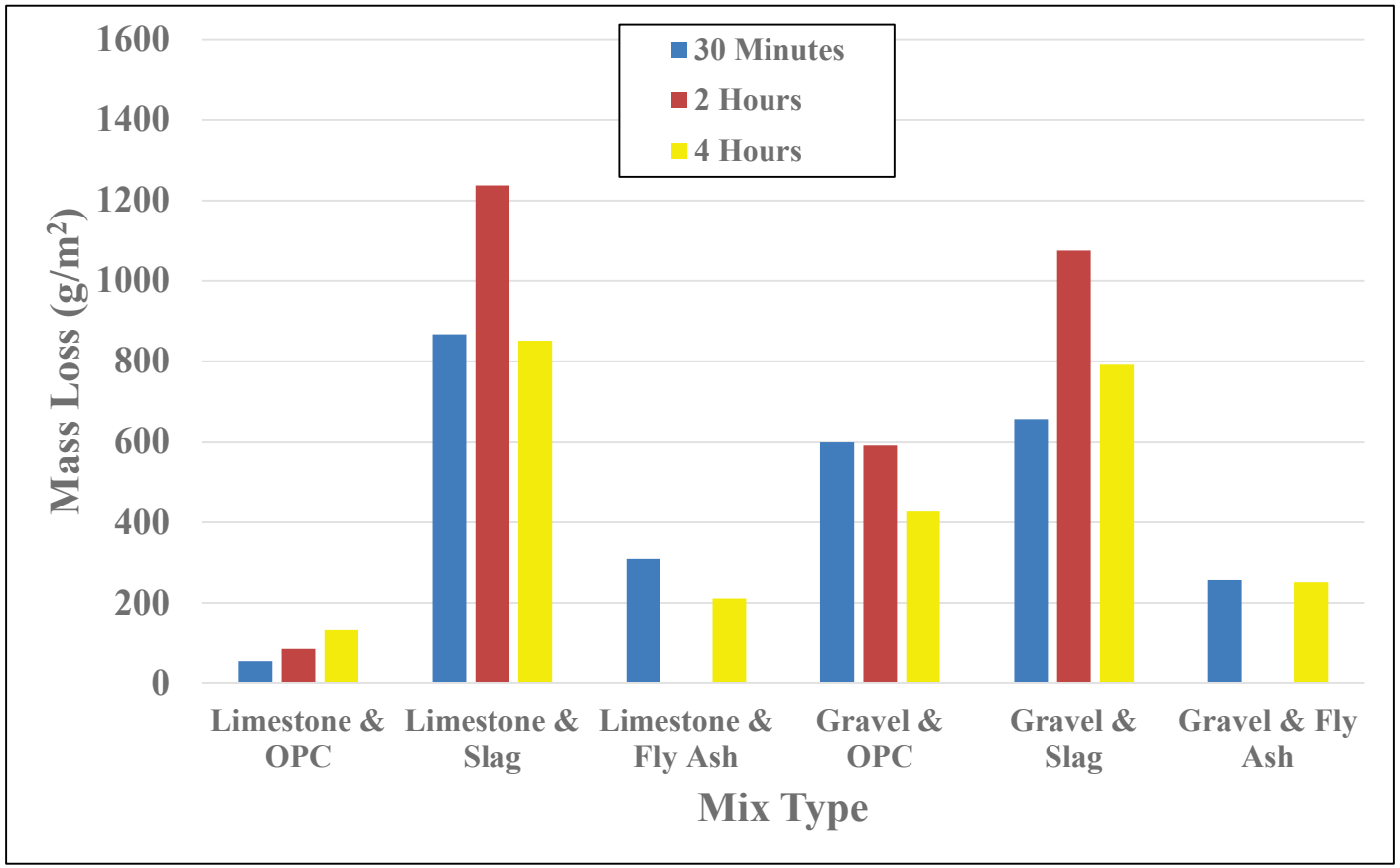
Comparison	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
30 Min v. 2 Hr	NO	YES		YES	NO	
30 Min v. 4 Hr	NO	YES	YES	YES	NO	YES
2 Hr v. 4 Hr	NO	NO		YES	NO	

C672 Results: Wax Scaling Data Across Mix Types



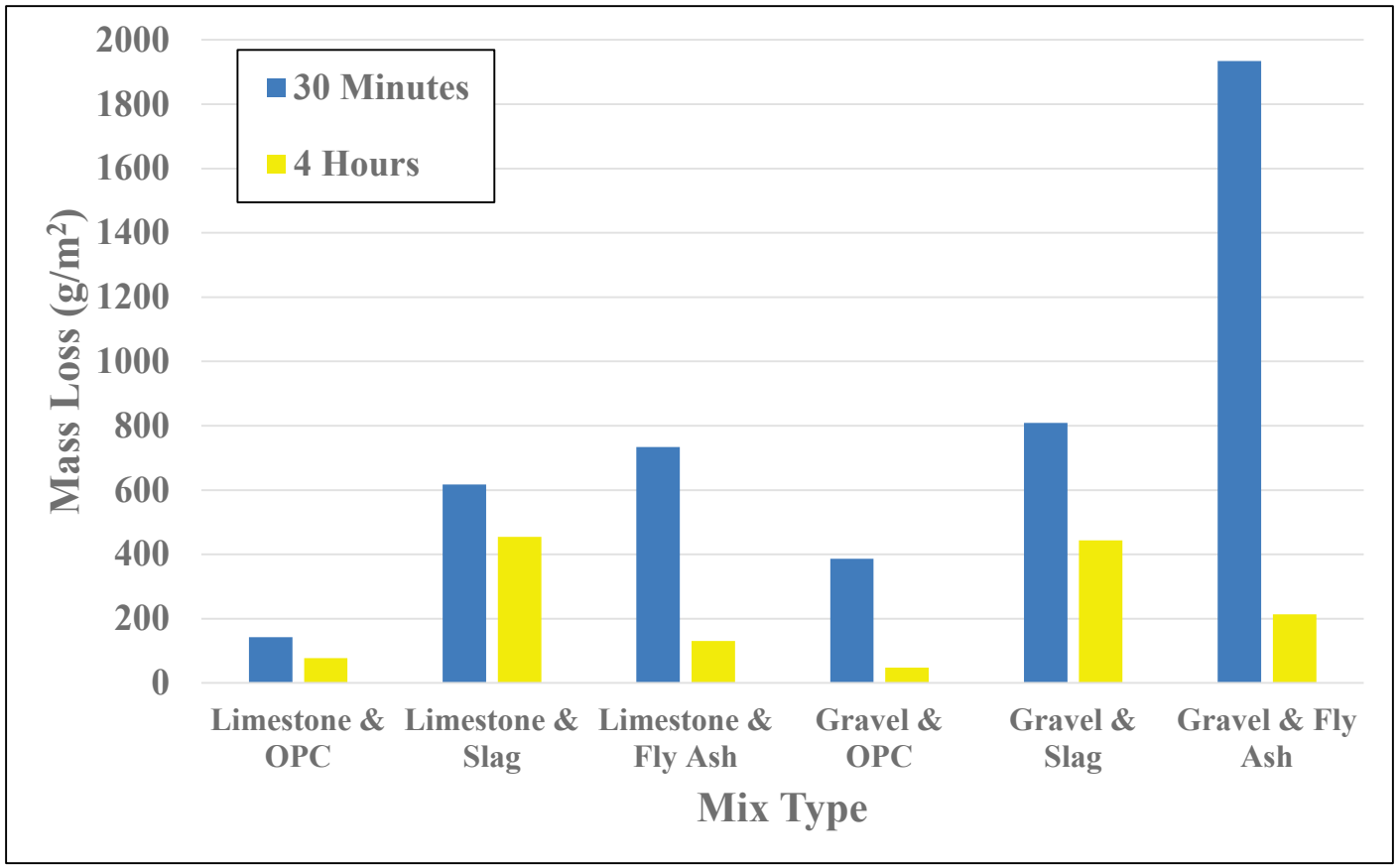
Comparison	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
30 Min v. 2 Hr	YES	NO		NO	NO	
30 Min v. 4 Hr	NO	YES	YES	NO	NO	NO
2 Hr v. 4 Hr	YES	YES		NO	NO	

C672 Results: PAMS Scaling Data Across Mix Types



Comparison	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
30 Min v. 2 Hr	NO	NO		NO	NO	
30 Min v. 4 Hr	NO	NO	NO	NO	NO	NO
2 Hr v. 4 Hr	NO	NO		NO	NO	

Results: Acrylic Scaling Data Across Mix Types



Comparison	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
30 Min v. 4 Hr	YES	NO	YES	NO	YES	YES

Conclusions

- Different curing compounds work best when applied at times that reflect mix characteristics and conditions of the concrete surface
- Linseed Oil and Acrylic formulations were sensitive to time of application. **30 minutes is too soon to apply linseed oil and acrylic formulations.**
- Two to four hours depending on conditions. Two hours application time very dependent on conditions.
- Wax varied but 2 hours was worst and 4 hours was best.
- PAMS formulations were not consistently time sensitive
- In particular PAMS performed inconsistently with Slag Cement

Conclusions

Table 6-1: Decision Matrix for Curing Compound Application Time Providing the Highest Degree of De-Icer Scaling Resistance

Aggregate	Cement Type	Compounds Used				Preferred Compound/Time	Alternative Compound/Time
		Linseed Oil	Wax	PAMS	Arcylic		
Limestone	OPC	30 Minutes	30 Minutes	30 Minutes	30 Minutes	PAMS at 30 Minutes	Acrylic at 30 Minutes
	30% Slag	2 Hours	4 Hours	30 Minutes	30 Minutes	Wax at 4 Hours	Linseed Oil at 2 Hours
	30% Fly Ash	4 Hours	4 Hours	30 Minutes	4 Hours	Acrylic at 4 Hours	PAMS at 30 Minutes
Gravel	OPC	2 Hours	30 Minutes	30 Minutes	4 Hours	Acrylic at 4 Hours	Wax at 30 Minutes
	30% Slag	2 Hours	30 Minutes	30 Minutes	4 Hours	Acrylic at 4 Hours	Linseed Oil at 2 Hours
	30% Fly Ash	4 Hours	30 Minutes	30 Minutes	4 Hours	Acrylic at 4 Hours	PAMS at 30 Minutes

Acknowledgements

- WISDOT
- Kevin McMullen, WCPA
- Andrea Breen, LaFarge North America
- Isabelle Girard and John Newton, UW Biotron Facility
- Jake Effinger, Tom McAdams, Dylan Kissinger, Jaime Yanez Rojas, and Turner Papendieck, UW students who assisted
- Curing compound suppliers
- Bill Lang, WSMTL
- Carole Kraak, WSMTL
- Ramsey Kropp