Research on CIR

Pavement Engineering and Science Program
University of Nevada, Reno

PCCAS, November 15, 2017

Superpave Mix Design of CIR

- Superpave Gyratory Compactor (SGC)
  - N_{design}
    - Graded: 75 gyrations
    - Non-Graded: 100 gyrations
  - Perforated mold
    - Allows water to seep out during compaction



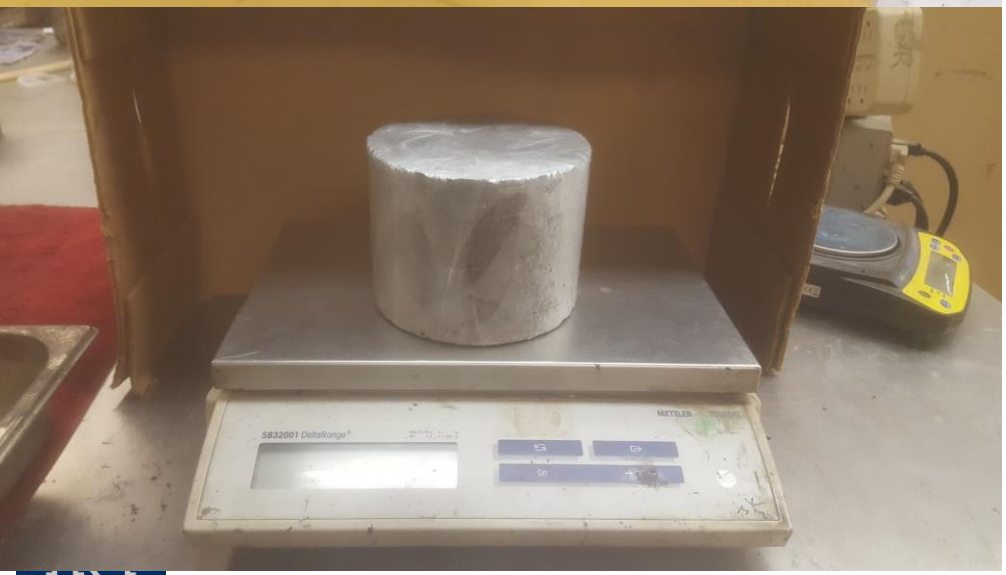
Identify Optimum Emulsion Content

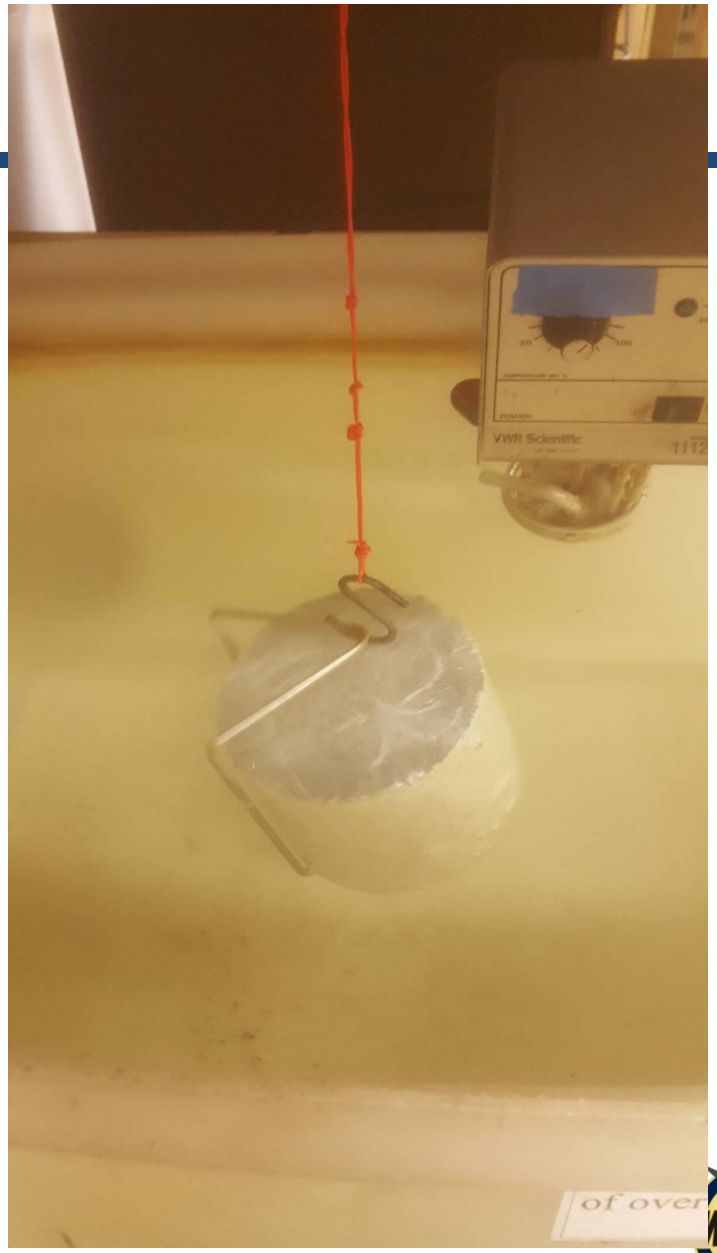
- Mix samples at: 2.5, 3.0, 3.5, and 4.0% emulsion by dry weight of RAP
- Water
  - Lime slurry
  - From moisture density curve
- Measure G_{mm} at emulsion content of 3.0% and calculate at others

Identify Optimum Emulsion Content

- Compact to N_{design} and measure G_{mb}
  - Cure the compacted CIR mix at 140°F to a constant mass ~ 24 hours
  - G_{mb} using ASTM D1188 parafilm
- Identify OEC:
  - Height: 115±5mm
  - Air voids (%AV): 13±1%

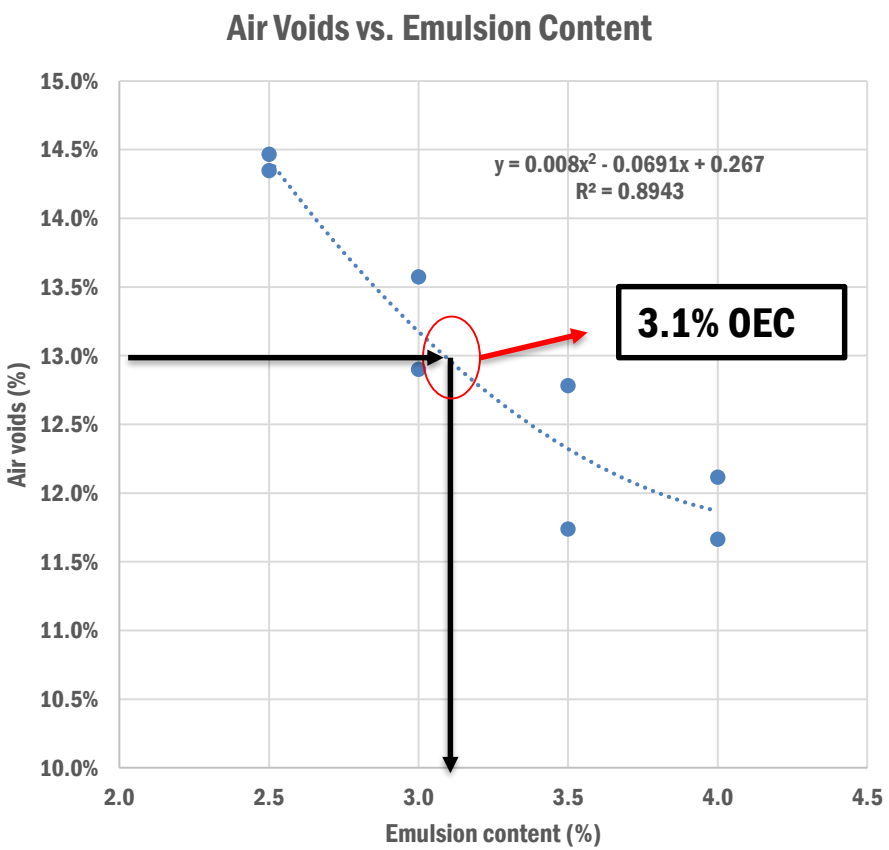
ASTM D1188 Parafilm

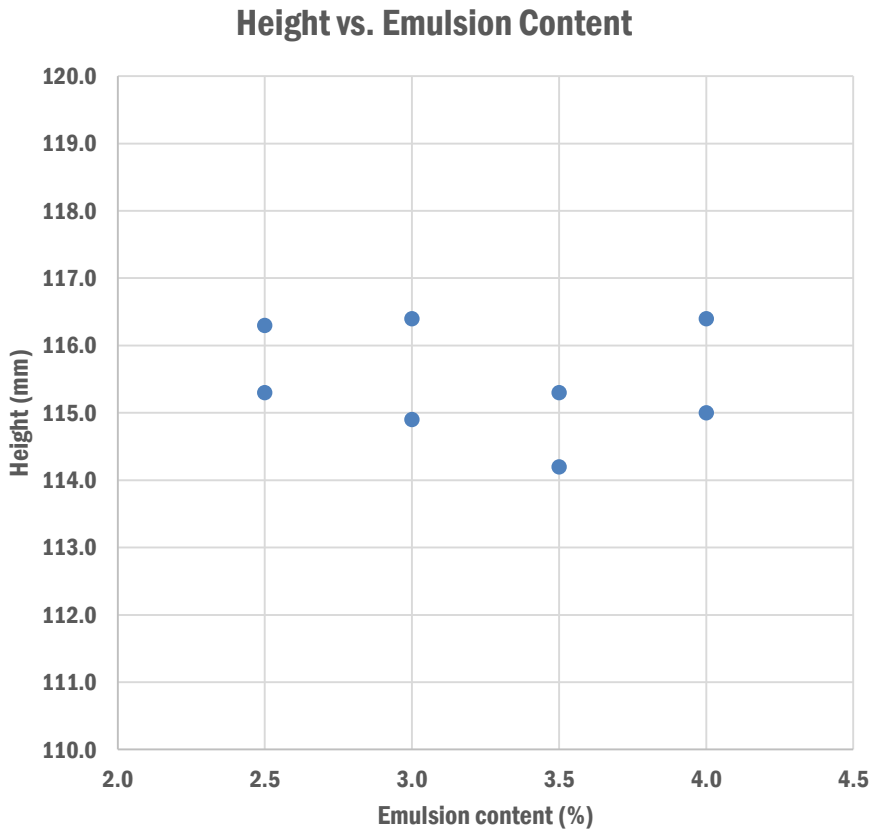




Optimum Emulsion Content (OEC)

Graded RAP - Emulsion type B - 6.0% Slurry Lime – 75 Gyrations





Moisture Sensitivity

- AASHTO T283
- Air Voids: 13±1%
- Curing: at 140°F to a constant mass ~ 24 hours
- Criteria:
  - Minimum dry TS at 77°F: 50 psi
  - Minimum TSR: 70%

Curing Time in Field

- Time to cure before allowing traffic
- ASTM D3910
- Torque 20g-cm

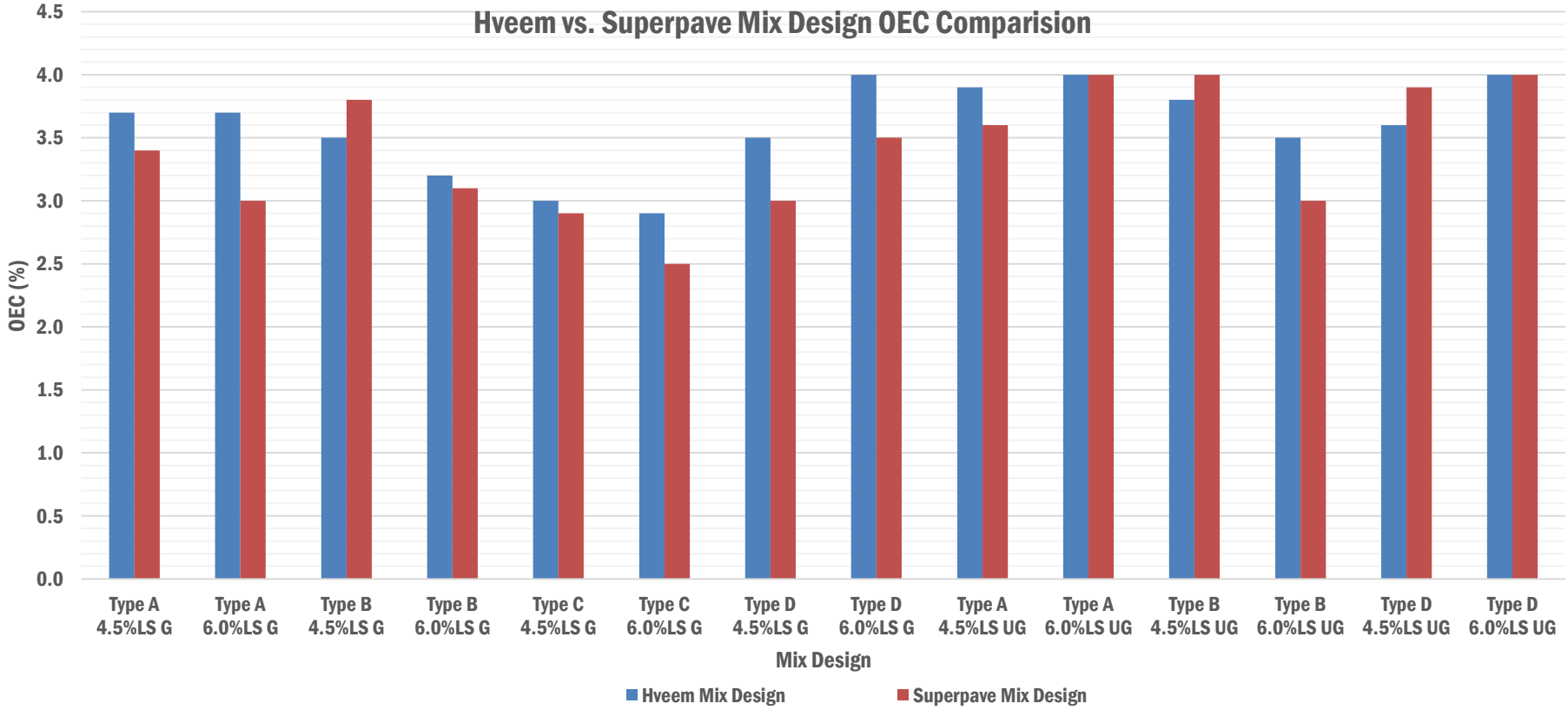
Resistance to Raveling

- Resistance to loss of aggregates under abrasion
- ASTM D7196
- Percent mass loss <2.0%

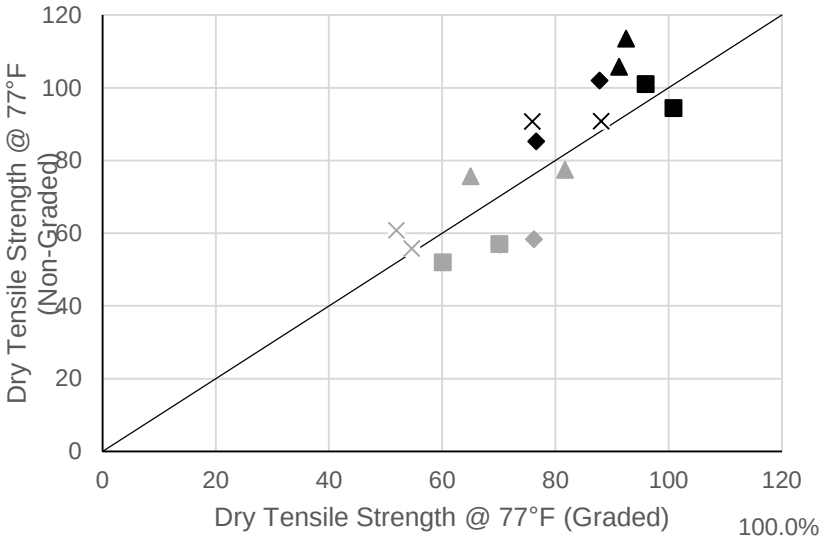
Hveem Mix Design of CIR

- Hveem Kneading Comapctor
  - Leveling Stress
    - Graded: 500 psi
    - Non-Graded: 1000 psi
  - All other steps remain the same as the Superpave Mix Design

Comparison of Superpave and Hveem Mix Designs

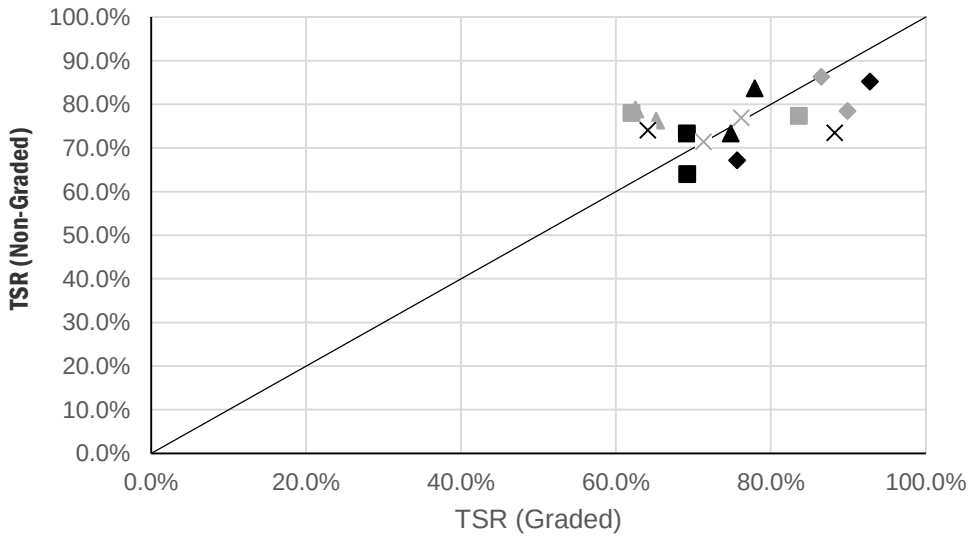


Tensile Strength: Non-Graded vs Graded

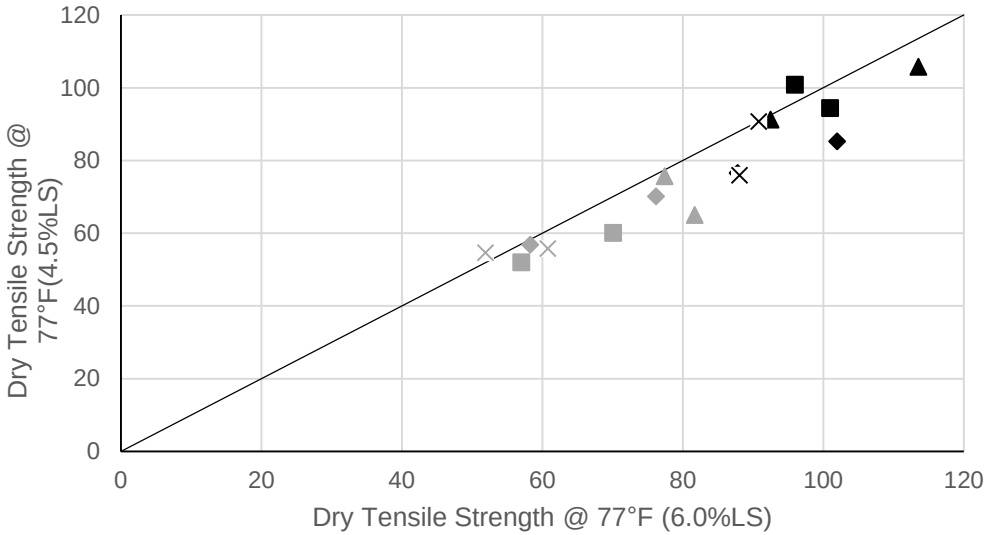


Dark: HV

Light: SP

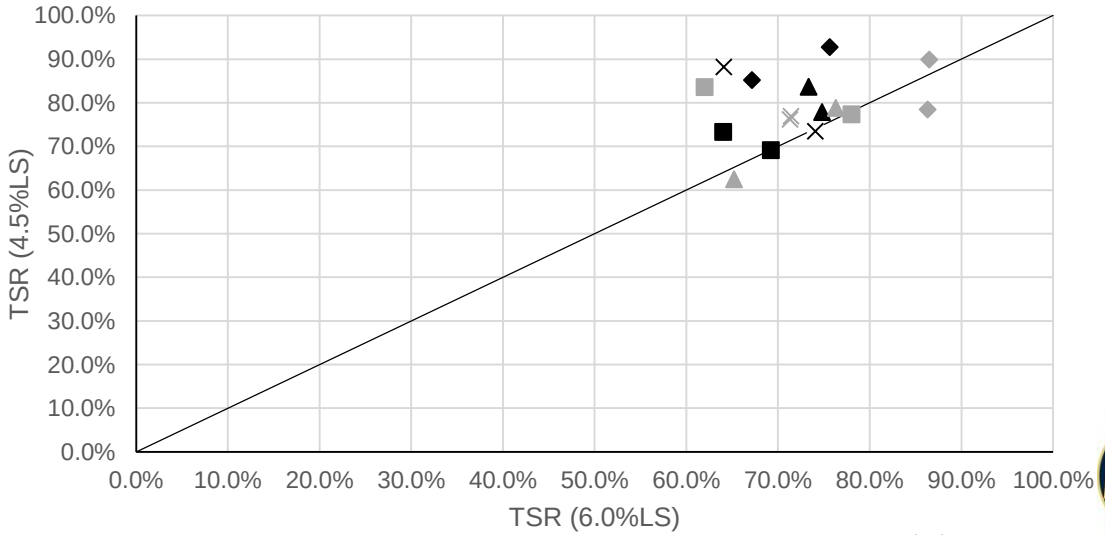


Tensile Strength: 4.5 vs 6.0 LS

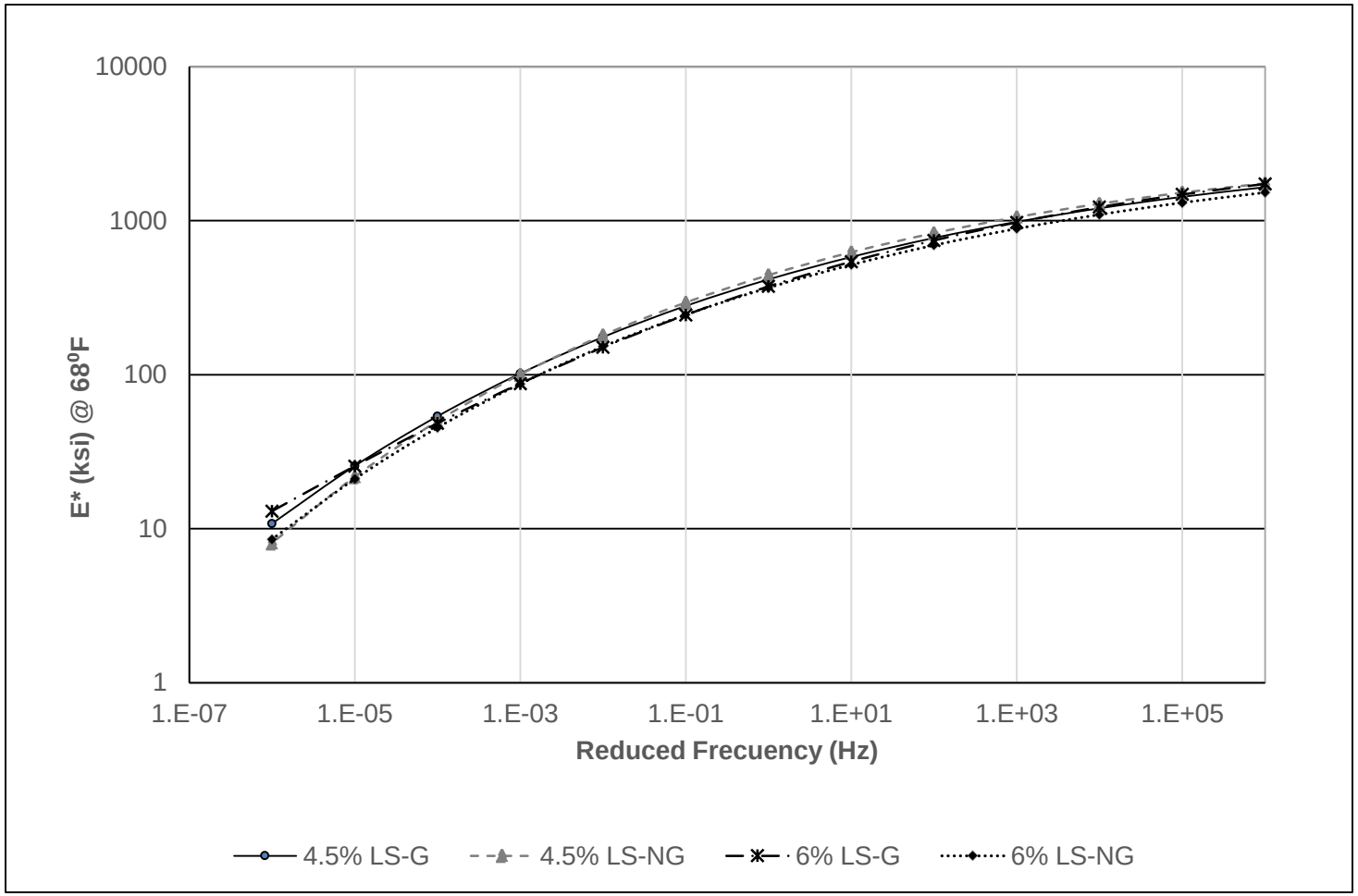


Dark: HV

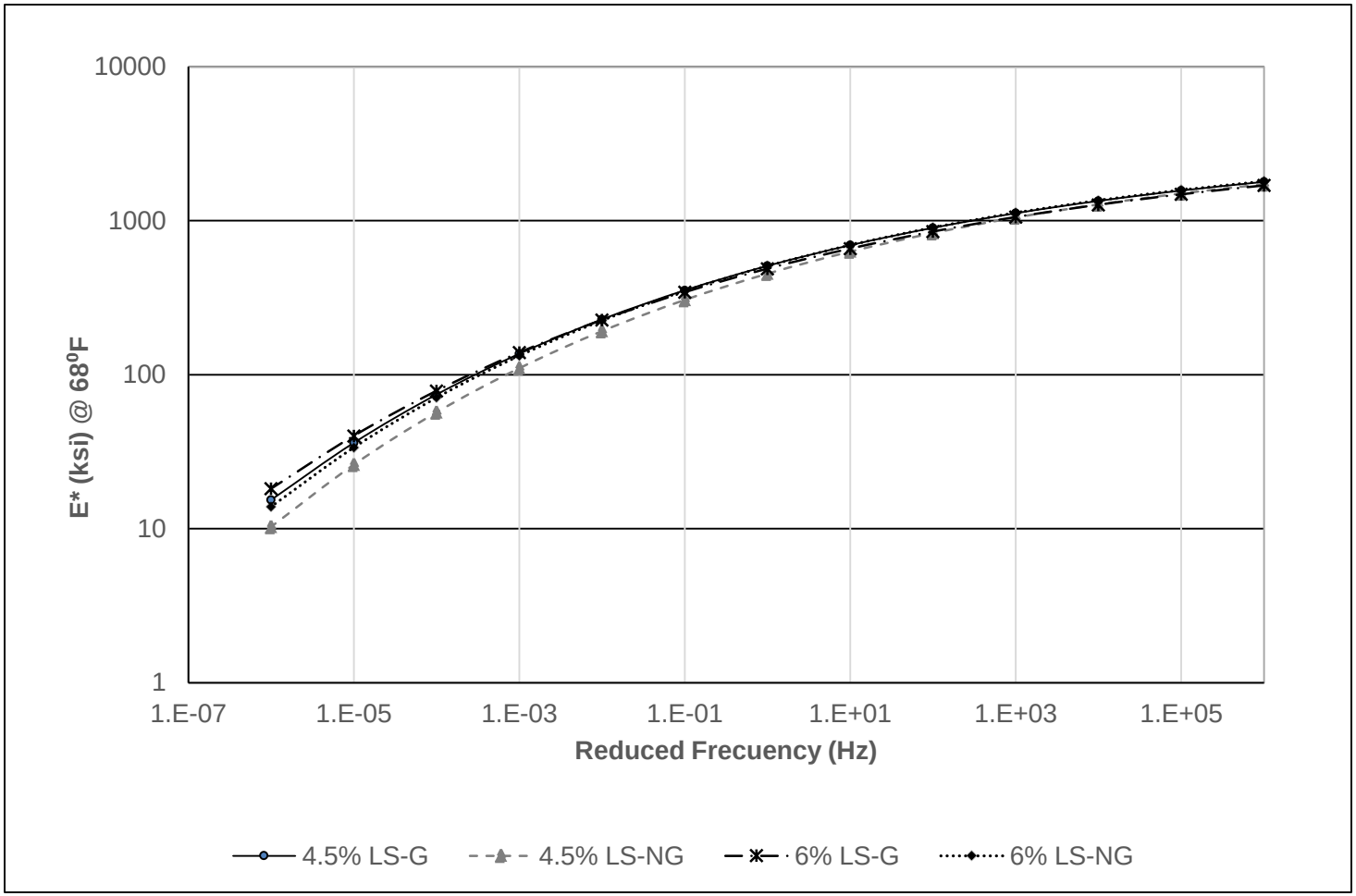
Light: SP



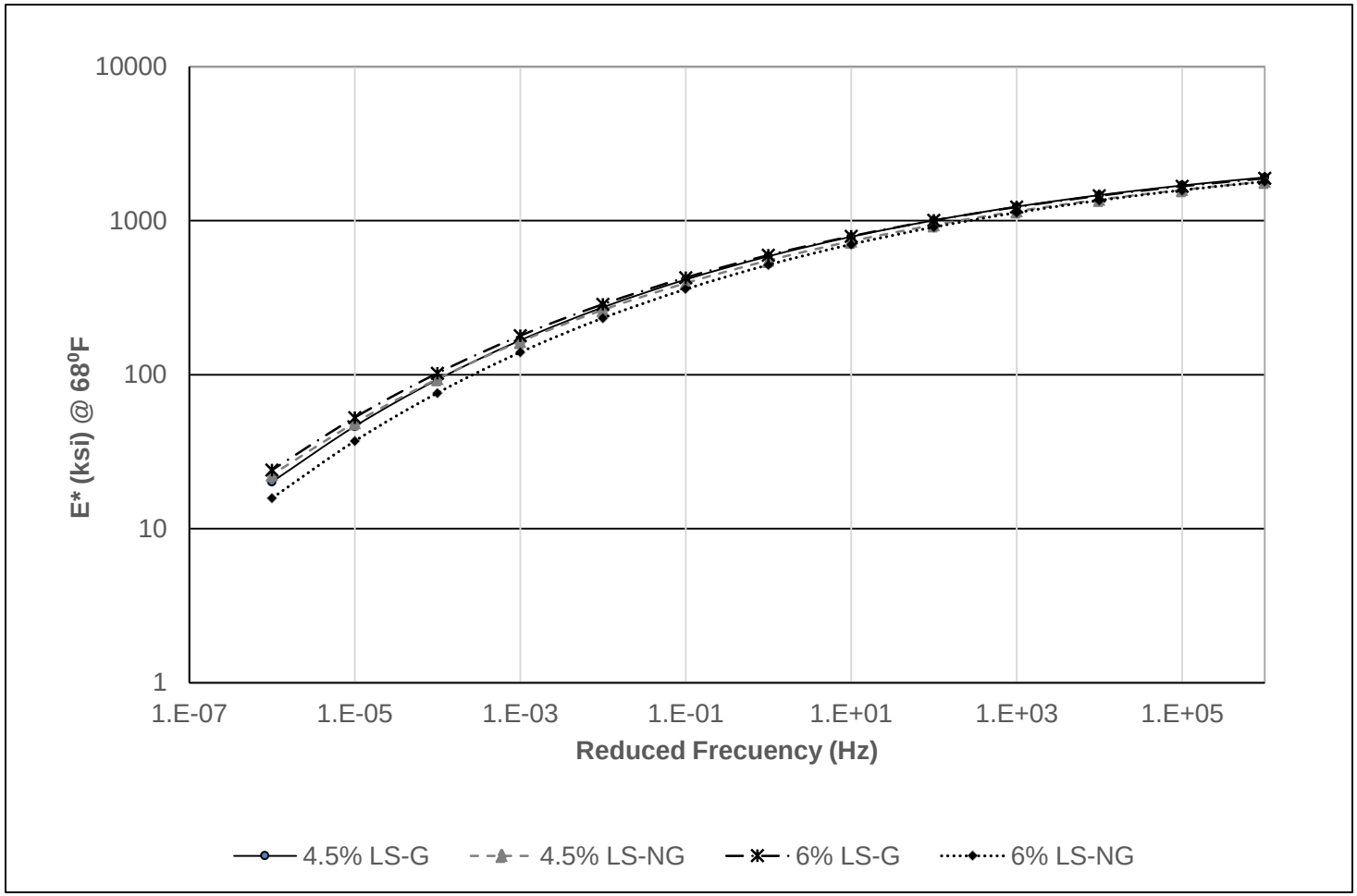
Emulsion A


10000
1000
100
10
1
E* (ksi) @ 68°F
1.E-07
1.E-05
1.E-03
1.E-01
1.E+01
1.E+03
1.E+05
Reduced Frecuency (Hz)
4.5% LS-G
4.5% LS-NG
6% LS-G
6% LS-NG

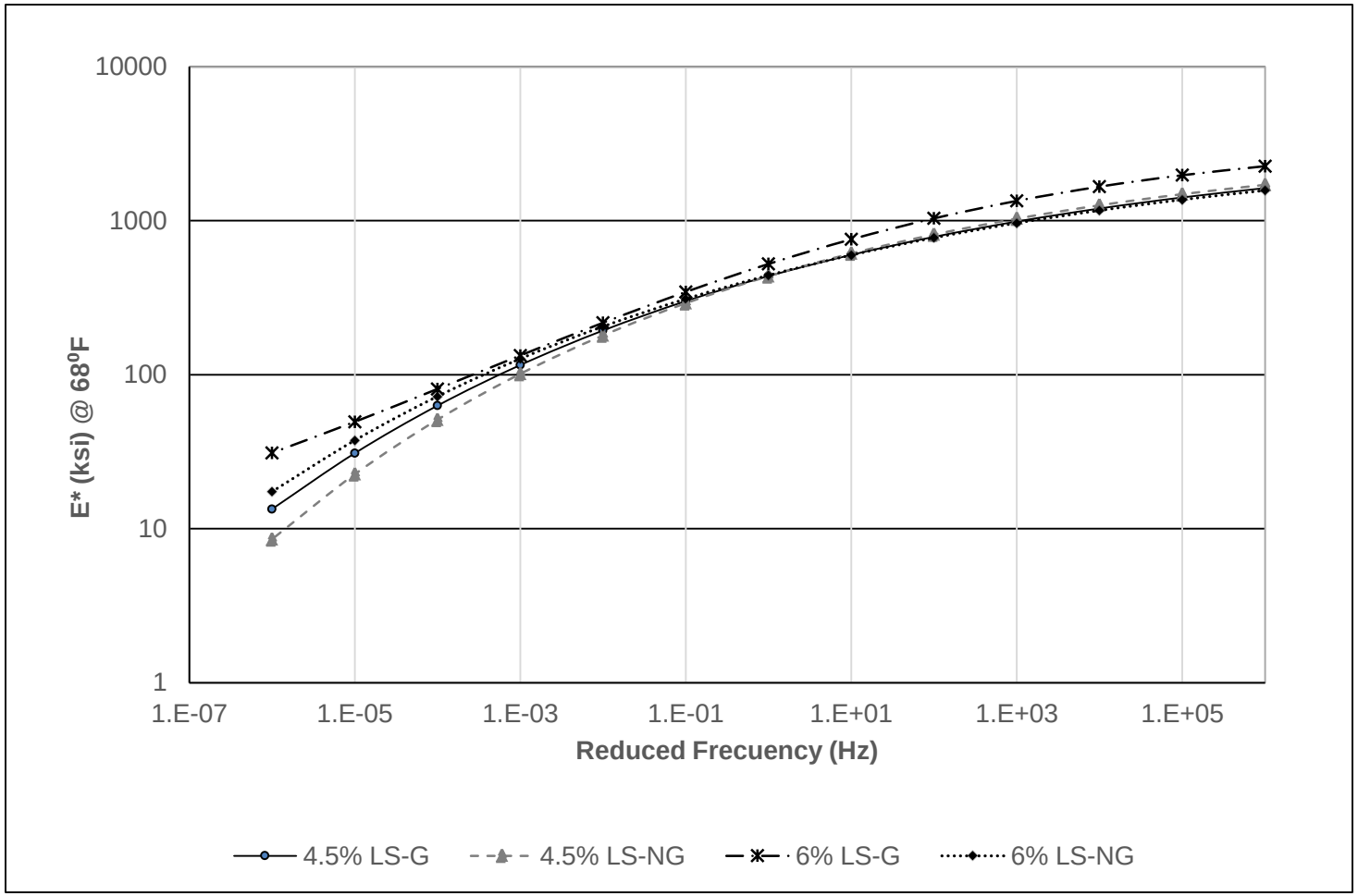
Emulsion B


10000
1000
100
10
1
E* (ksi) @ 68°F
1.E-07
1.E-05
1.E-03
1.E-01
1.E+01
1.E+03
1.E+05
Reduced Frecuency (Hz)
4.5% LS-G
4.5% LS-NG
6% LS-G
6% LS-NG

Emulsion C


10000
1000
100
10
1
E* (ksi) @ 68°F
1.E-07
1.E-05
1.E-03
1.E-01
1.E+01
1.E+03
1.E+05
Reduced Frecuency (Hz)
4.5% LS-G
4.5% LS-NG
6% LS-G
6% LS-NG

Emulsion D


10000
1000
100
10
1
E* (ksi) @ 68°F
1.E-07
1.E-05
1.E-03
1.E-01
1.E+01
1.E+03
1.E+05
Reduced Frecuency (Hz)
4.5% LS-G
4.5% LS-NG
6% LS-G
6% LS-NG

Current Activities

- Repeated Load Triaxial: Rutting Model
- Flexural Beam Fatigue: Fatigue Model
- Overlay Tester: Reflective Cracking

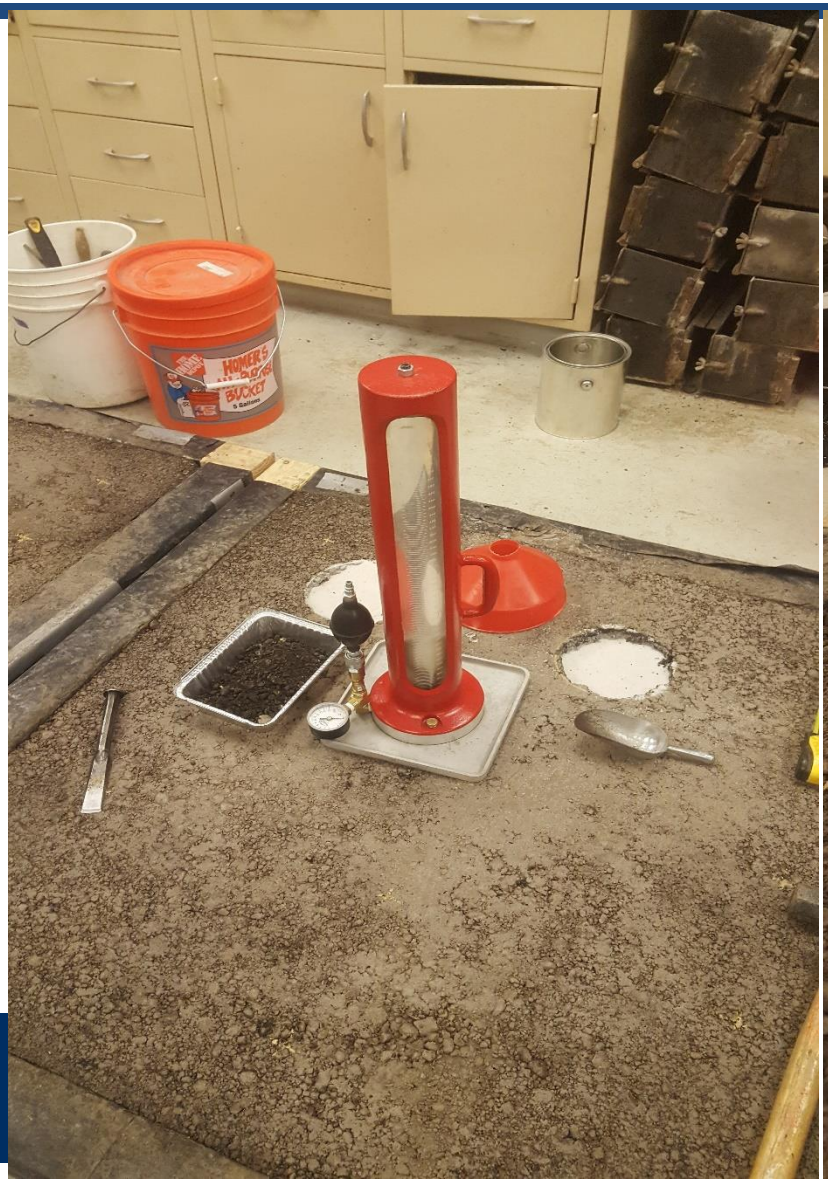
In-Place Air Voids of CIR Layer

- Sand Cone
- Water Balloon
- NCAT Permeameter
- Cores

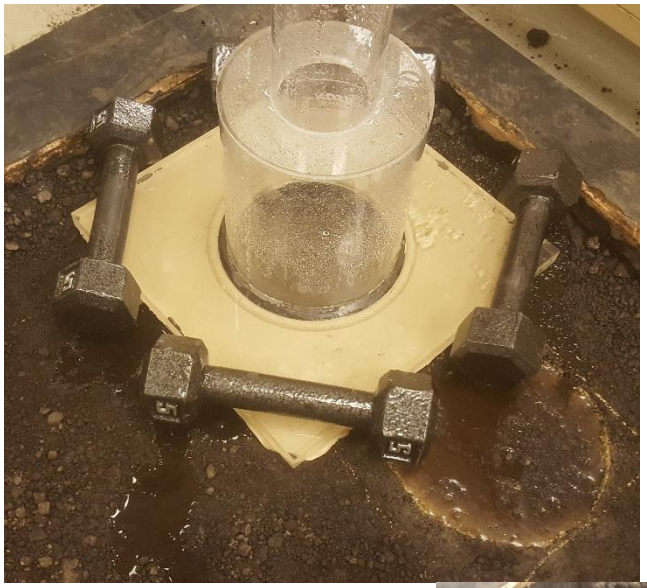
Mix and Compact

Construct the Slabs

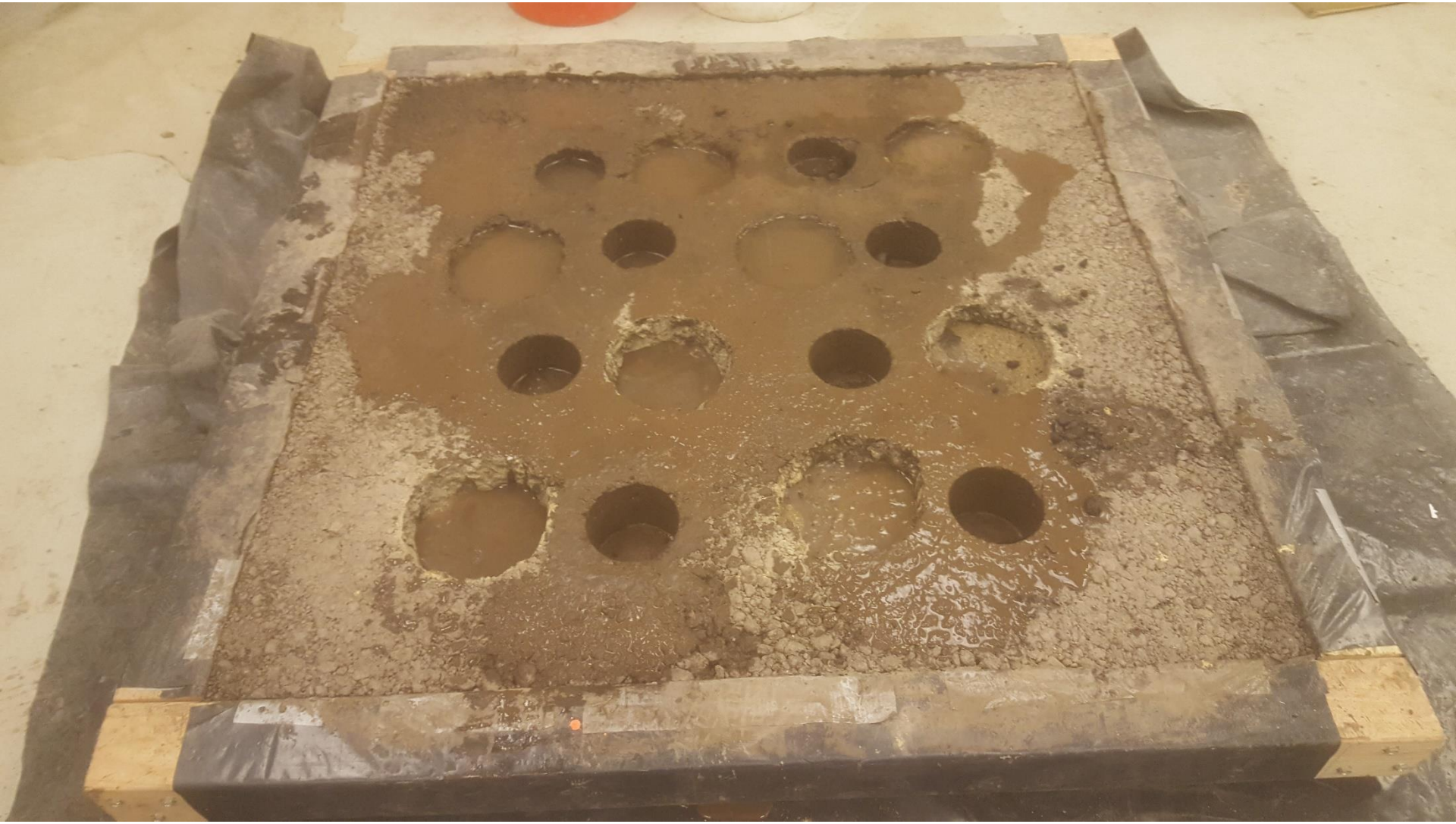
Water Balloon and Sand Cone Testing



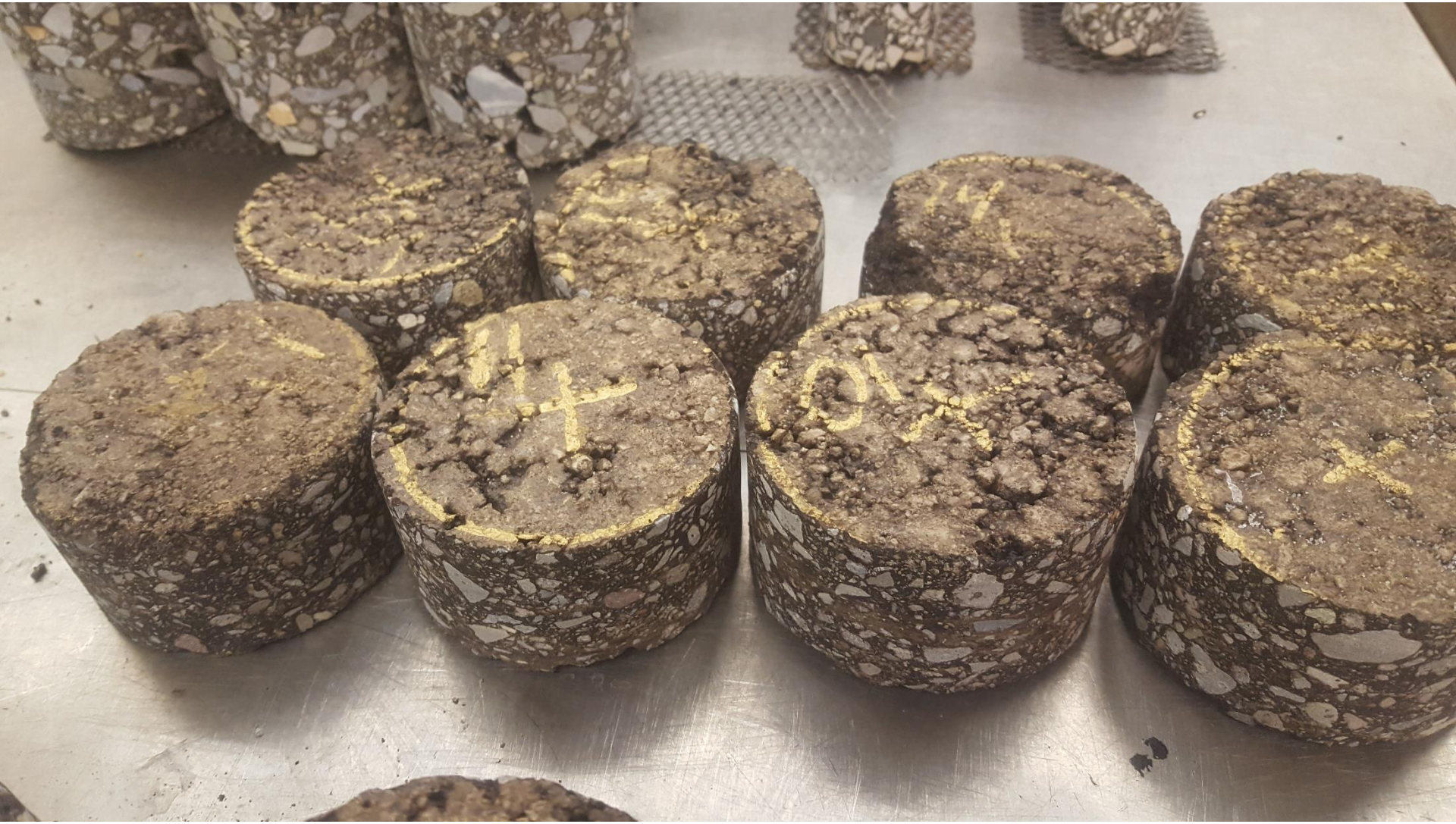
NCAT Permeameter



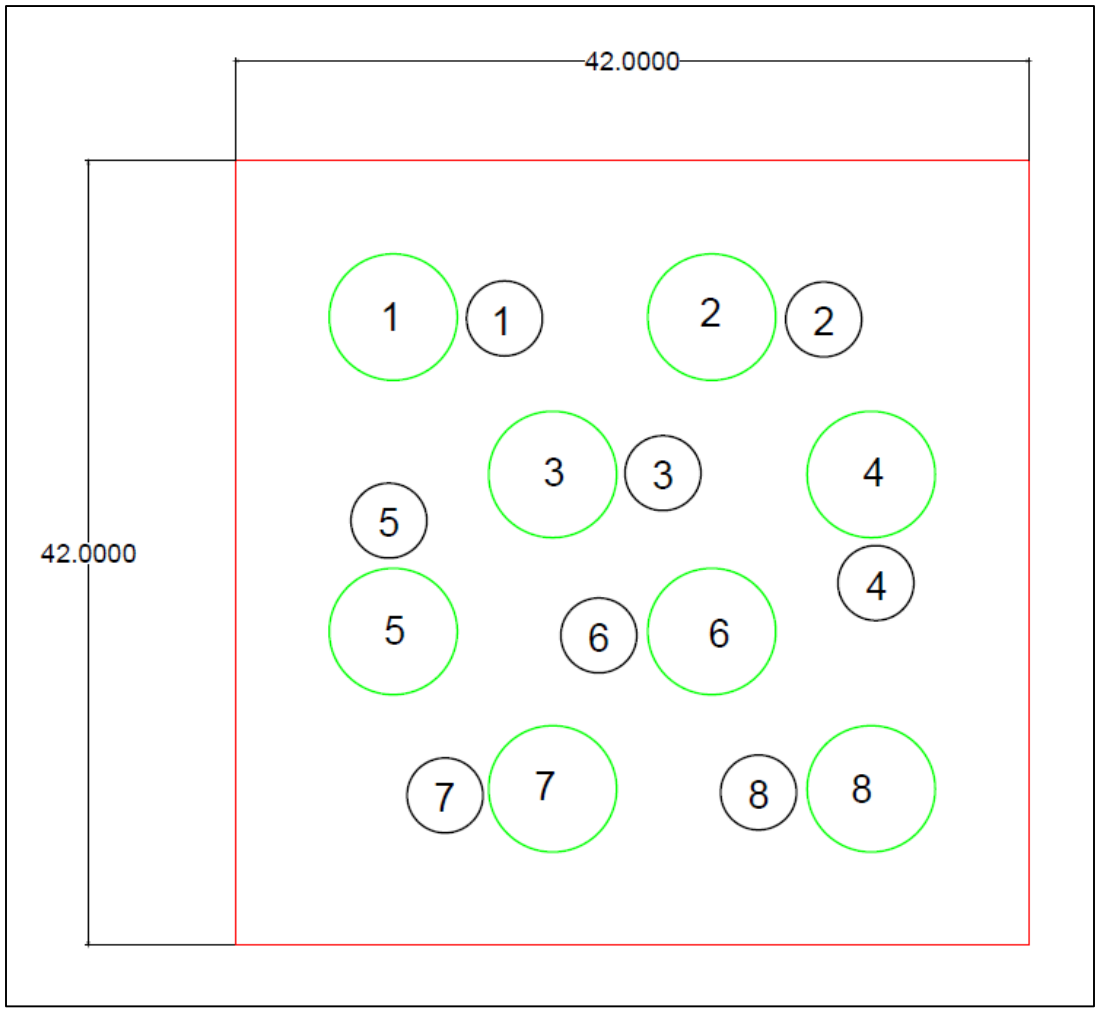
Cutting the Cores after 14-days



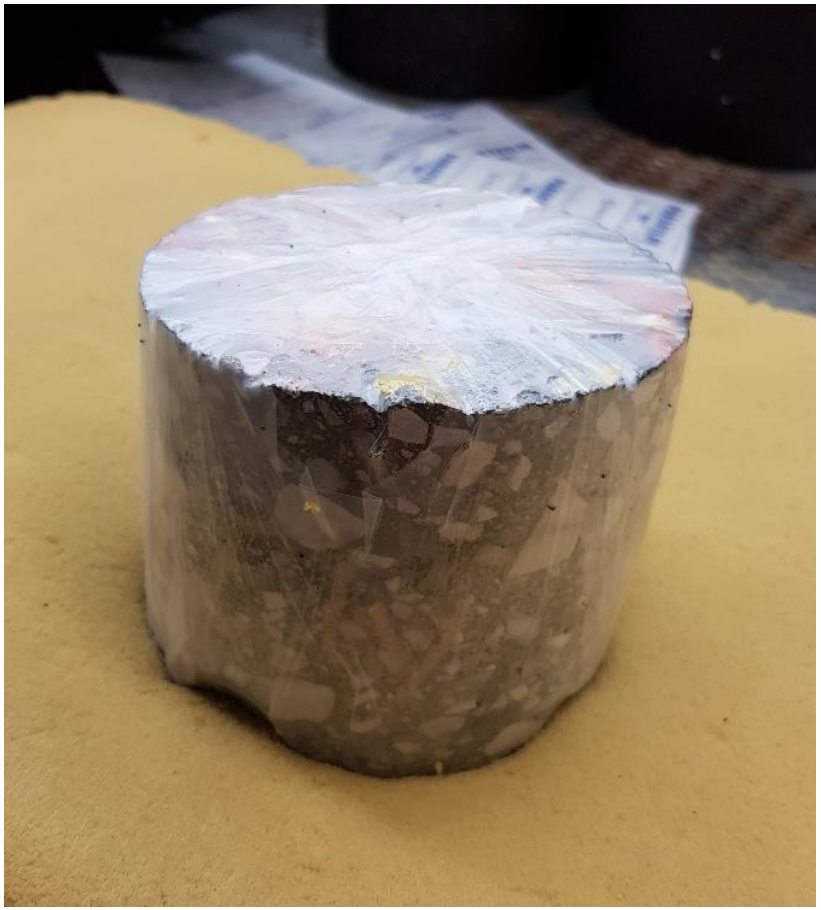
The Cores Look Good



Locations



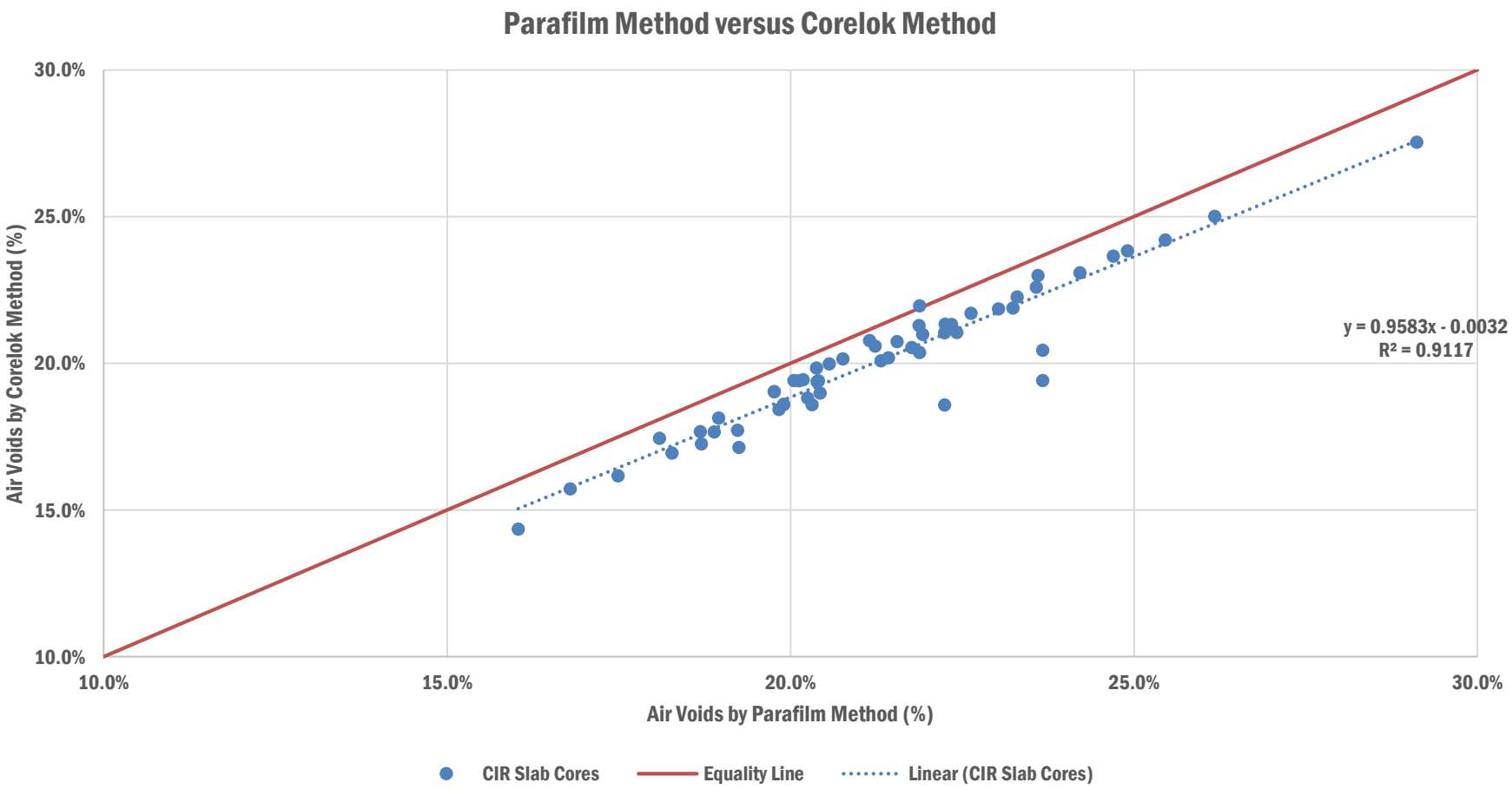
Sp. Gr. of Cores



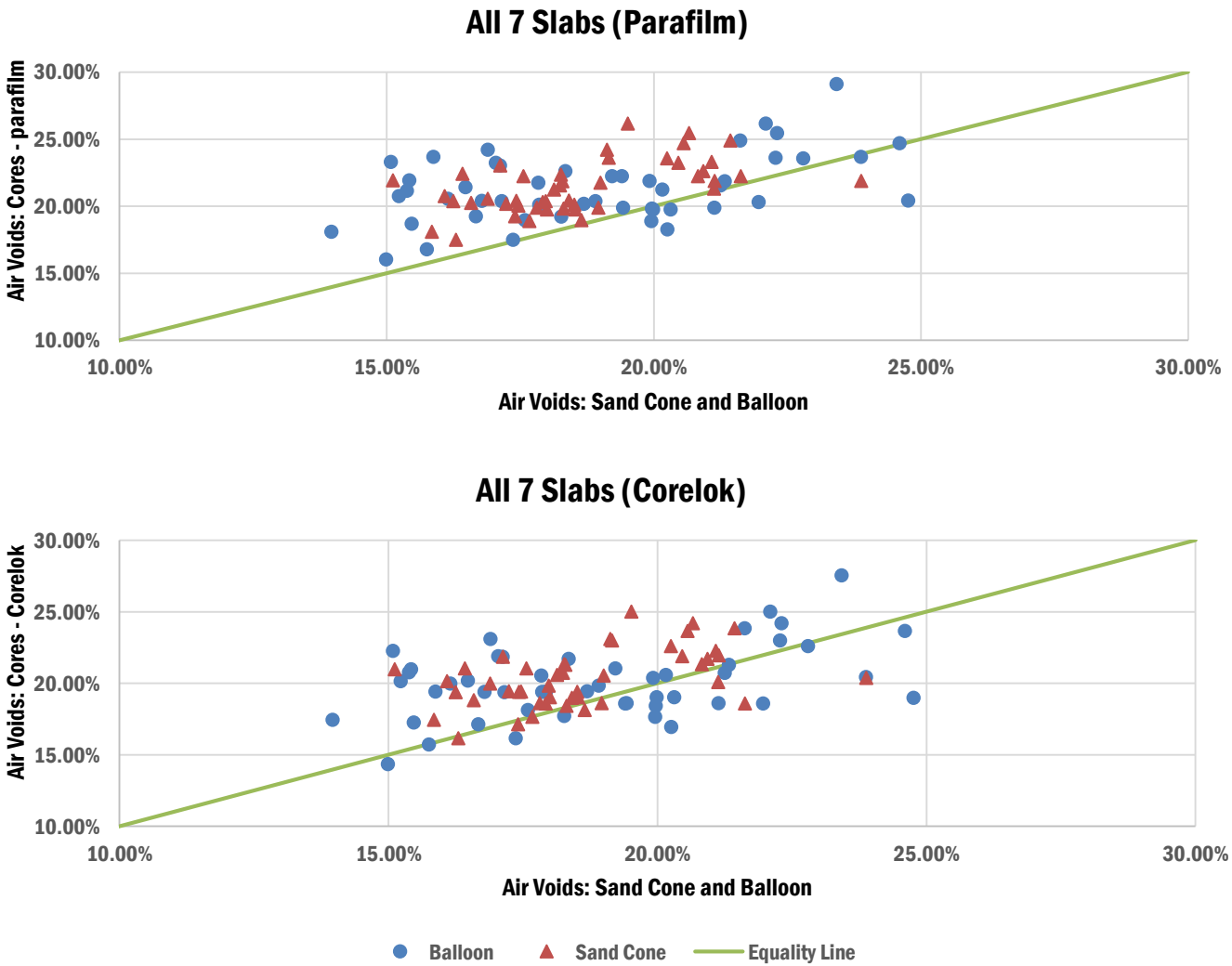
Parafilm

Corelok

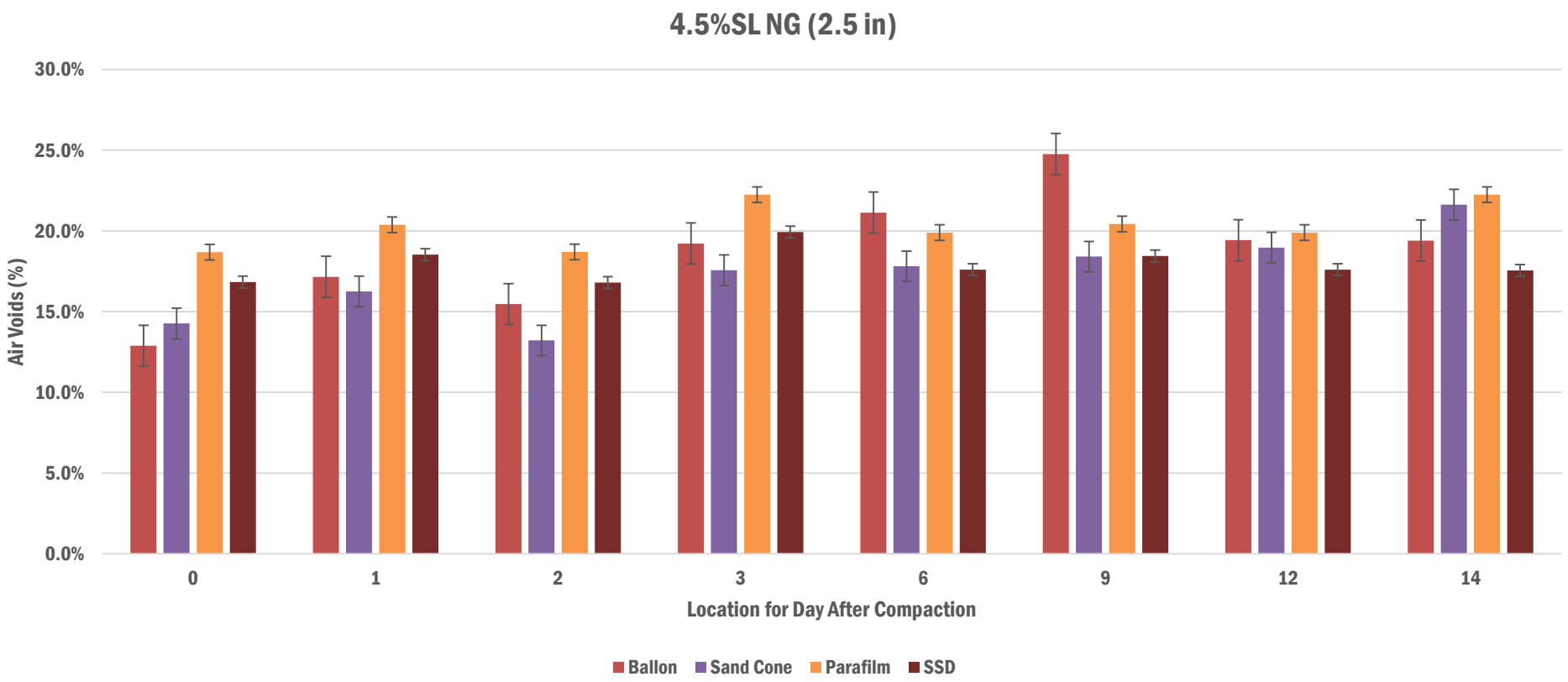
Air Voids: Parafilm Vs. Corelok



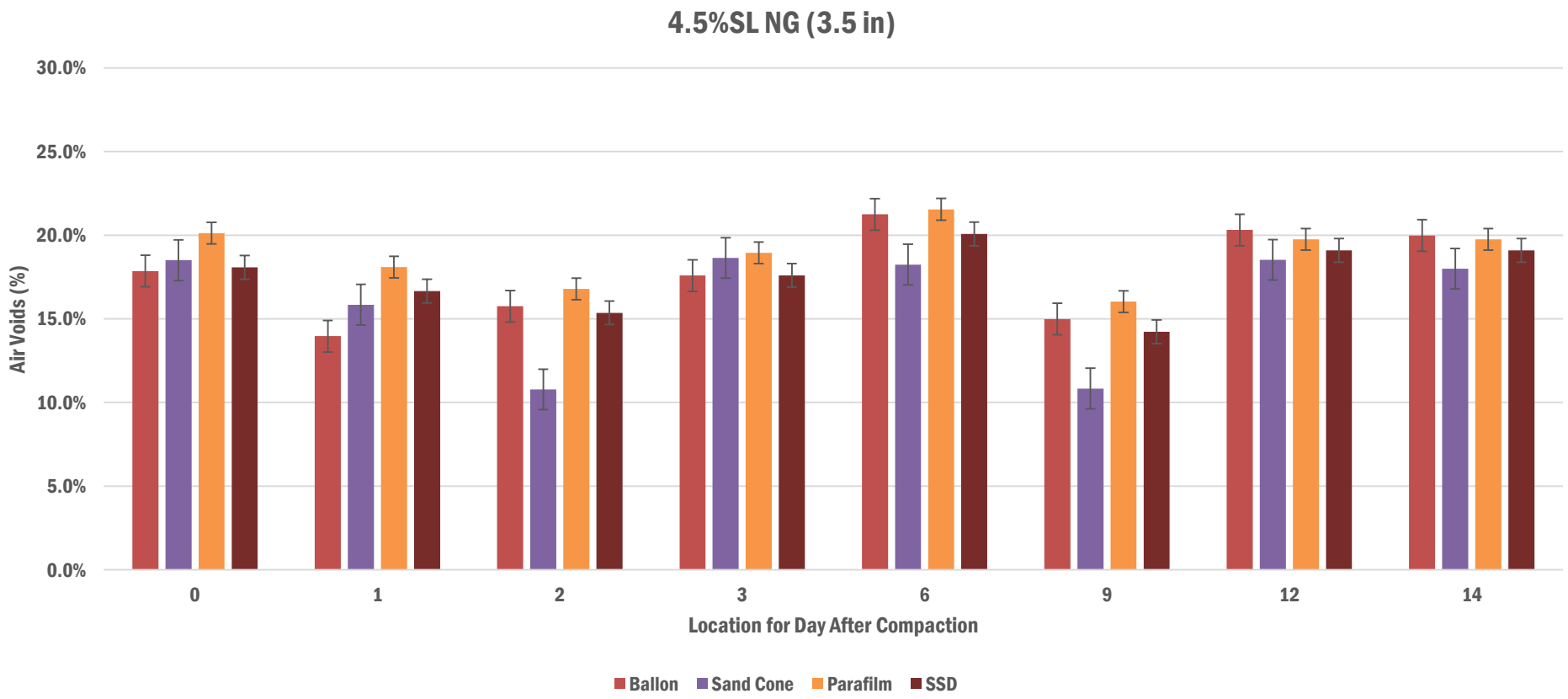
ALL Data


All 7 Slabs (Parafilm)
Air Voids: Cores - parafilm
30.00%
25.00%
20.00%
15.00%
10.00%
10.00%
15.00%
20.00%
25.00%
30.00%
Air Voids: Sand Cone and Balloon
All 7 Slabs (Corelok)
Air Voids: Cores - Corelok
30.00%
25.00%
20.00%
15.00%
10.00%
10.00%
15.00%
20.00%
25.00%
30.00%
Air Voids: Sand Cone and Balloon
Balloon
Sand Cone
Equality Line

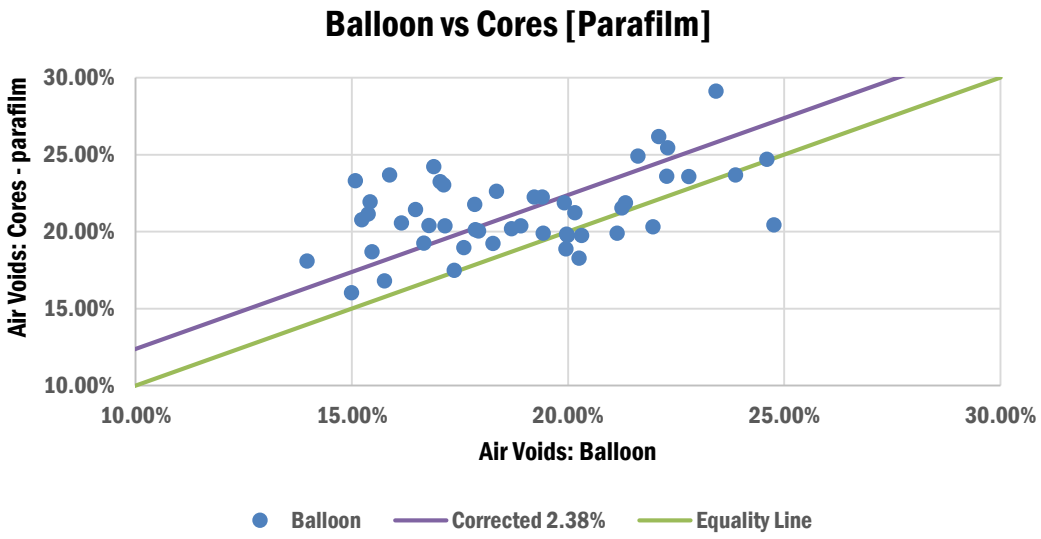
Comparison on 2.5” Slab

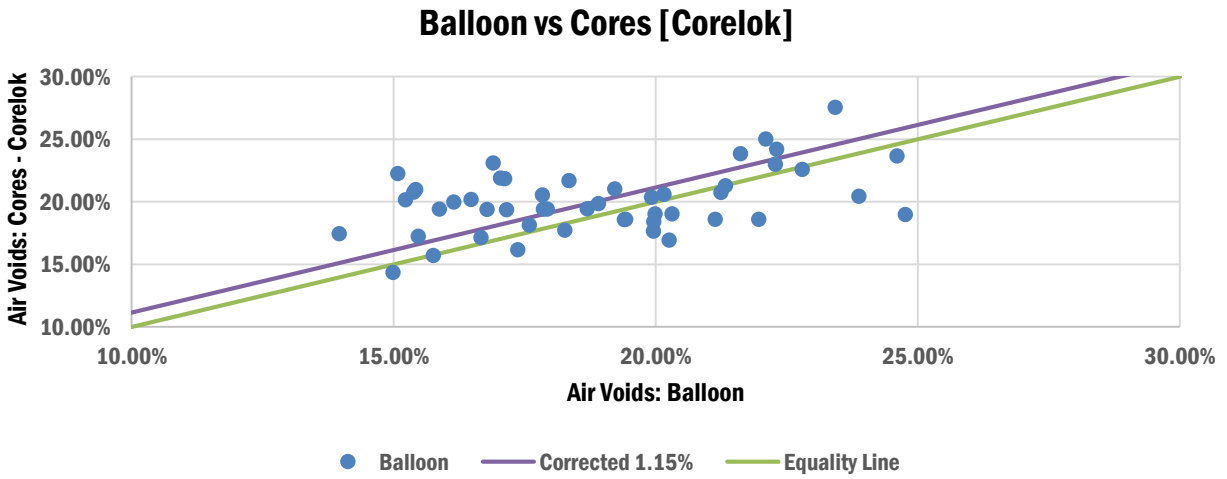


Comparison on 3.5” Slab

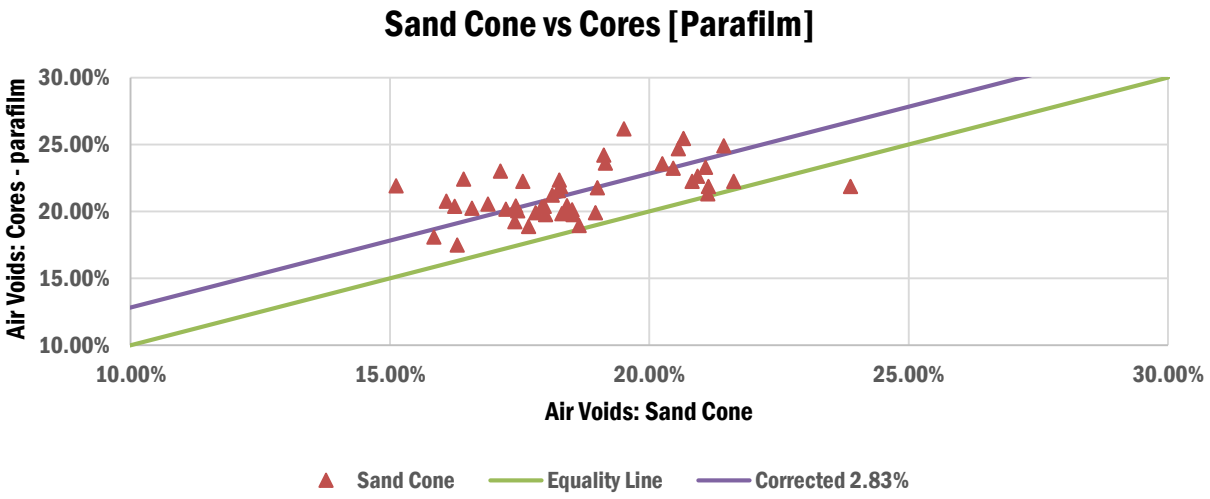


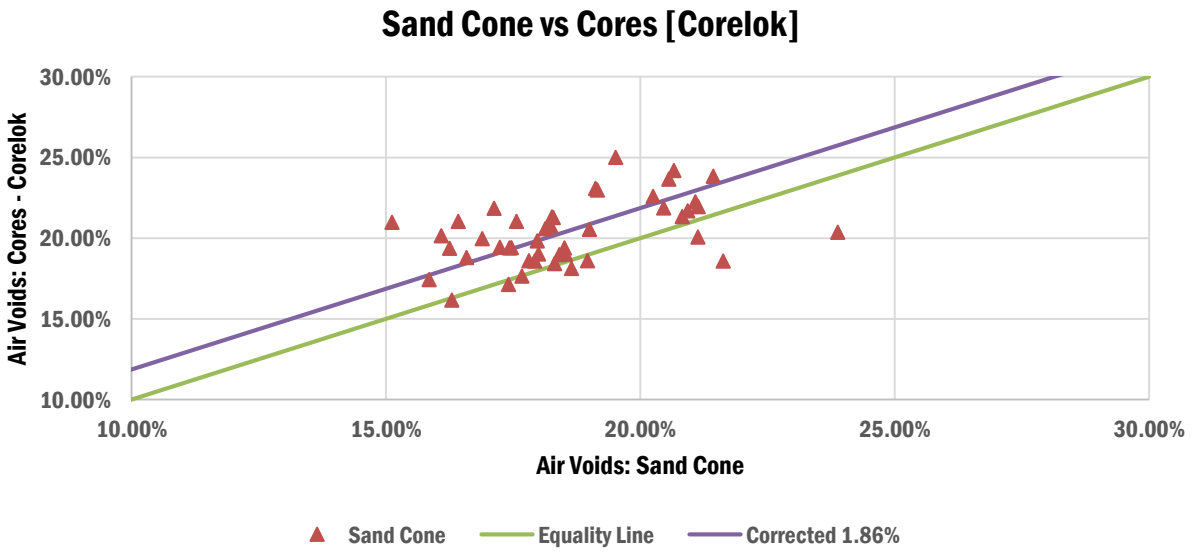
Balloon Correction





Sand Cone Correction





T-test Analysis: Differences

T-test Parameters	Balloon-Parafilm	Balloon-Corelok	Sand Cone-Parafilm	Sand Cone-Corelok
n	49	49	49	49
t	-0.6580	0.0026	-0.6665	-1.0372
p-value	0.5137	0.9980	0.5083	0.3048
95% Confidence Interval	[-1.8 to 0.9]	[-0.8 to 0.8]	[-0.9 to 0.5]	[-1.1 to 0.3]
Standard Deviation	4.63	2.80	2.38	2.51

Applications: Sand Cone- Parafilm

- Use the sand cone method to measure the in-place air voids of the compacted CIR layer
- Add 2.8% to the in-place air voids calculated from the Sand Cone measurement to calculate the adjusted in-place air voids
- There is 95% confidence that the adjusted in-place air voids will be: -0.9 to +0.5 from the actual in-place air voids measured on cores using the parafilm method

Field Verification: Fernley, NV

Balloon - Parafilm			Balloon - Corelok		
Avg. AV: Balloon, %	22.7		Avg. AV: Balloon, %	22.7	
Corrected Avg. AV: Balloon, %	25.1		Corrected Avg. AV: Balloon, %	23.9	
Avg. AV: Cores, %	22.0		Avg. AV: Cores, %	20.0	
Difference	-3.1		Difference	-3.9	
95% Confidence Interval for the Difference	[-1.8 to 0.9]	No	95% Confidence Interval for the Difference	[-0.8 to 0.8]	No

Field Verification: Fernley, NV

Sand Cone - Parafilm			Sand Cone - Corelok		
Avg. AV: Sand Cone, %	19.4		Avg. AV: Sand Cone, %	19.4	
Corrected Avg. AV: Sand Cone, %	22.2		Corrected Avg. AV: Sand Cone, %	21.3	
Avg. AV: Cores, %	21.9		Avg. AV: Cores, %	20.0	
Difference	-0.30	OK	Difference	-1.3	No
95% Confidence Interval for the Difference	[-0.9 to 0.5]		95% Confidence Interval for the Difference	[-1.1 to 0.3]	

Thank You!