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High RAP Research Studies

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Current Projects Related to RAP

- High RAP Mixtures (VTTI contract)
  - Goal: Address binder contents of high RAP mixes
- In-Service Binder Aging and Performance: RAP Mixtures (VCTIR)
  - Goal: Investigate binder aging and performance of RAP mixtures
- TPF-5(230) Evaluation of Plant Produced High Percentage RAP Mixtures in the Northeast (pooled fund)
  - Goal: Understand how RAP interacts with the virgin materials in a mixture
  - Develop proper techniques and procedures to design & construct RAP mixtures with equal or better performance than all-virgin mixtures

High RAP Mixtures

- Objective: Evaluate the effect of increasing binder content (+0.5% and +1.0) on the performance of high RAP content surface mixes

- Four mixes: 0%, 20%, 40%, and 100% RAP
- Mix performance evaluated using
  - Dynamic modulus
  - Flow number and APA (for rutting)
  - Beam fatigue (for cracking)

High RAP Mixtures

- Results
  - 0% and 20% RAP mixes were VDOT-approved: for both mixes, performance improved with +0.5% binder
  - 40% RAP mix was not VDOT-approved: adding binder worsened rutting performance of the mix
  - 100% RAP mixes were very stiff even after +1.5% binder was added

High RAP Mixtures

- Conclusion:
  - Adding additional binder improved lab performance of mixtures, except 40% RAP mix
  - Additional binder content has the potential to improve mix field performance
  - However, new volumetric specifications for mix design are needed or adjusted mixes will not pass specs

In-Service Binder Aging and Performance: RAP Mixtures

- Purpose and Scope
  - Part 1 – ’07 high RAP sites
  - How does RAP content influence binder grade and mixture performance?
- Evaluation
  - 15 individual locations paved with 11 high RAP mixes
  - 7 locations paved with 7 non-high-RAP mixes

In-Service Binder Aging and Performance: RAP Mixtures

- Planned Testing
  - Visual Survey of Pavement Surface
  - Cores
    - Volumetrics
    - Dynamic modulus
    - Extraction & recovery (top and bottom ½ of each core)
    - Performance grading, multiple stress creep recovery (MSCR) test, shear modulus mastercurve (G*)
    - Modulus mastercurve generation (binder and mixture)

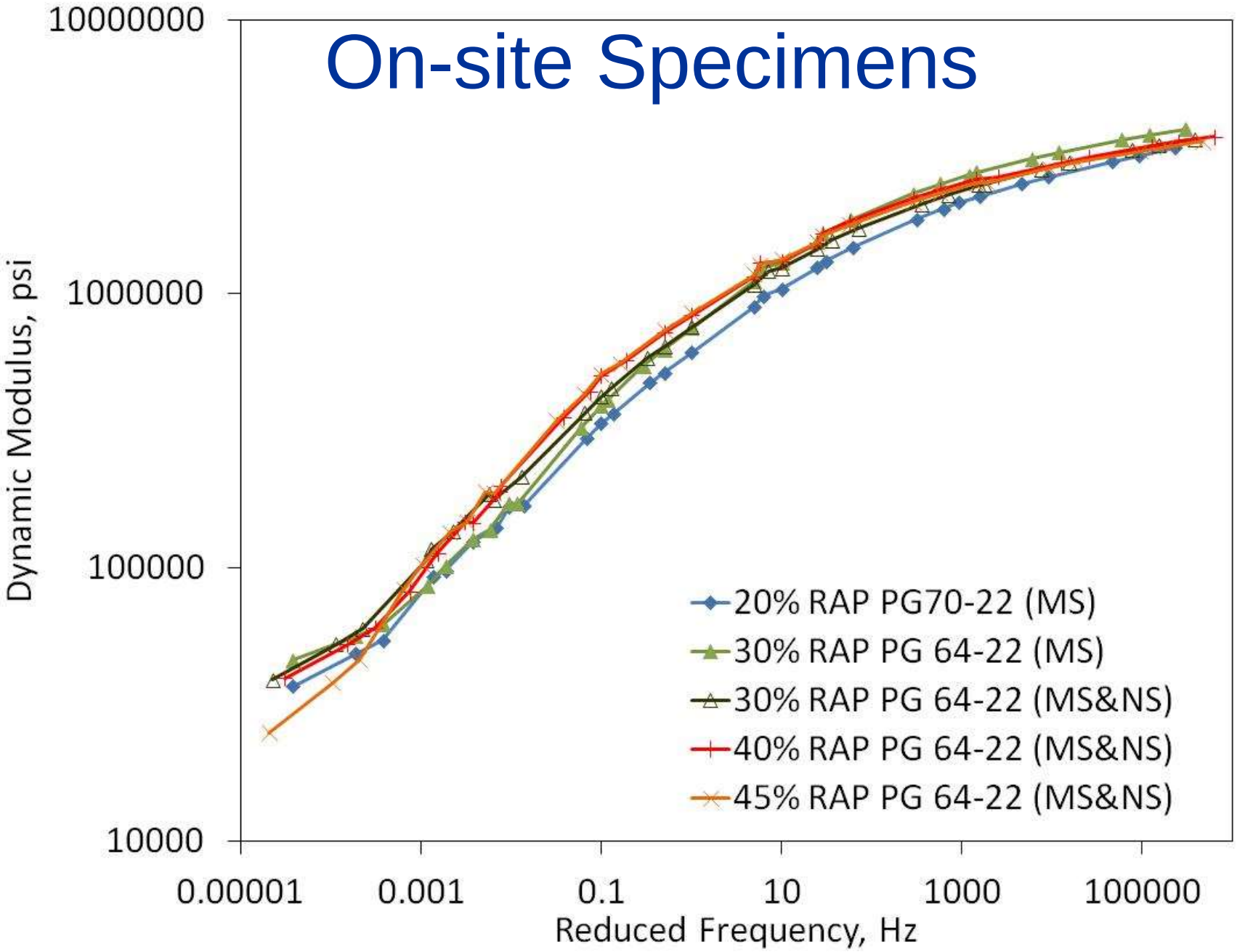
In-Service Binder Aging and Performance: RAP Mixtures

- Purpose and Scope
  - Part 2 – new high RAP sites
  - Can we design, produce, and place mixtures with RAP contents ≥40%?
- Evaluation
  - Construct field projects
  - Document processes and collect materials for testing
  - Laboratory analysis and performance testing
  - Long-term field performance monitoring

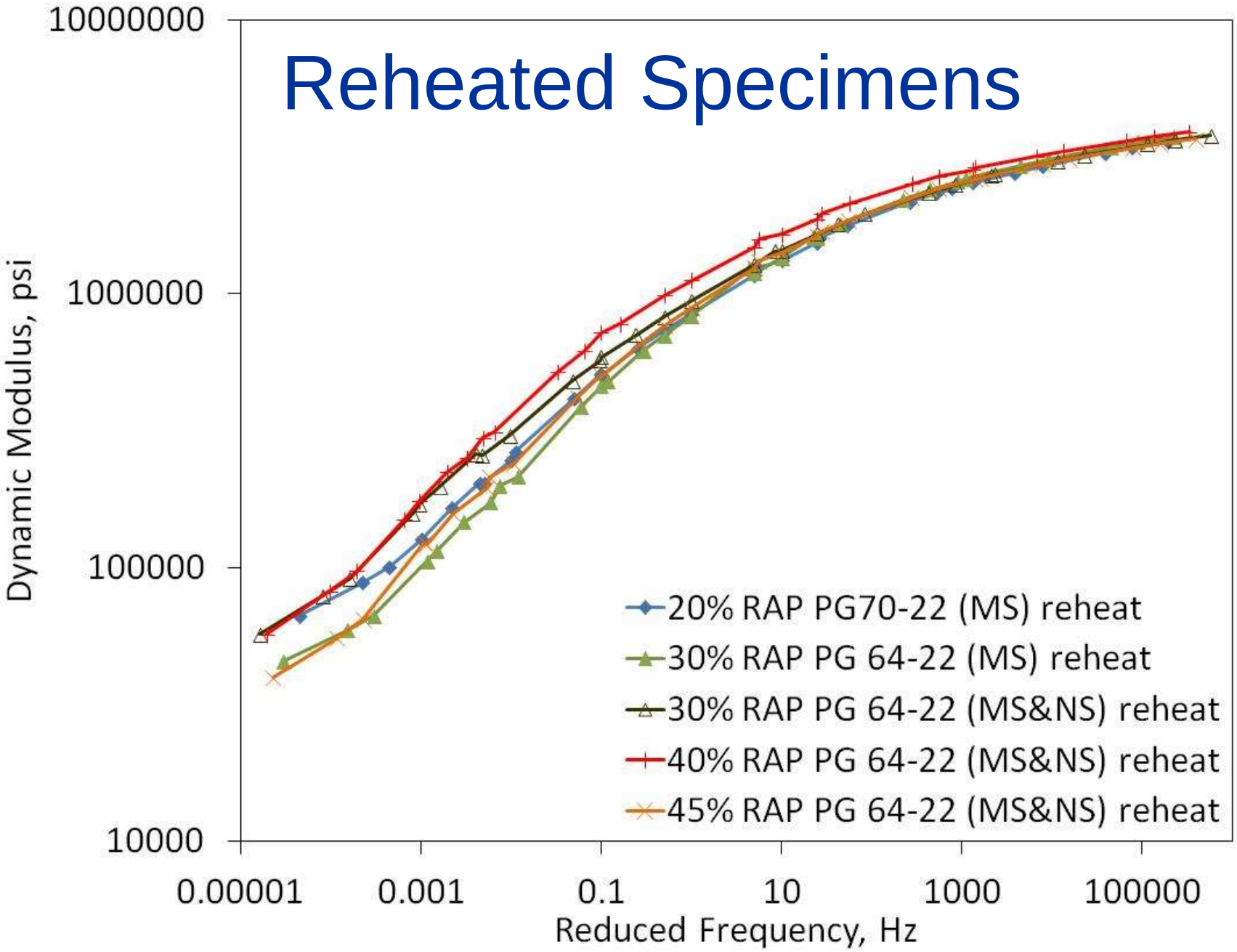
Rt. 3 King George County, June 2013

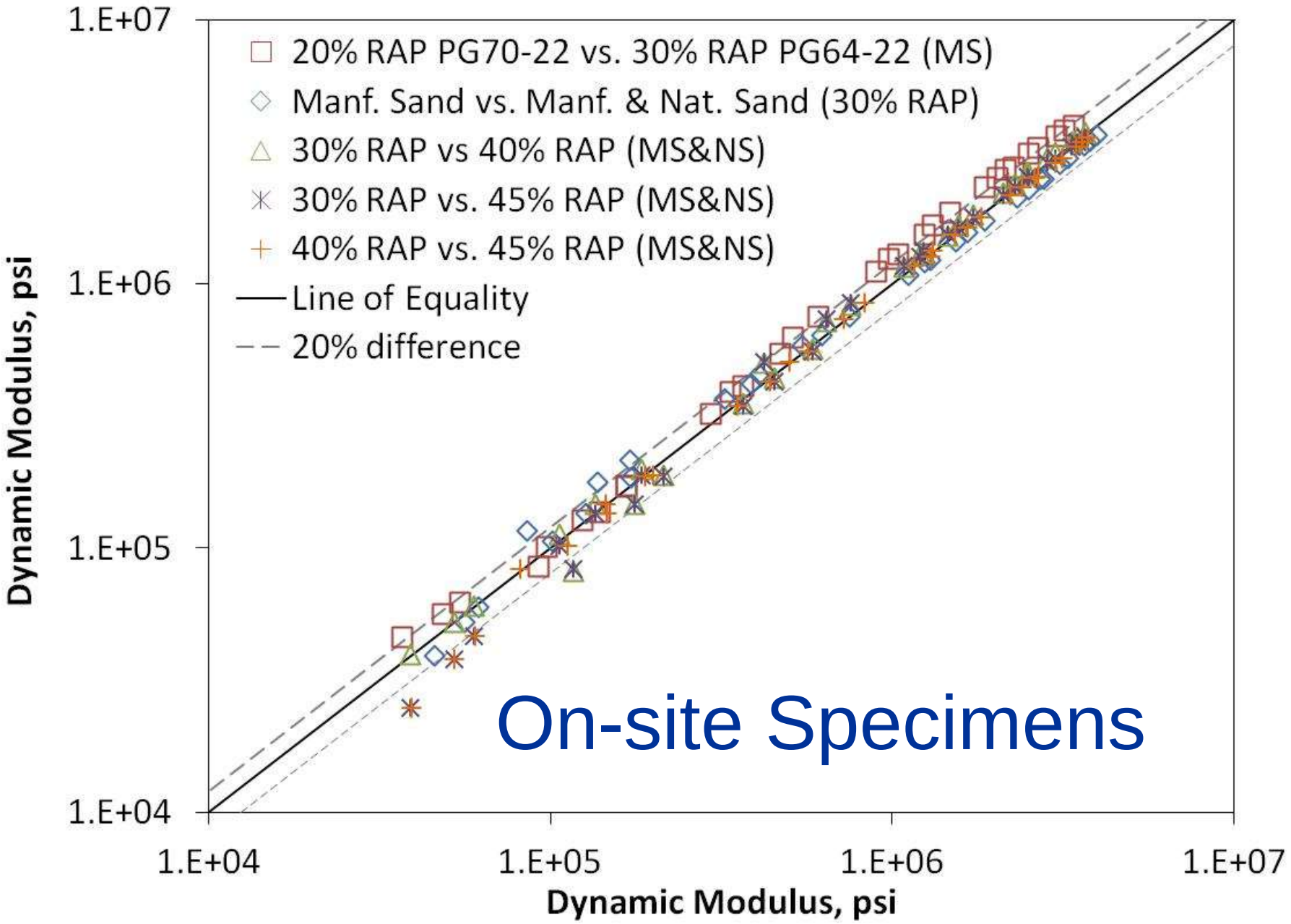
- SM-12.5 mix designs
  - 20% RAP, PG 70-22, manufactured sand
  - 30% RAP, PG 64-22, manufactured sand
  - 30% RAP, PG 64-22, manf. & natural sand
  - 45% RAP, PG 64-22, manf. & natural sand
- 5th mixture – adjustment to 45% design
  - 40% RAP, PG 64-22, manf. & natural sand

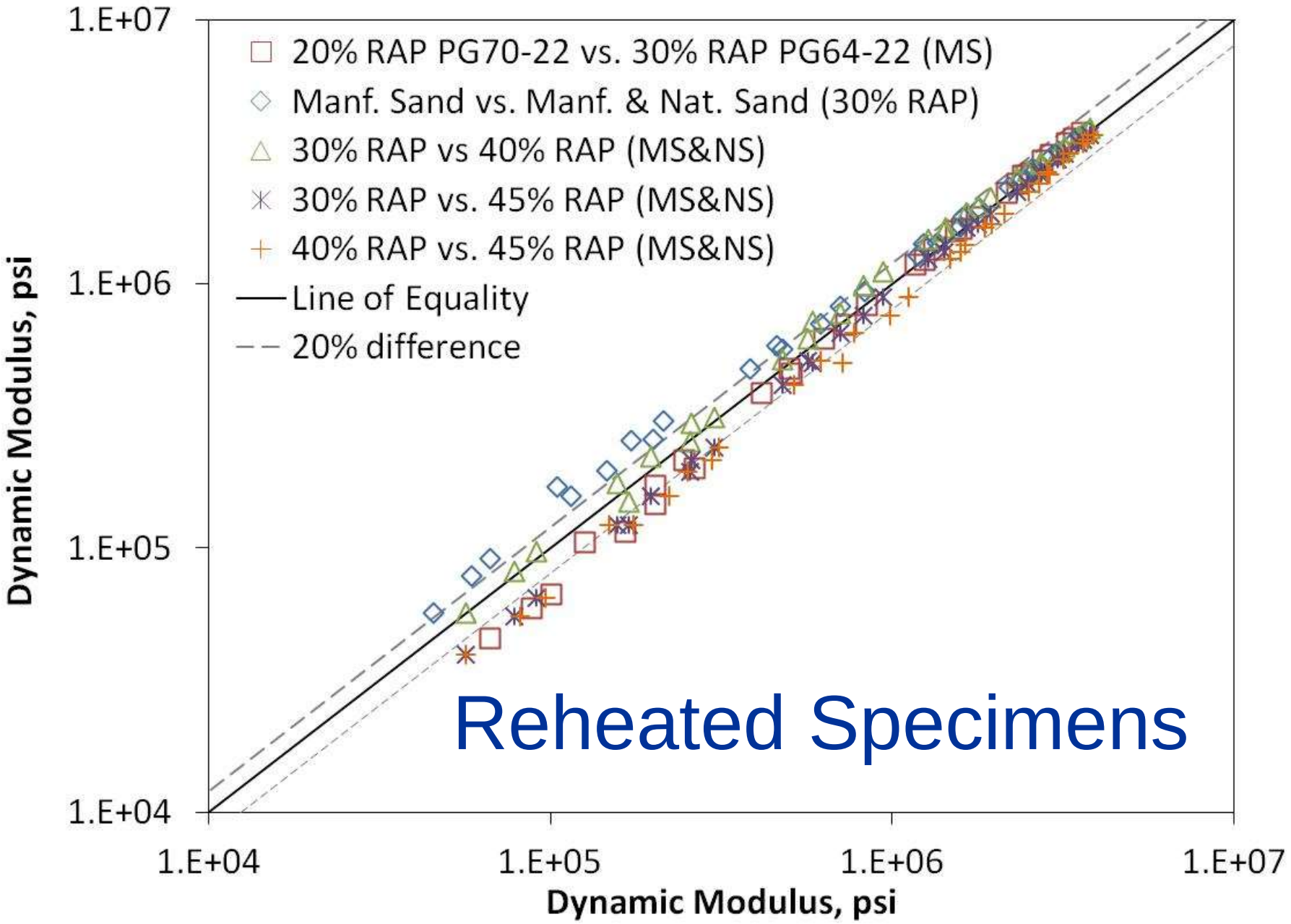
On-site Specimens

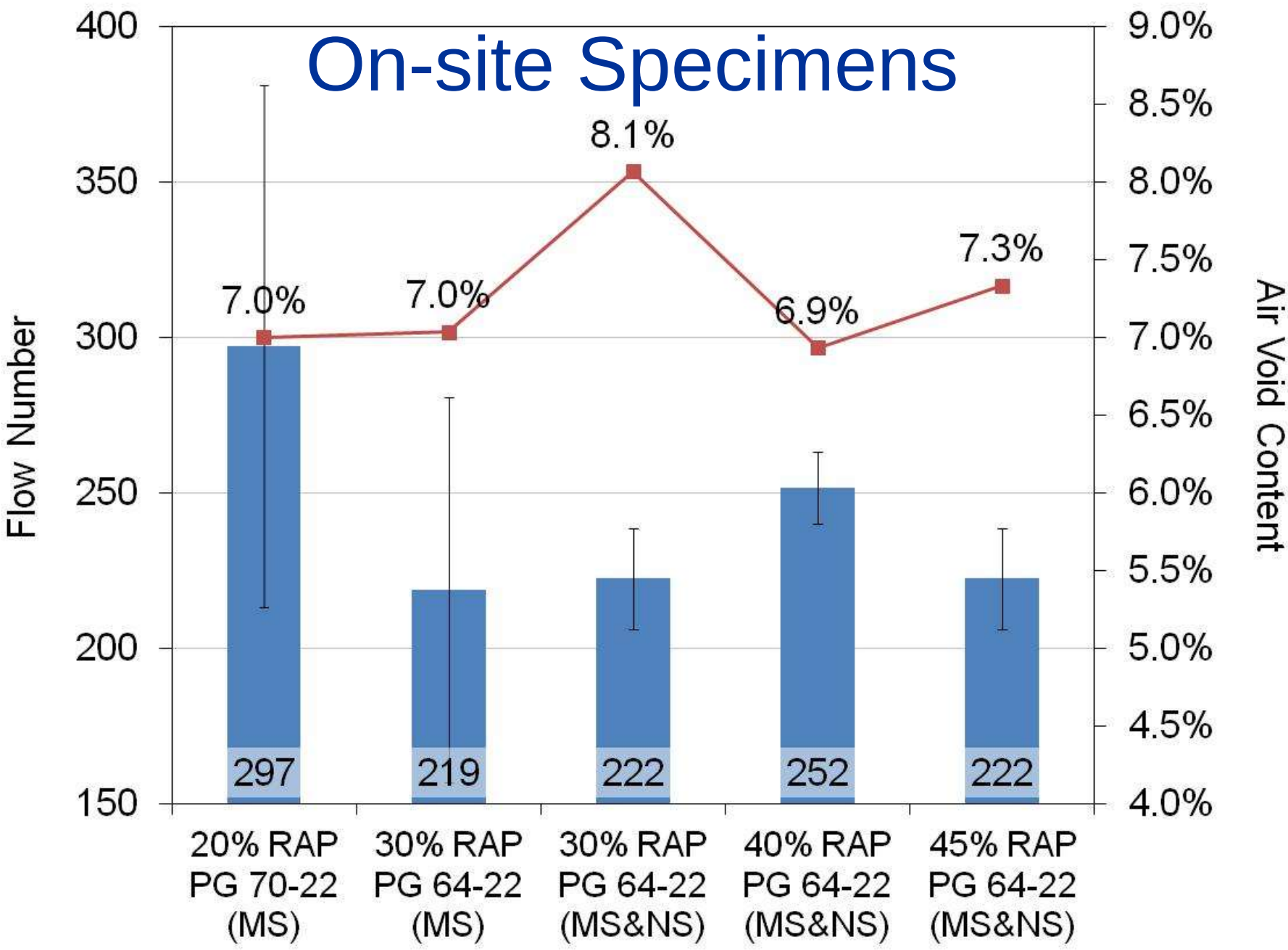


Reheated Specimens



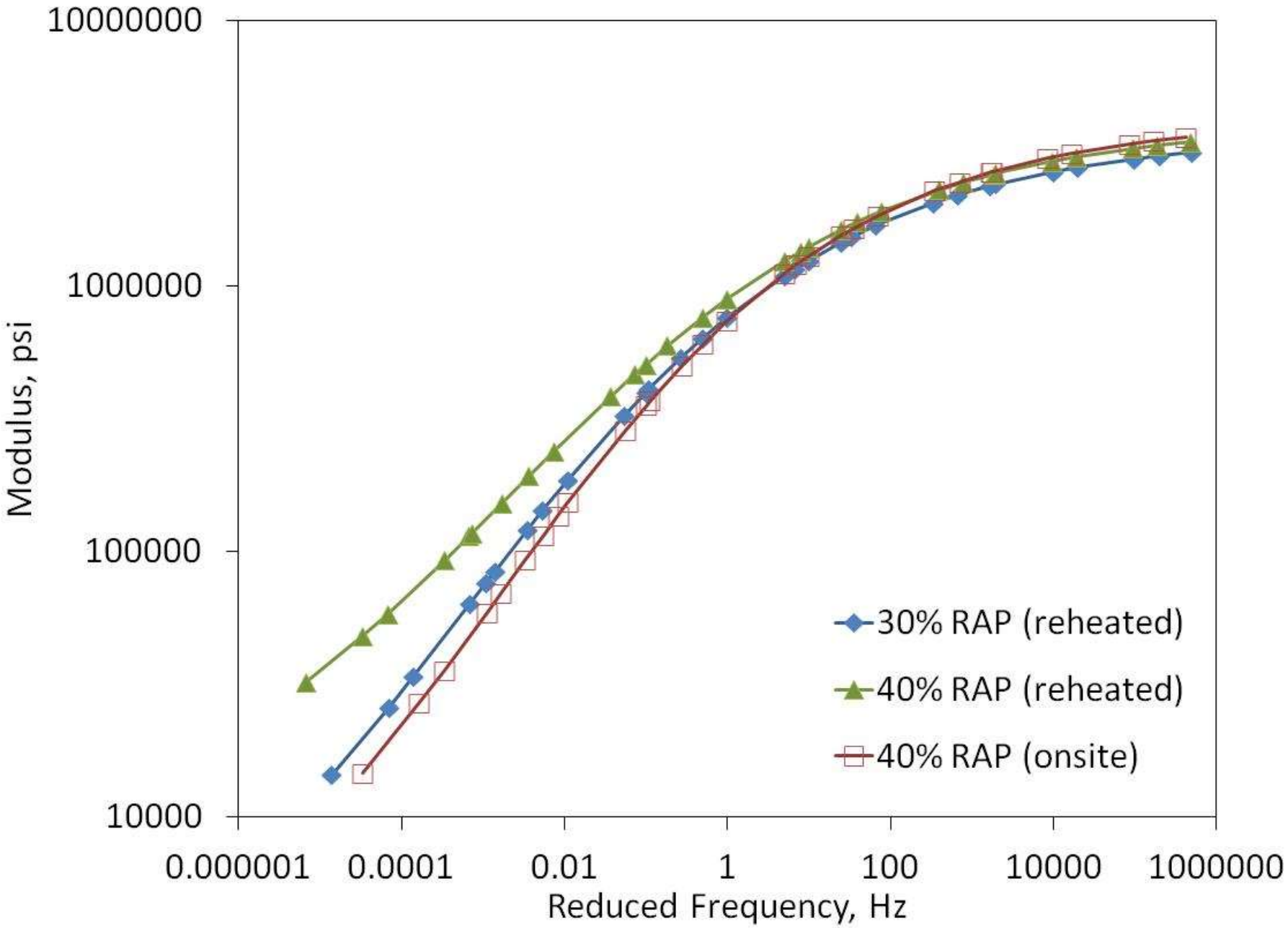

1.E+07
1.E+06
1.E+05
1.E+04
Dynamic Modulus, psi
20% RAP PG70-22 vs. 30% RAP PG64-22 (MS)
Manf. Sand vs. Manf. & Nat. Sand (30% RAP)
30% RAP vs 40% RAP (MS&NS)
30% RAP vs. 45% RAP (MS&NS)
40% RAP vs. 45% RAP (MS&NS)
Line of Equality
20% difference
On-site Specimens
1.E+04
1.E+05
1.E+06
1.E+07
Dynamic Modulus, psi

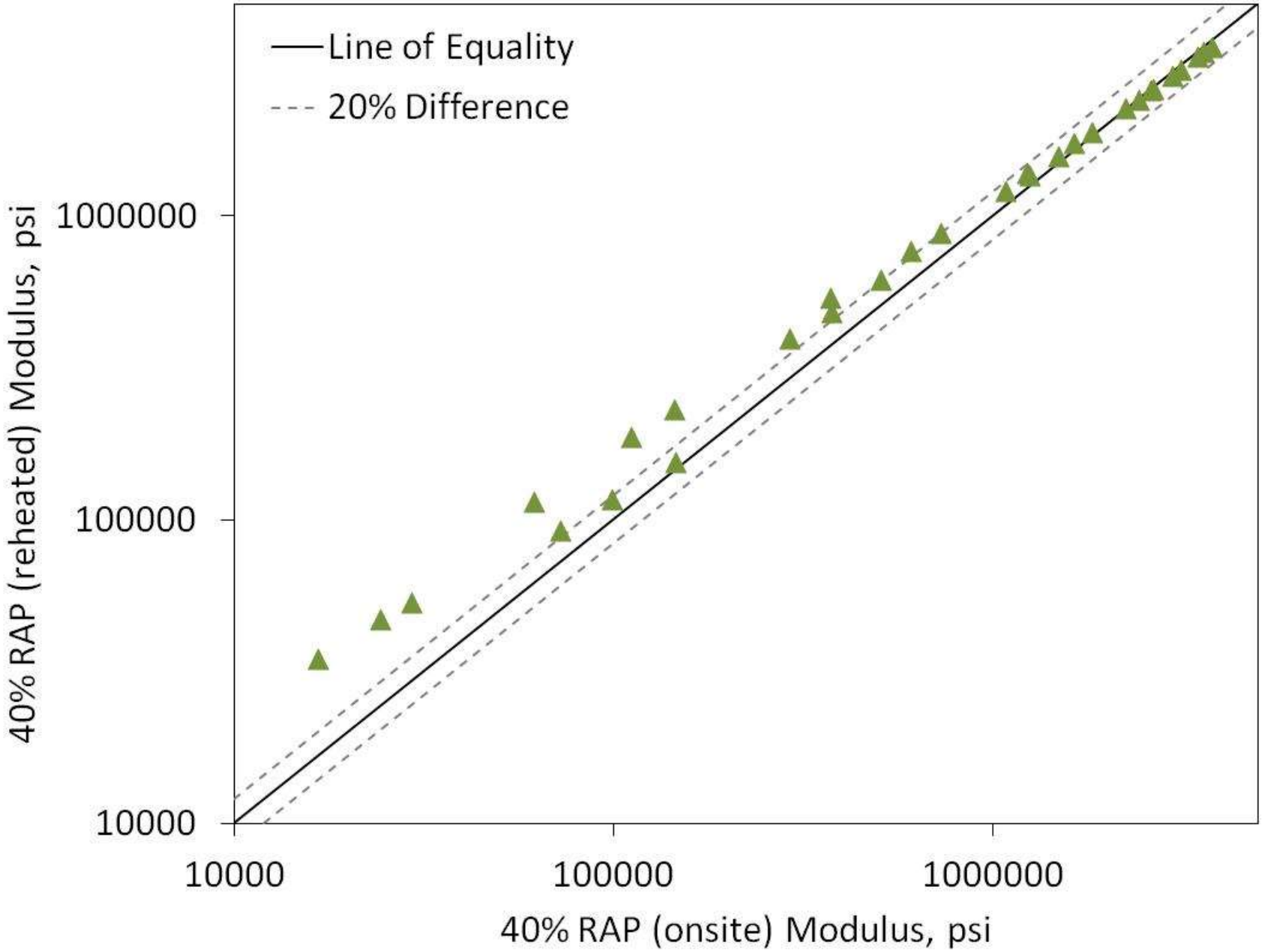

1.E+07
1.E+06
1.E+05
1.E+04
Dynamic Modulus, psi
20% RAP PG70-22 vs. 30% RAP PG64-22 (MS)
Manf. Sand vs. Manf. & Nat. Sand (30% RAP)
30% RAP vs 40% RAP (MS&NS)
30% RAP vs. 45% RAP (MS&NS)
40% RAP vs. 45% RAP (MS&NS)
Line of Equality
20% difference
Reheated Specimens
1.E+04
1.E+05
1.E+06
1.E+07
Dynamic Modulus, psi

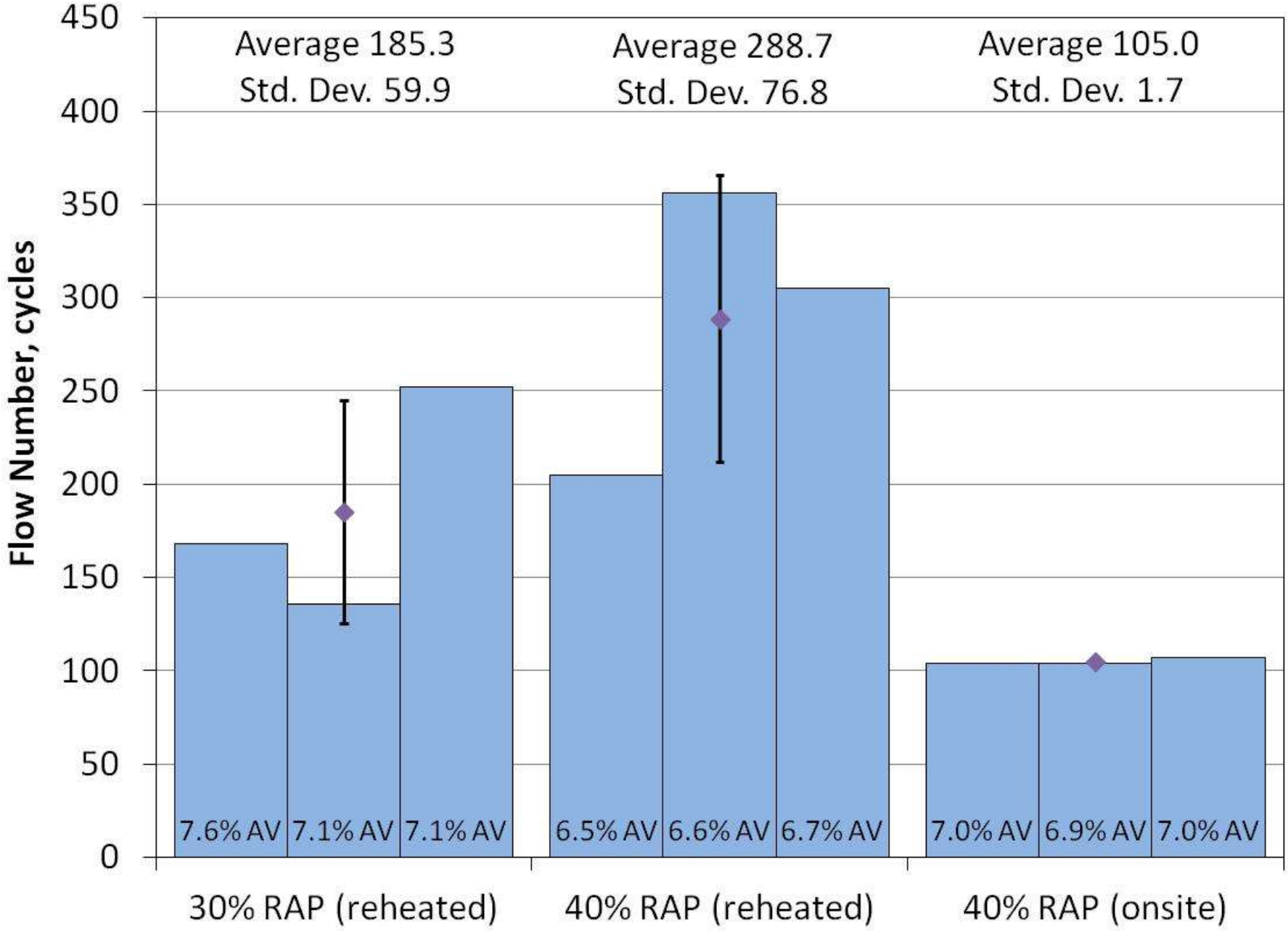

On-site Specimens
Flow Number
Air Void Content
400
350
300
250
200
150
9.0%
8.5%
8.0%
7.5%
7.0%
6.5%
6.0%
5.5%
5.0%
4.5%
4.0%
7.0%
7.0%
8.1%
6.9%
7.3%
297
219
222
252
222
20% RAP PG 70-22 (MS)
30% RAP PG 64-22 (MS)
30% RAP PG 64-22 (MS&NS)
40% RAP PG 64-22 (MS&NS)
45% RAP PG 64-22 (MS&NS)

City of Hampton, August 2013

- 2 SM-9.5 mixtures
  - 30% RAP, PG 64-22
  - 40% RAP, PG 64-22
- Testing
  - 40% RAP specimens made on site
  - 30% and 40% RAP reheated specimens
  - Cores


10000000
1000000
100000
10000
Modulus, psi
0.000001
0.0001
0.01
1
100
10000
1000000
Reduced Frequency, Hz
30% RAP (reheated)
40% RAP (reheated)
40% RAP (onsite)


Line of Equality
20% Difference
40% RAP (reheated) Modulus, psi
1000000
100000
10000
10000
100000
1000000
40% RAP (onsite) Modulus, psi


Average 185.3
Std. Dev. 59.9
Average 288.7
Std. Dev. 76.8
Average 105.0
Std. Dev. 1.7
Flow Number, cycles
450
400
350
300
250
200
150
100
50
0
7.6% AV
7.1% AV
7.1% AV
6.5% AV
6.6% AV
6.7% AV
7.0% AV
6.9% AV
7.0% AV
30% RAP (reheated)
40% RAP (reheated)
40% RAP (onsite)

Next Steps…

- Mix Testing
  - Cracking - Texas Overlay Test
  - Rutting – APA Rut Tester
  - Fatigue – Beam Fatigue
- Cores
  - Permeability
  - Dynamic modulus
  - Extraction and recovery
  - Binder grading
- Performance predictions with AASHTO Pavement ME
- Performance monitoring of pavements

So What Does It Mean? (So far…)

- Good design is important for RAP mixtures
  - Especially binder content
- Successful 40% RAP mixtures are possible
  - Design, production, and construction
- Need to look at:
  - Effects of reheating
  - Understanding dynamic modulus/flow number values
  - Long term performance

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Thank You!

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