THE USE OF ATOMIC FORCE MICROSCOPY TO EVALUATE WARM MIX ASPHALT

OHIO ASPHALT PAVING CONFERENCE

38th Annual Conference

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Outline

- Background
- Objective
- Methodology
- Results
- Conclusions

Background

- WMA has received considerable attention to reduce energy consumption and pollutant emissions during production & placement.

- Despite the number of research studies conducted in the past on the use of WMA technologies, there are still concerns about the long term performance of WMA mixtures:
  - Moisture induced damage

Background

- Several laboratory studies evaluated the moisture susceptibility of WMA.
  - ✓ Most of those studies used the macro-scale tests such as AASHTO T283.
- There is no consensus on the effect of WMA on the moisture susceptibility of asphalt mixtures.
- Data obtained from the field so far does not indicate inferior performance of WMA.
- Some data also suggests that the resistance of WMA to moisture damage improves with time.

Background

- Moisture damage is caused by the failure of the bond between the asphalt binder and the aggregate or within the binder itself.

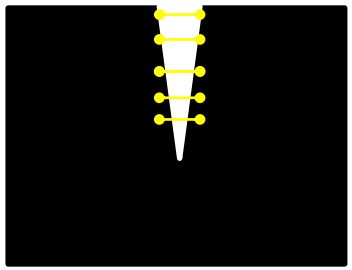
- Need to study the micro-mechanisms that influence:
  - ✓ the adhesive bonds between the asphalt binder and the aggregate
  - ✓ the cohesive bonds within the asphalt binder

Background

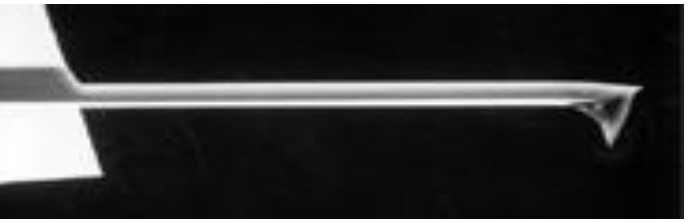
Healing

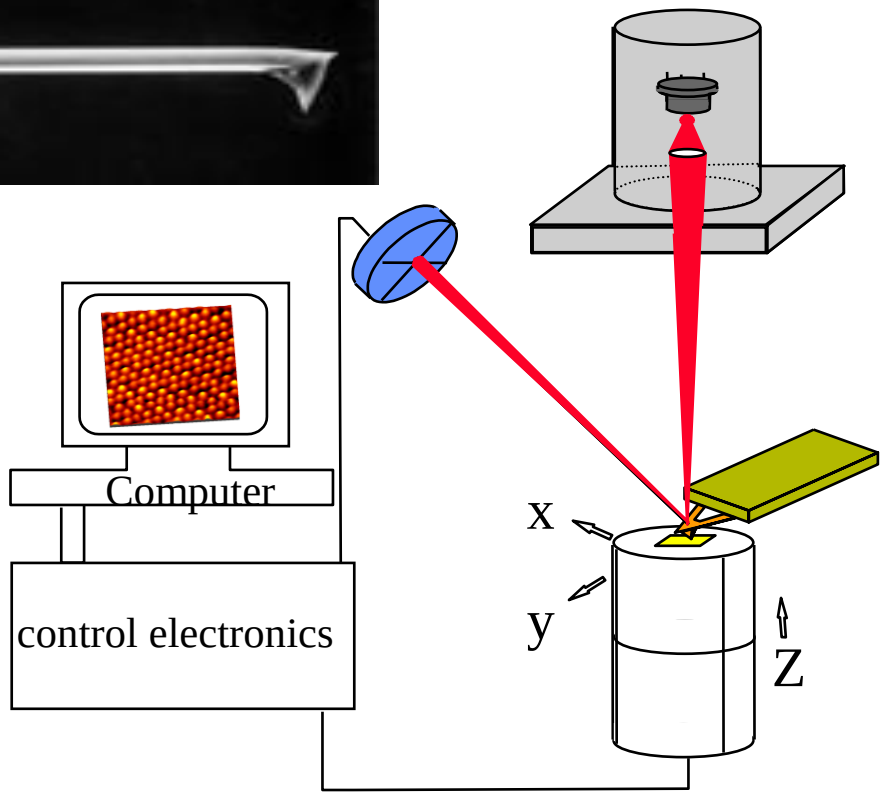
Wetting

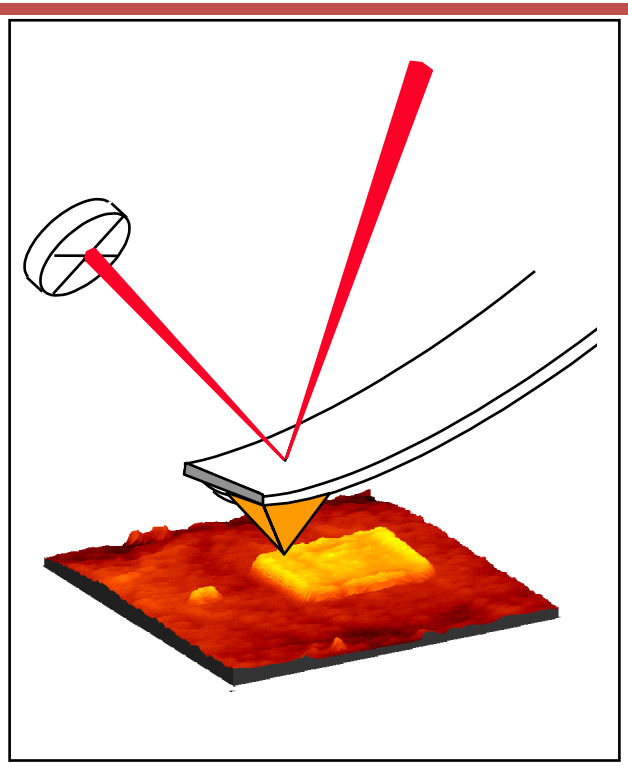
Intrinsic Healing

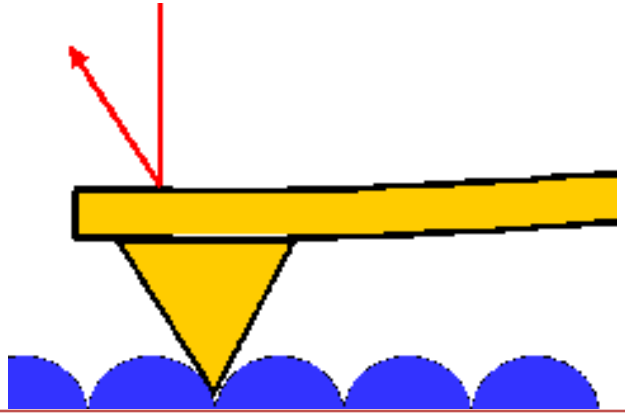


Atomic force Microscopy









- Forces between the tip and the sample lead to a deflection of the cantilever according to Hooke's law.
- Deflection is measured using a laser spot reflected from cantilever collected by a detector

Objective

- Evaluate the moisture susceptibility and healing characteristics of WMA using AFM and compare it to that of HMA.

Materials

- **Asphalt binders:**
  - ✓ PG 64-22
  - ✓ PG 70-22M (SBS polymer modified)
- **Four types of WMA technologies are used:**
  - ✓ Foamed WMA produced by water injection
  - ✓ Advera:
  - ✓ Evotherm M1
  - ✓ Sasobit:

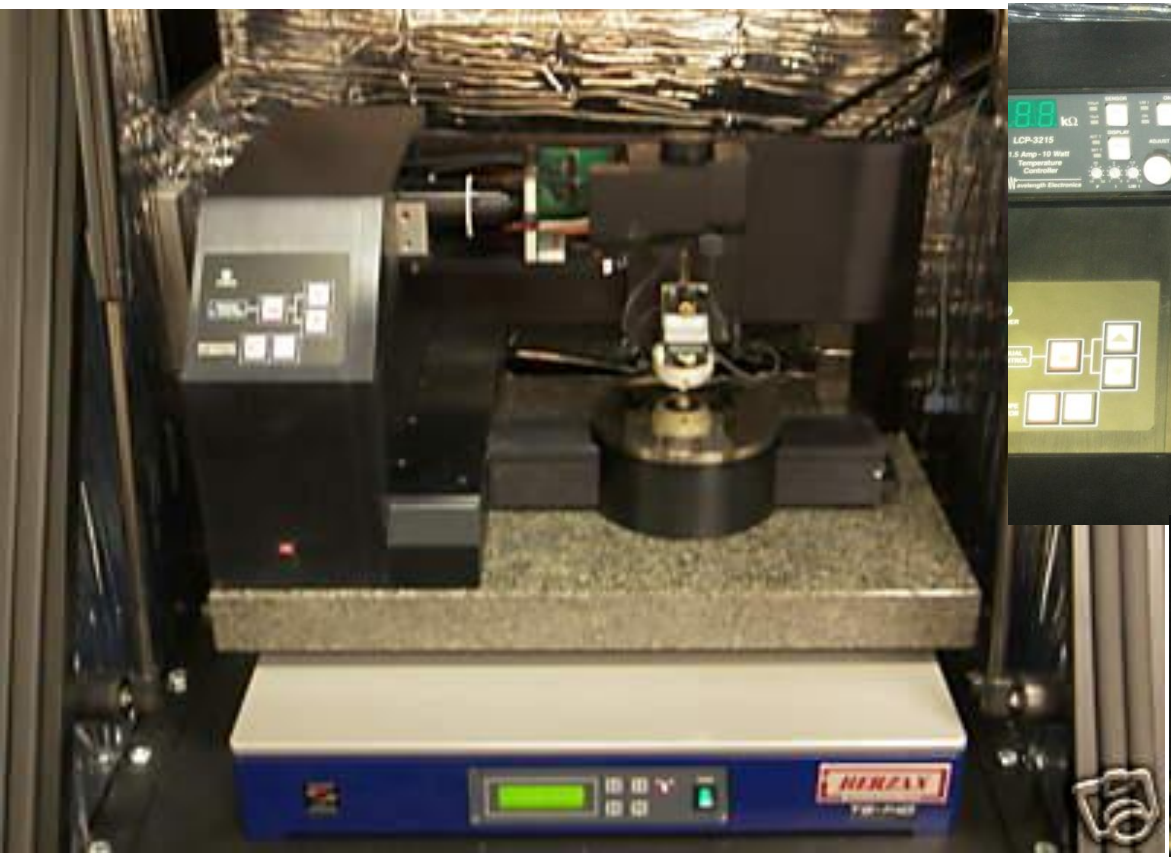
Materials

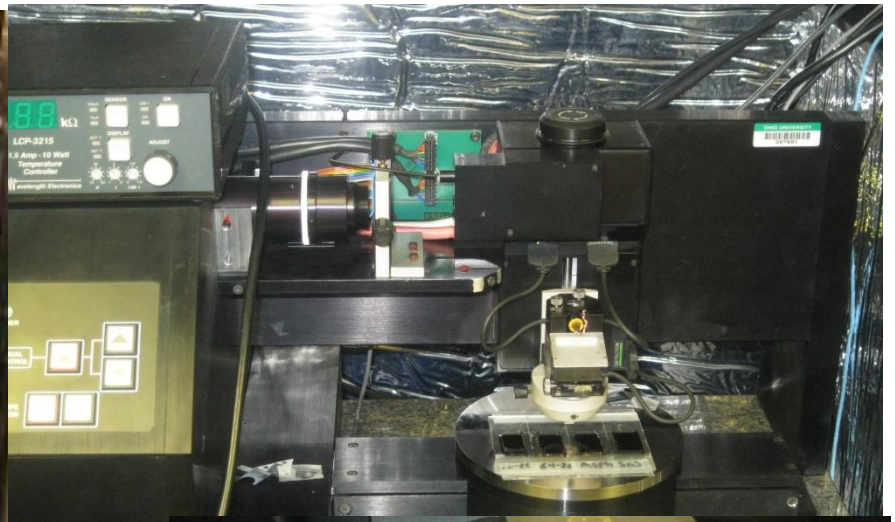
Mixtures

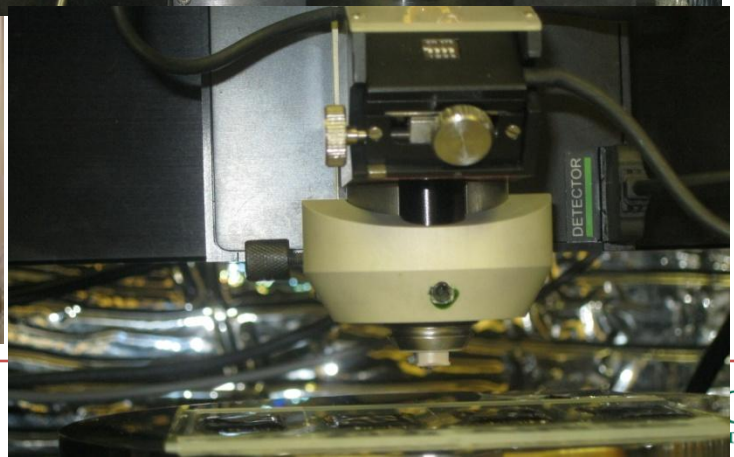
Aggregate Type	Crushed Gravel	Crushed Gravel
Mix Type	Surface, Superpave 12.5 mm	Surface, Superpave 12.5 mm
Binder Type	PG 70-22	PG 64-22
AC%	5.9%	6.2%

AFM Techniques

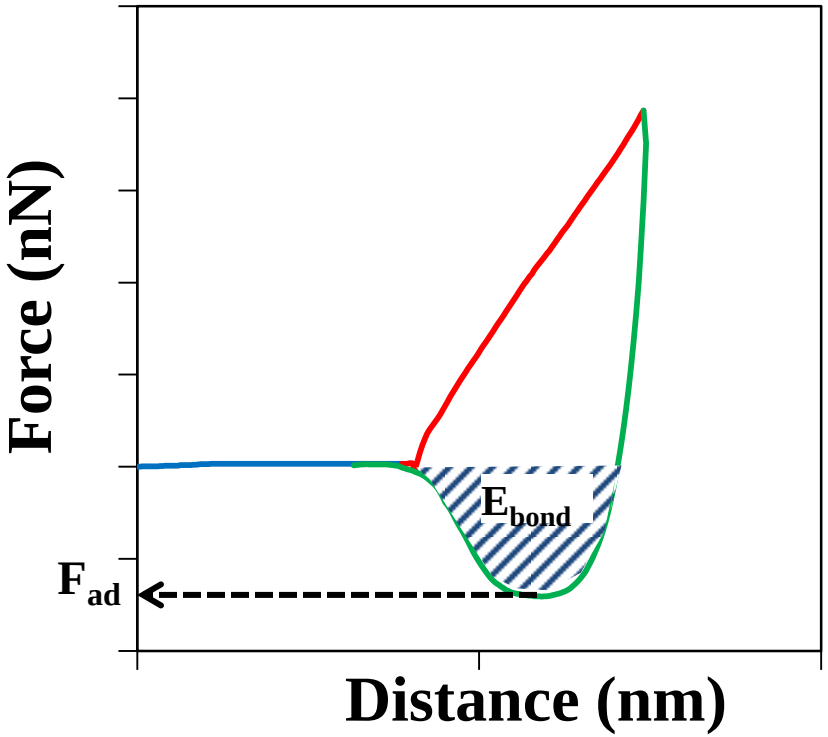
- Agilent 5500 LS AFM was used in this research

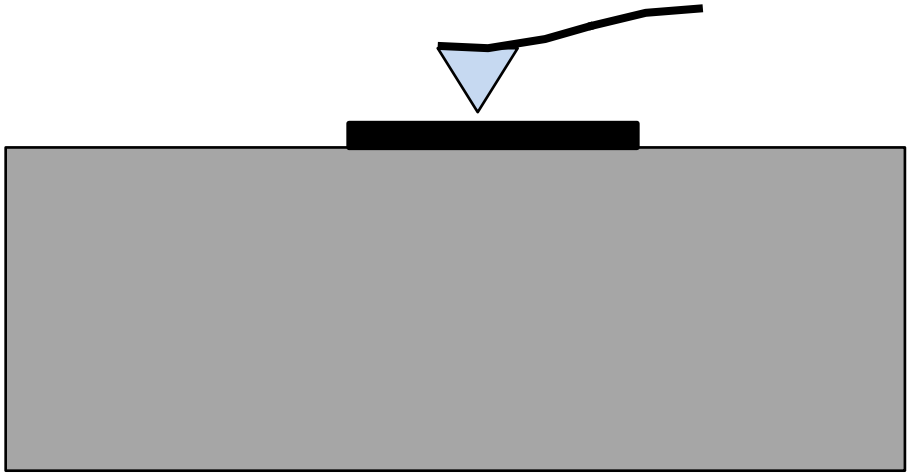






AFM Force Spectroscopy





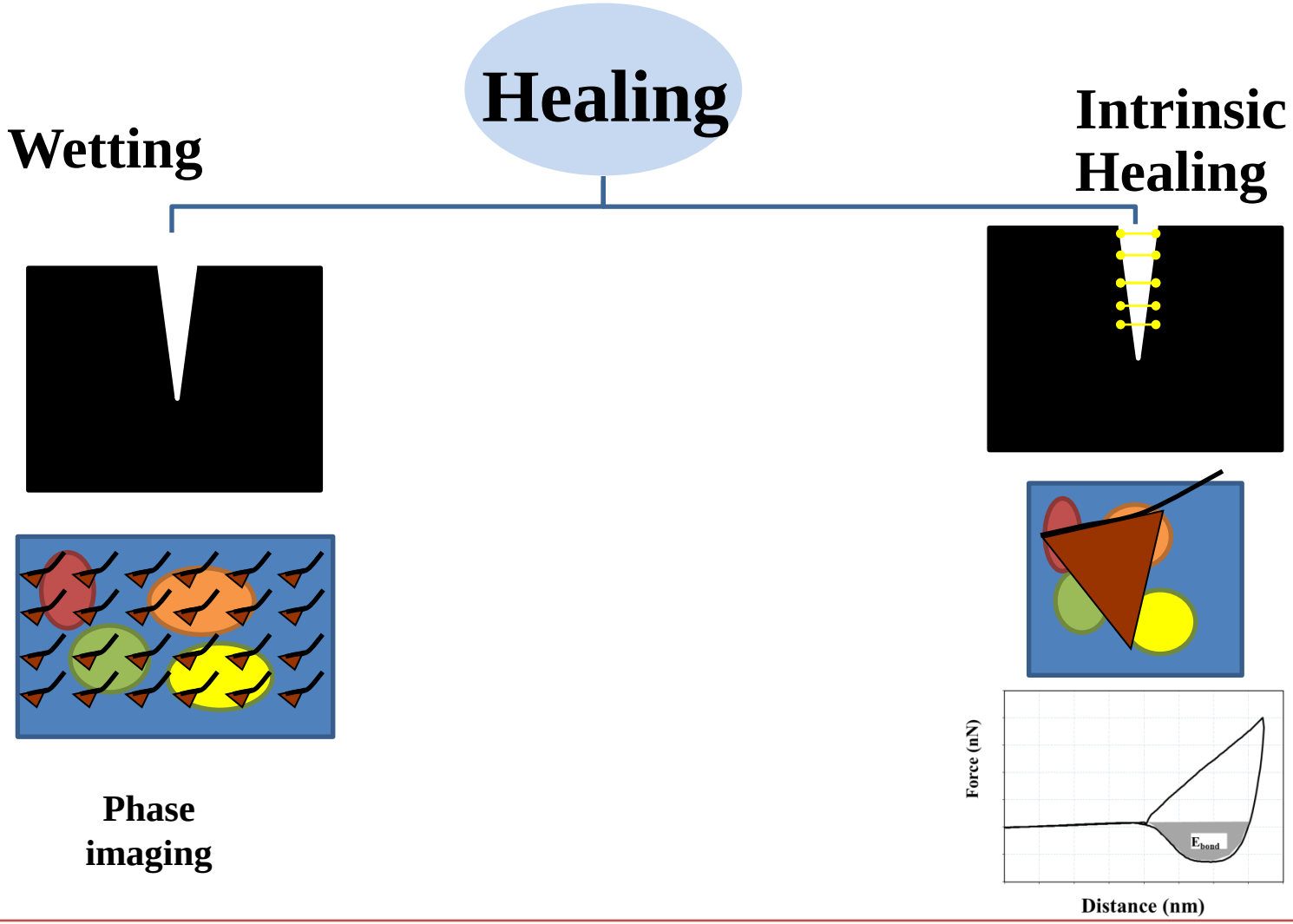
- The sample is probed at a fixed spot on the surface.
- The measurement is performed as an approach-retraction cycle
- The total force exhibited at the tip during the process is monitored

AFM Force Spectroscopy

- Force spectroscopy experiments were conducted on dry and wet conditioned samples using:
  - Silicon Nitride Tips → **Adhesive Force**
  - Chemically functionalized:
    - ✓Carboxyl (-COOH)
    - ✓Hydroxyl (-OH)

    → **Cohesive Force**
- Samples were conditioned by placing them in a bath of tap water at a temperature of 25°C for 24 hours.
- The samples were then removed and were left to dry out for 24 hours in a dry chamber.

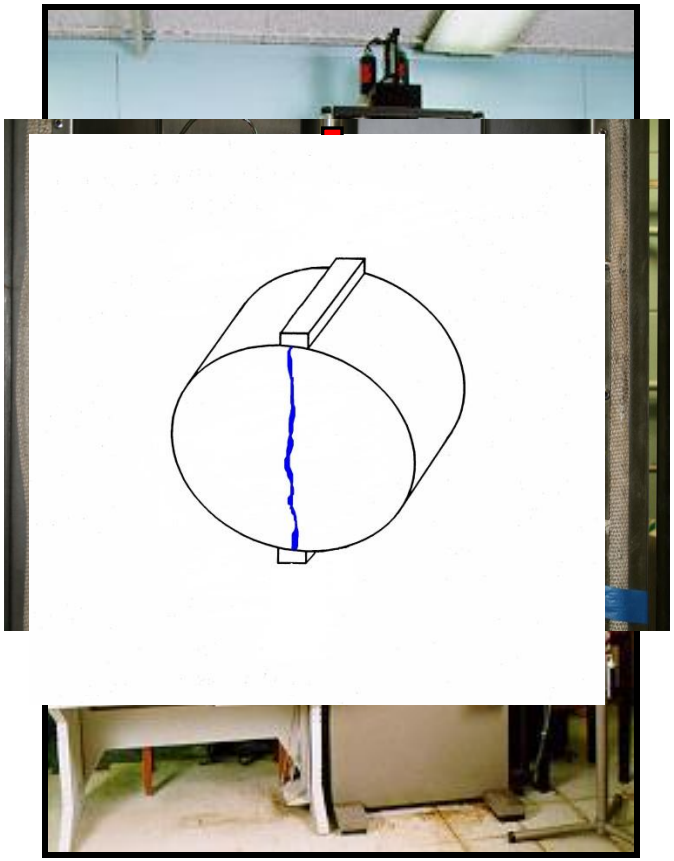
Healing Approach



Macro-Scale Tests

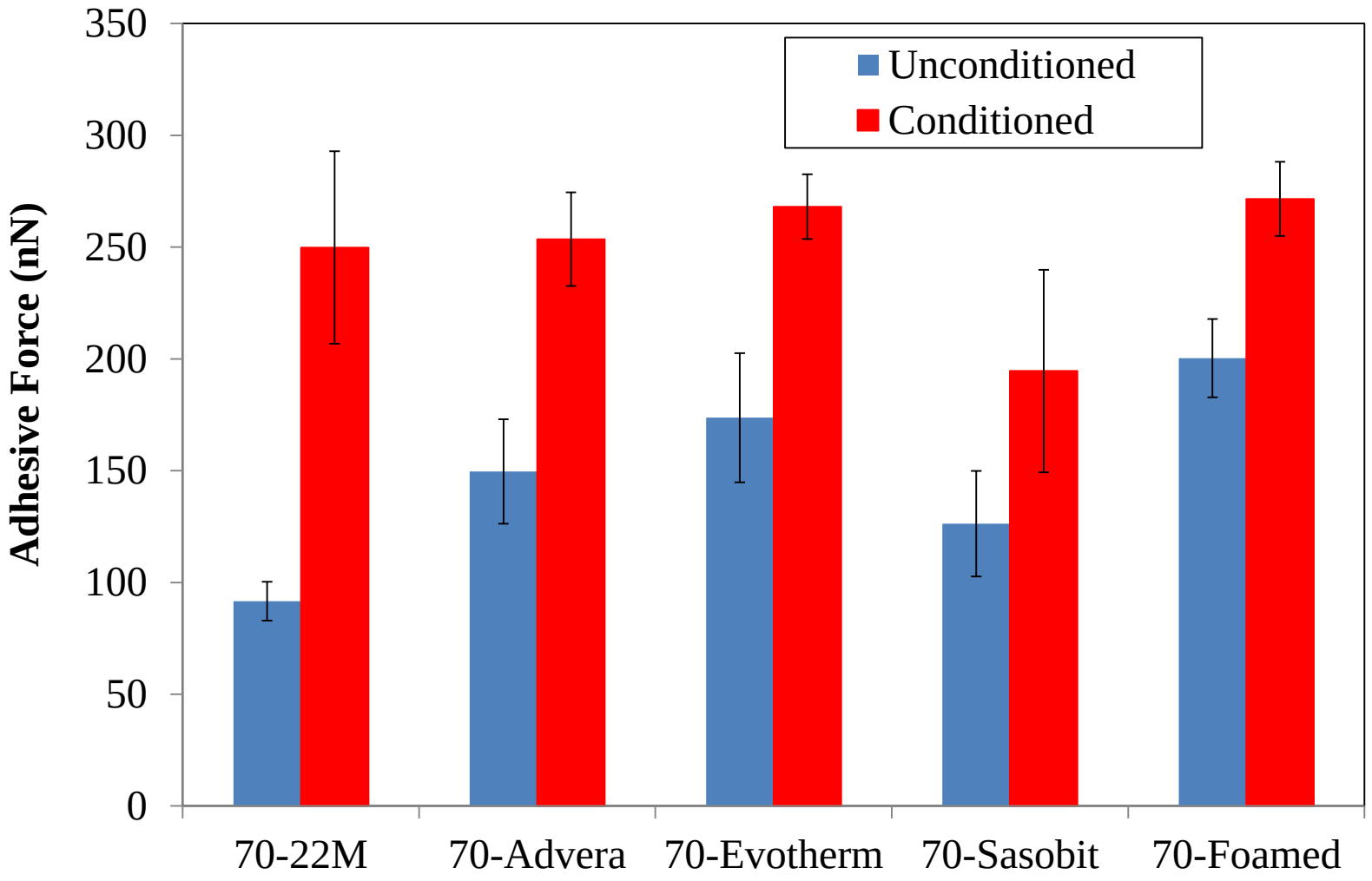
- The main test conducted to evaluate the macro-scale properties:

- Mixture: AASHTO T-283 Test:
  - ✓ ITS Dry Samples
  - ✓ ITS Wet Samples
  - ✓ Tensile Strength Ratio (TSR)

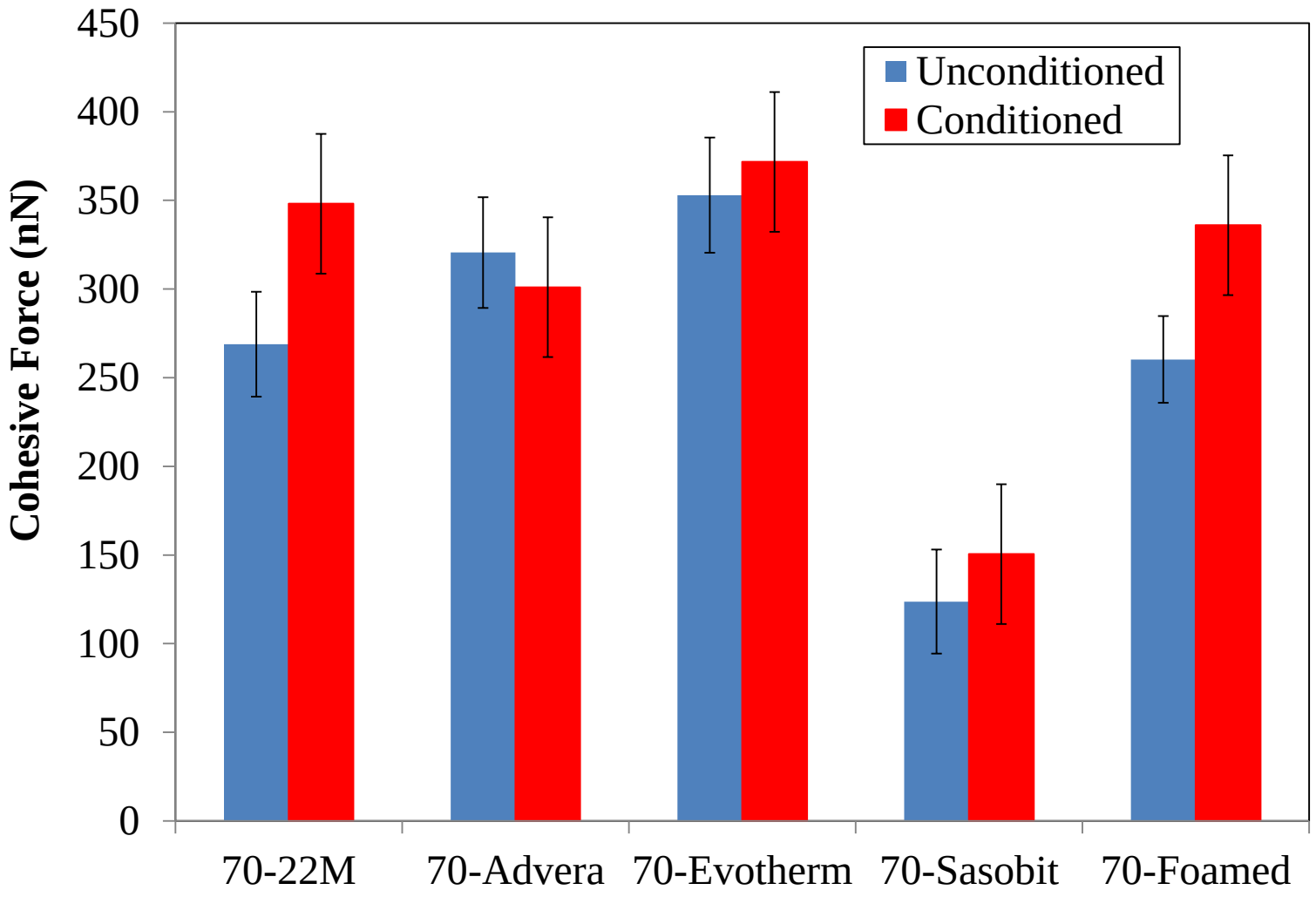


Results

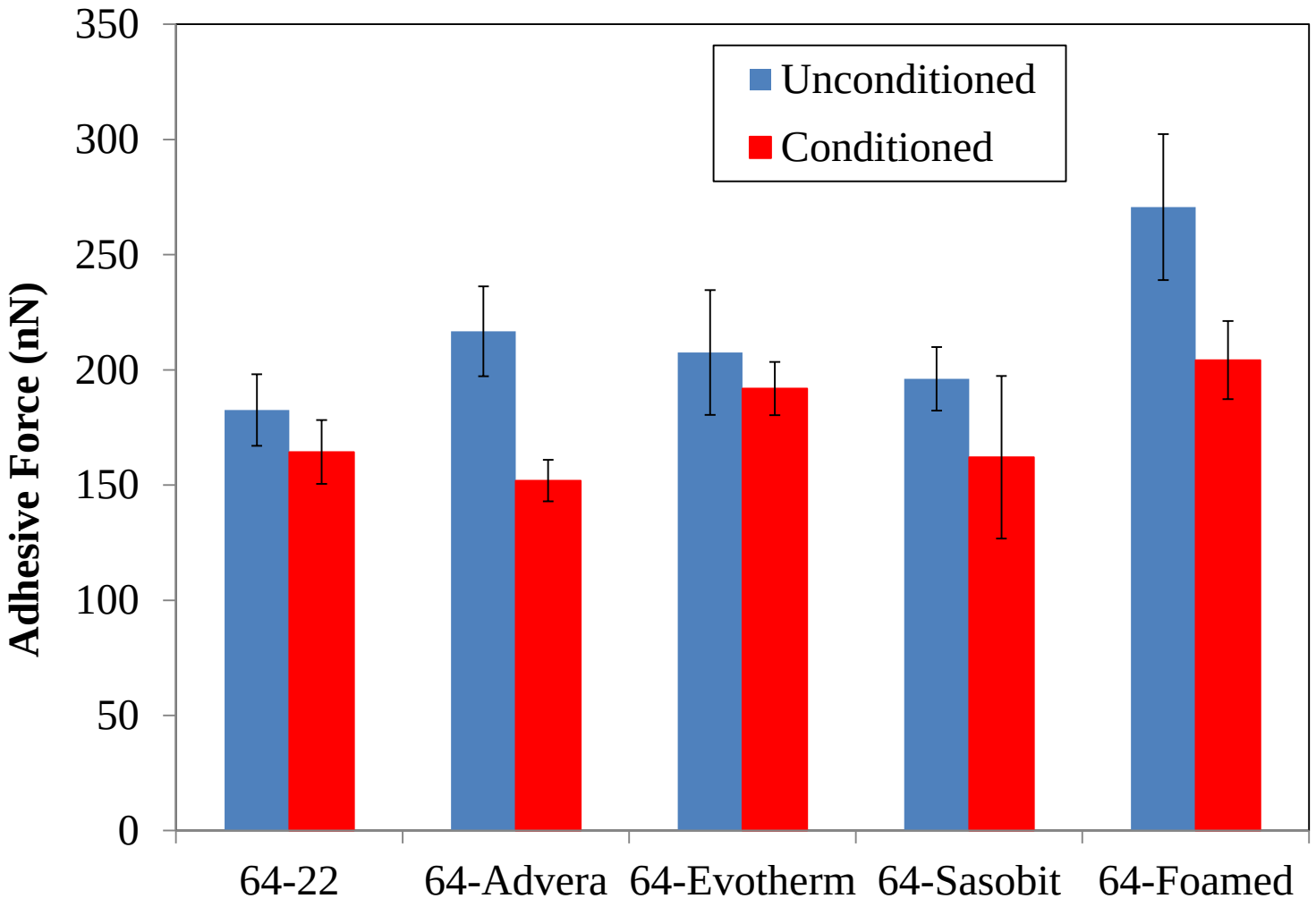
Force Spectroscopy: Adhesive Forces: 70-22M



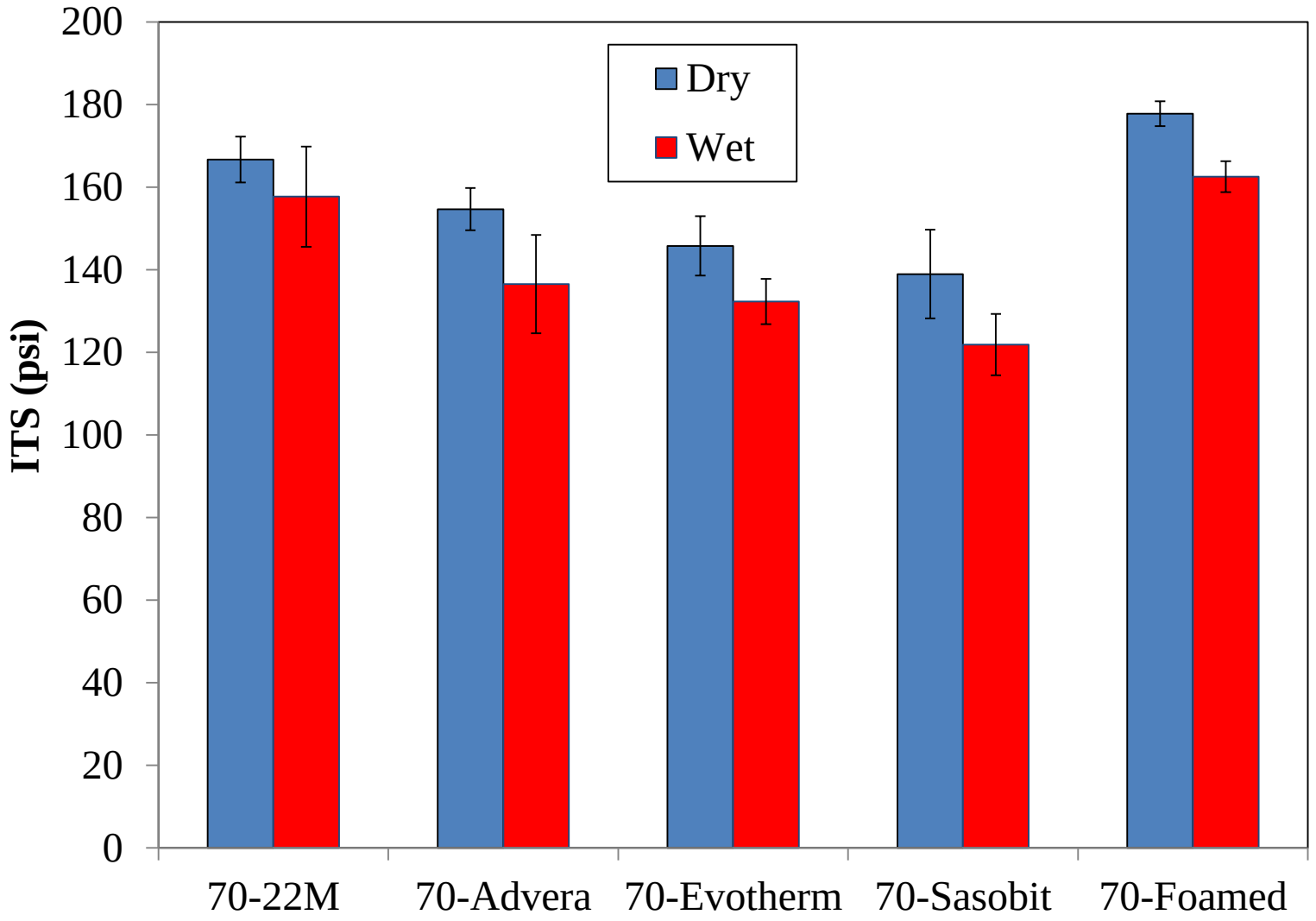
Force Spectroscopy: Cohesive Forces (-OH): 70-22M



Force Spectroscopy: Adhesive Forces: 64-22



Macro-Scale Test : AASHTO T283 Results



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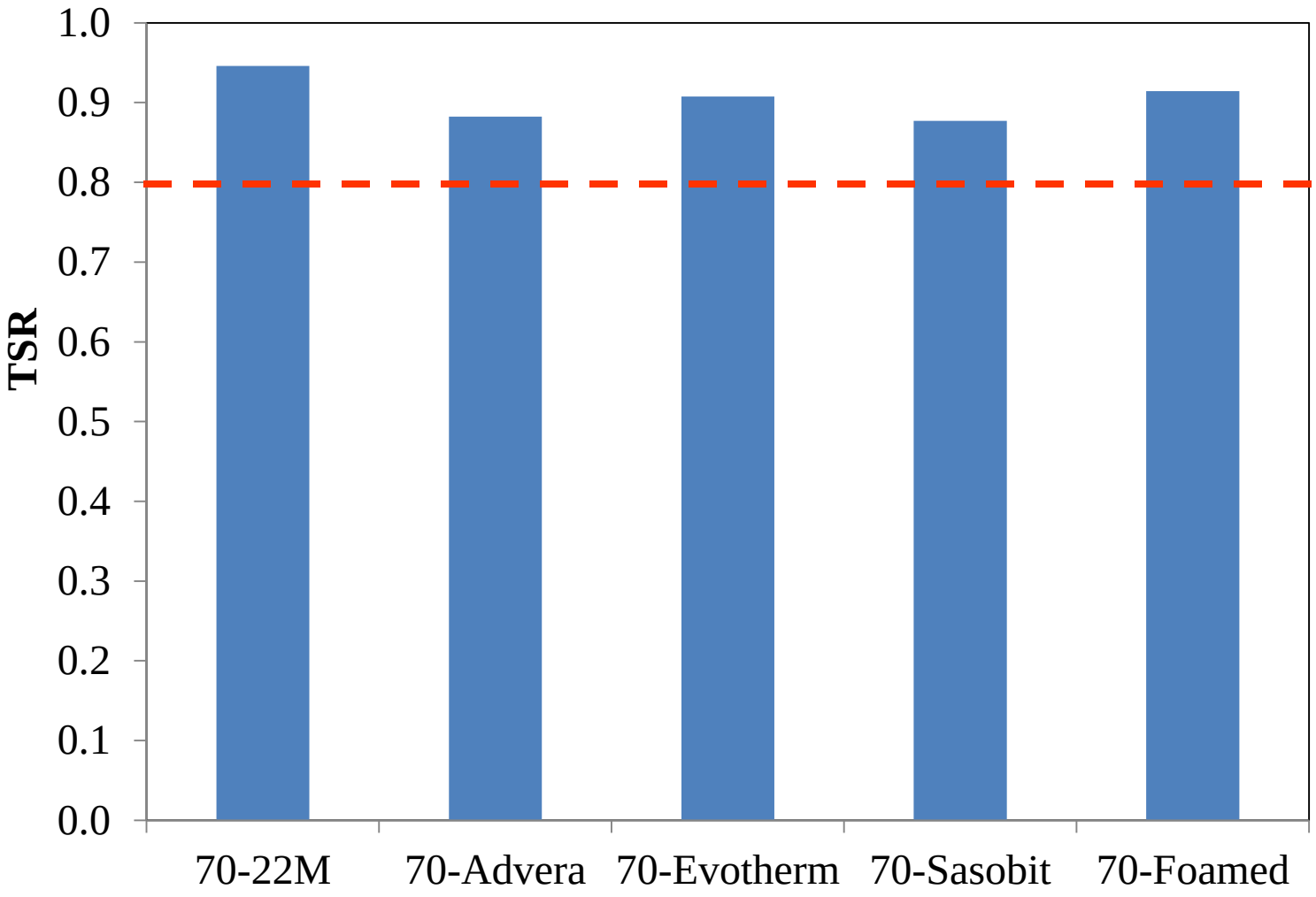

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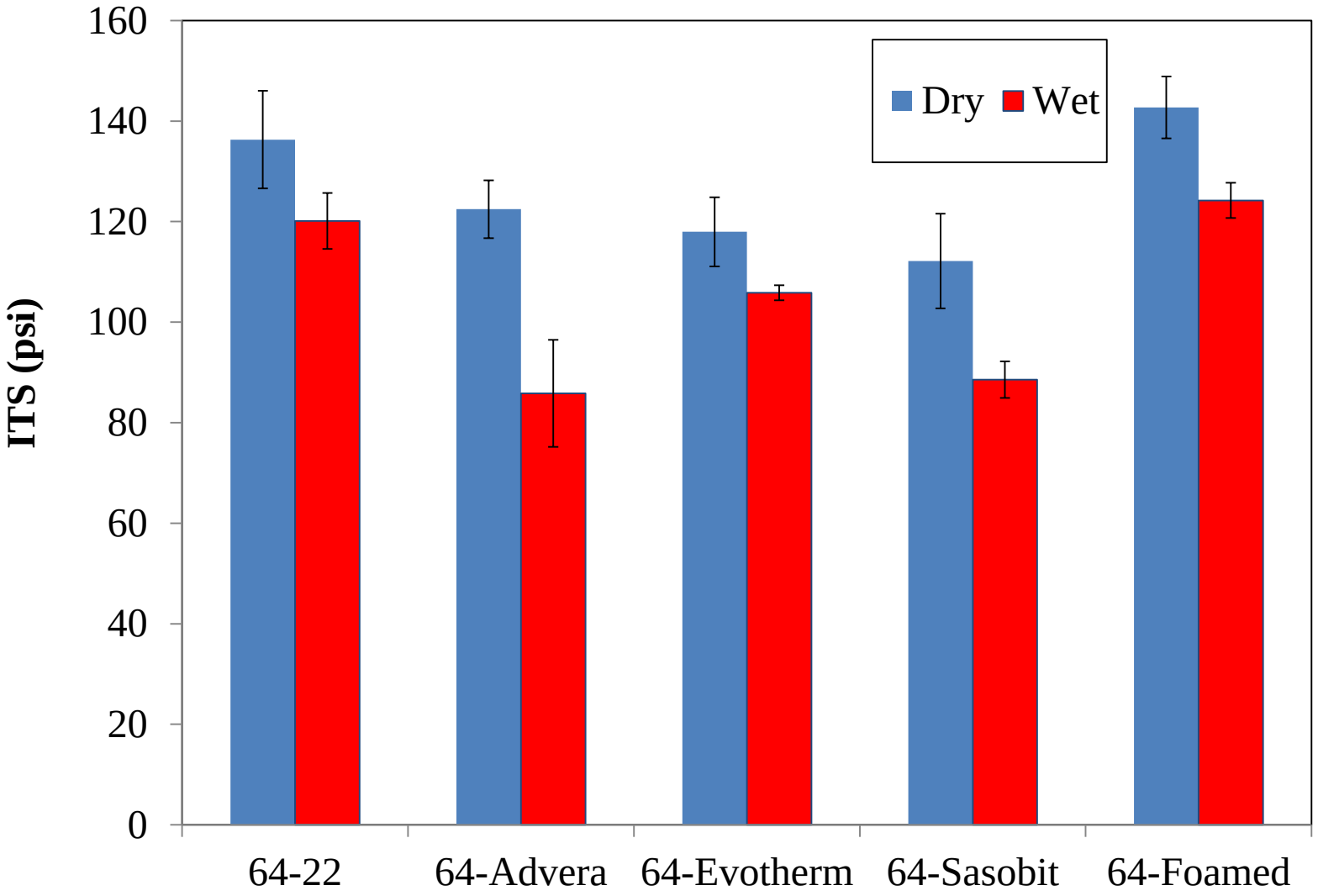

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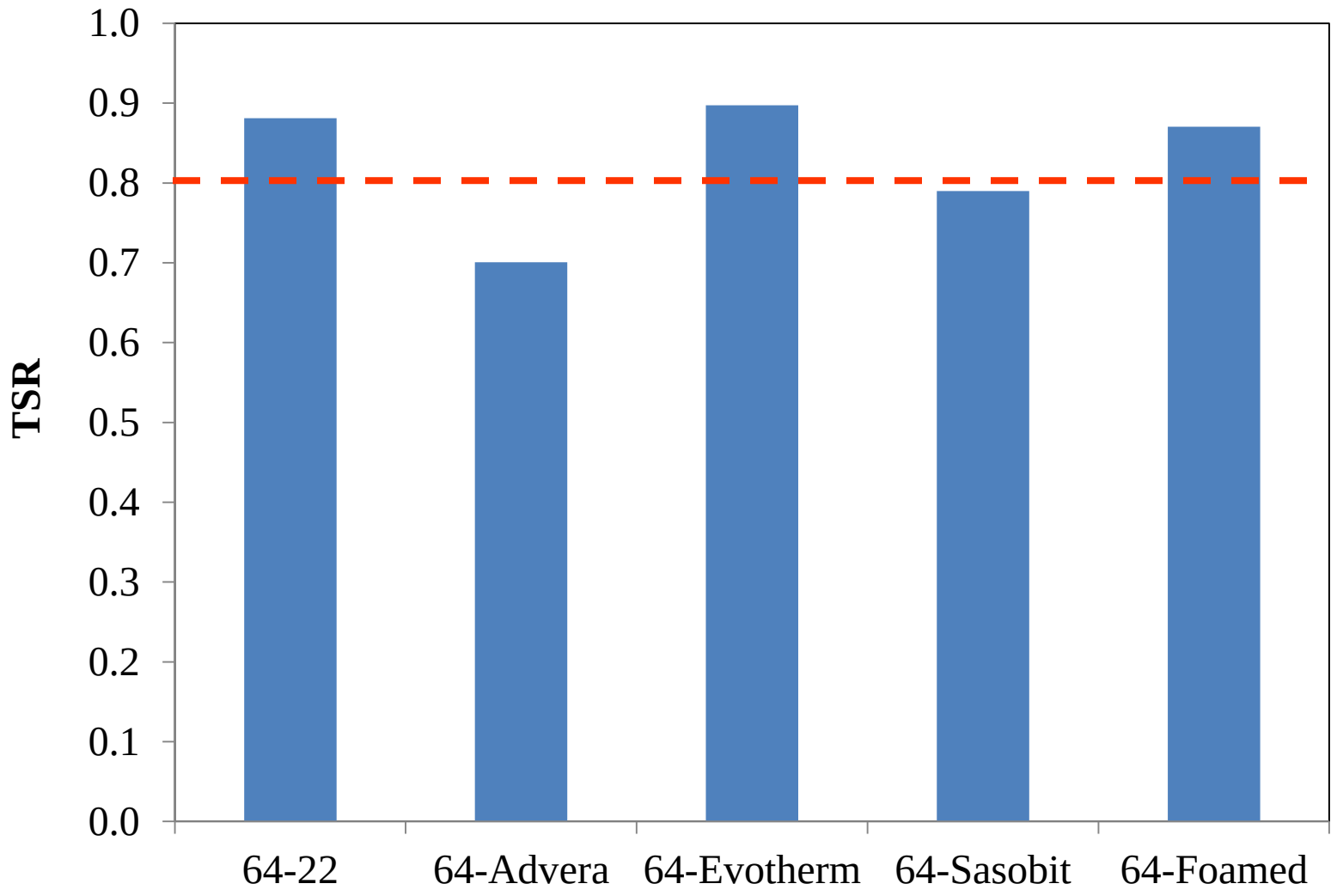
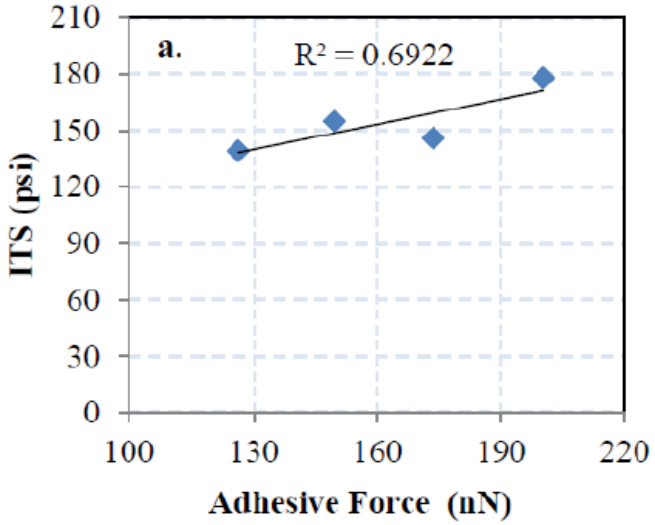
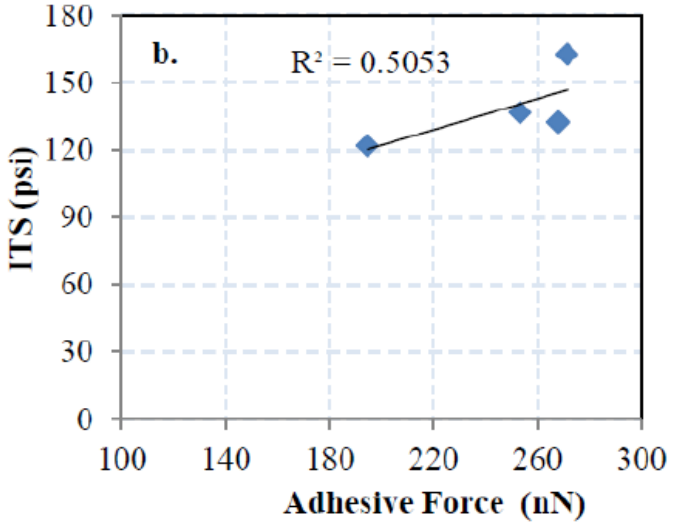
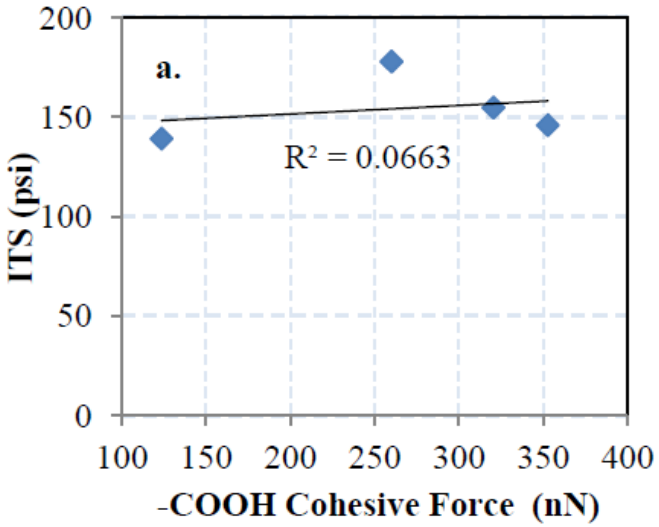
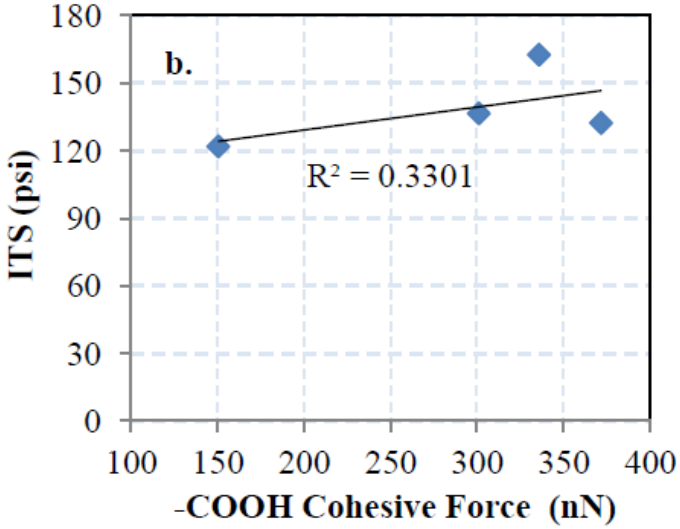


Correlation between Cohesive/Adhesive force & ITS









Healing Experiments Results

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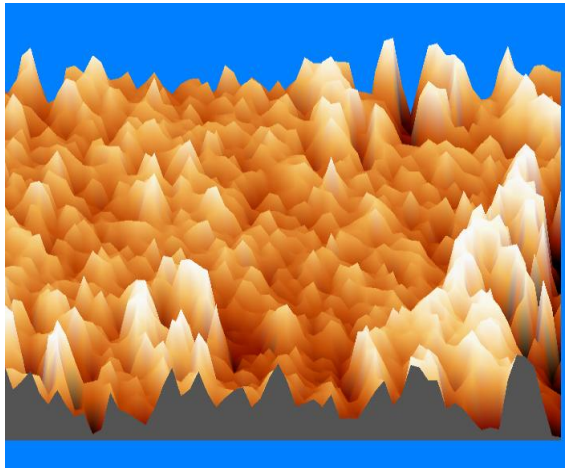

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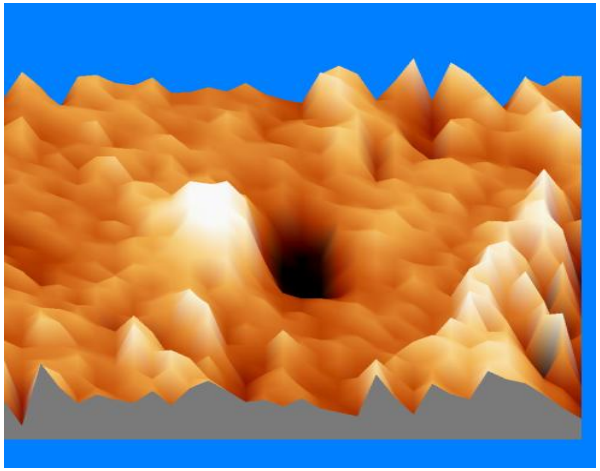

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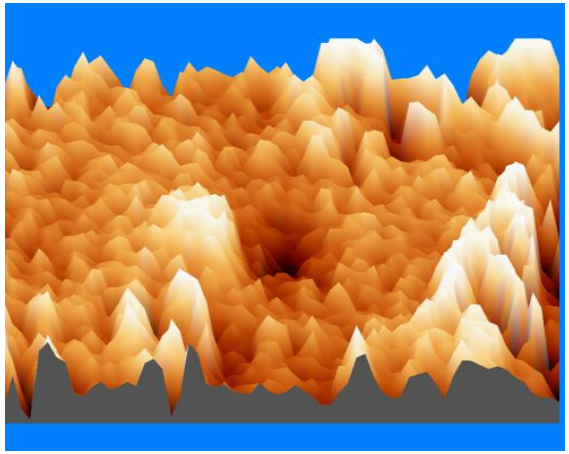

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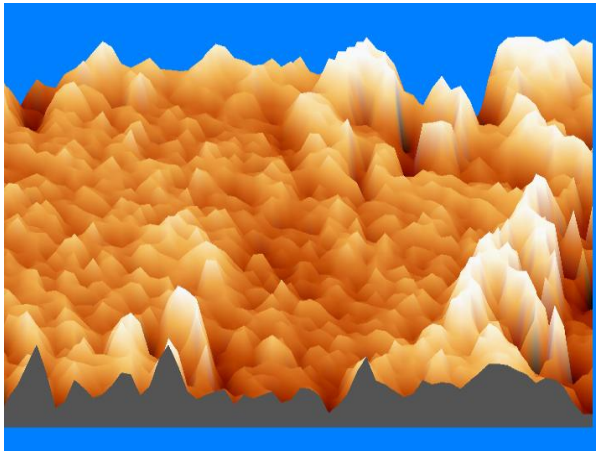
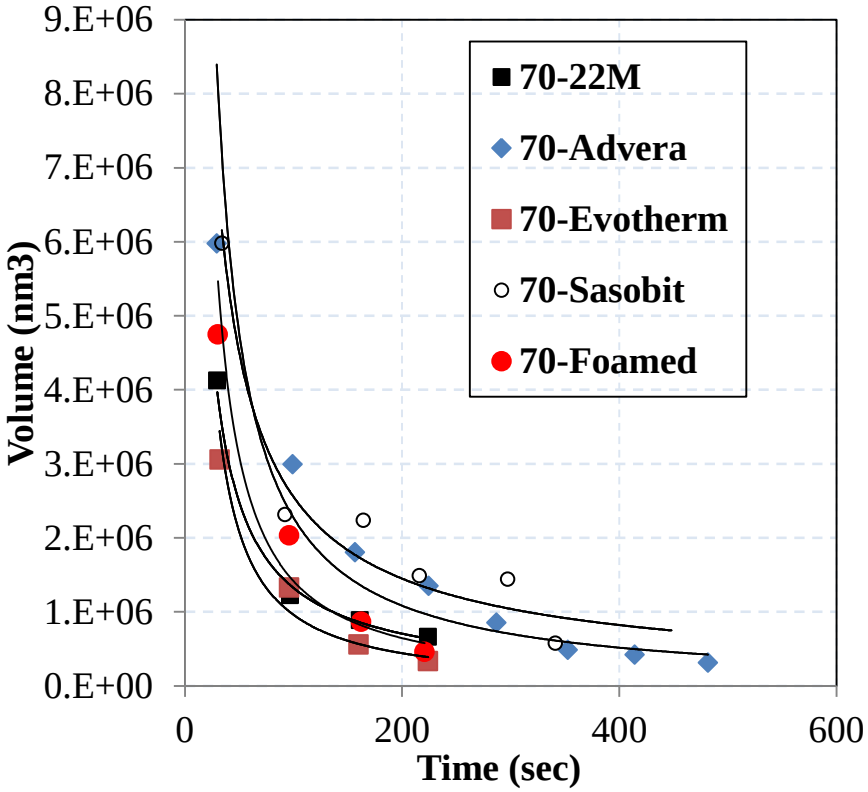
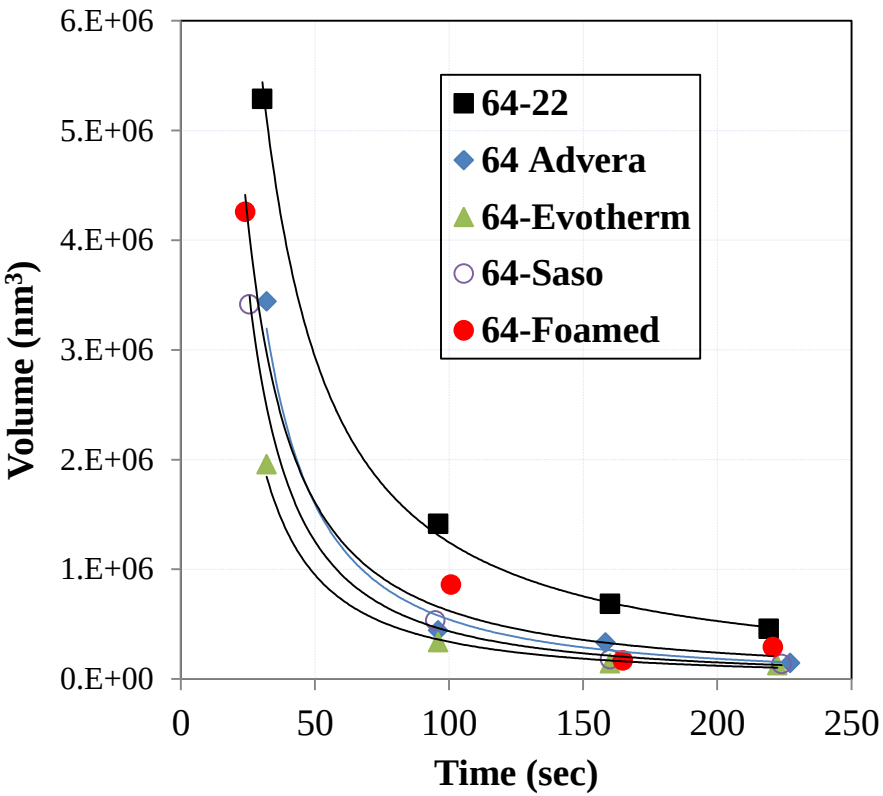
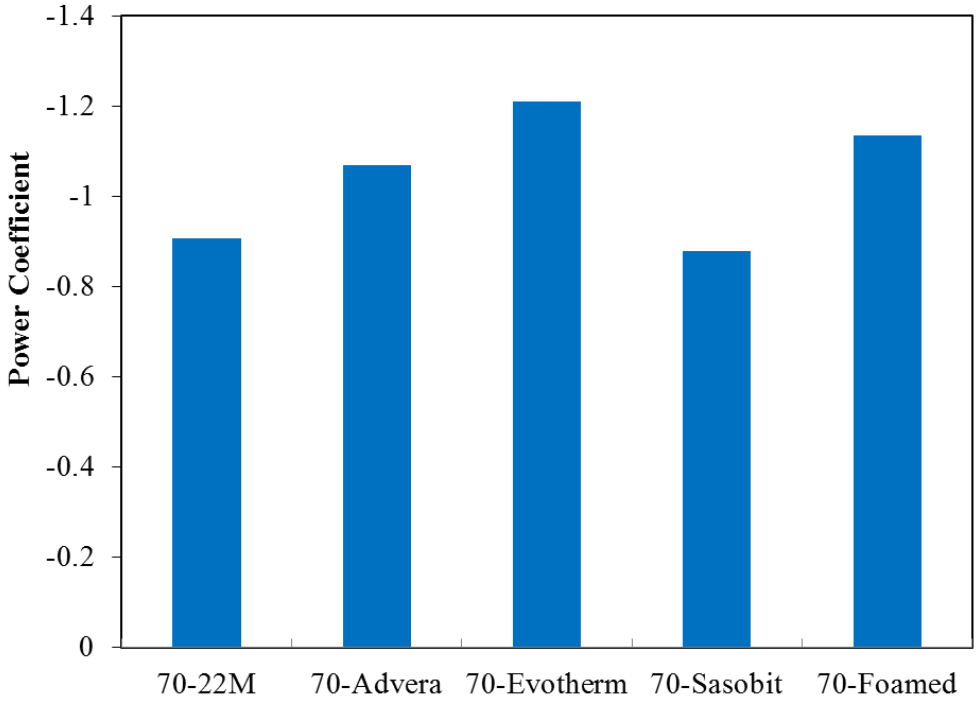


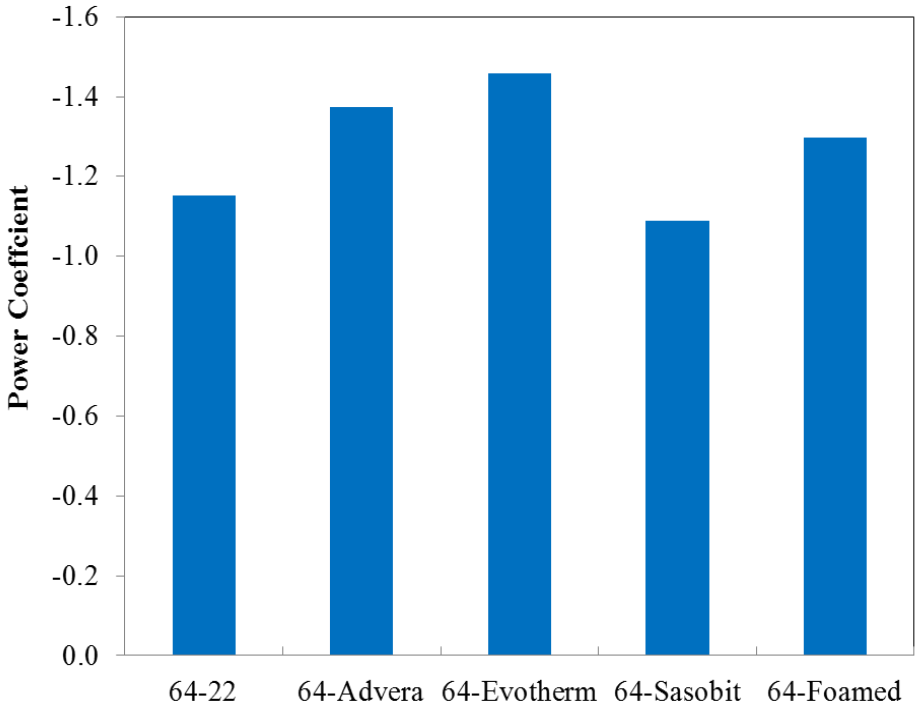
Healing Results



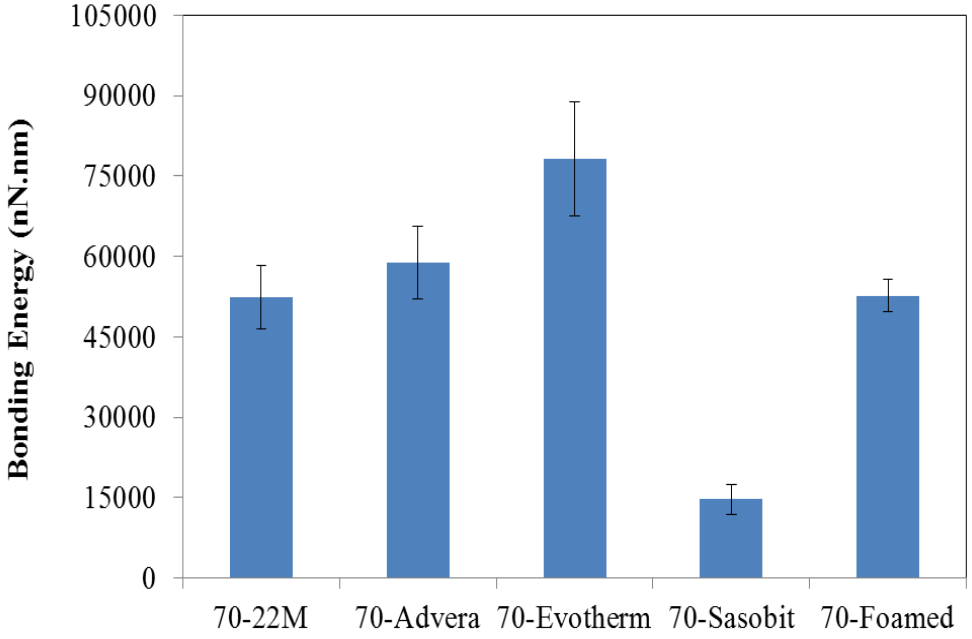


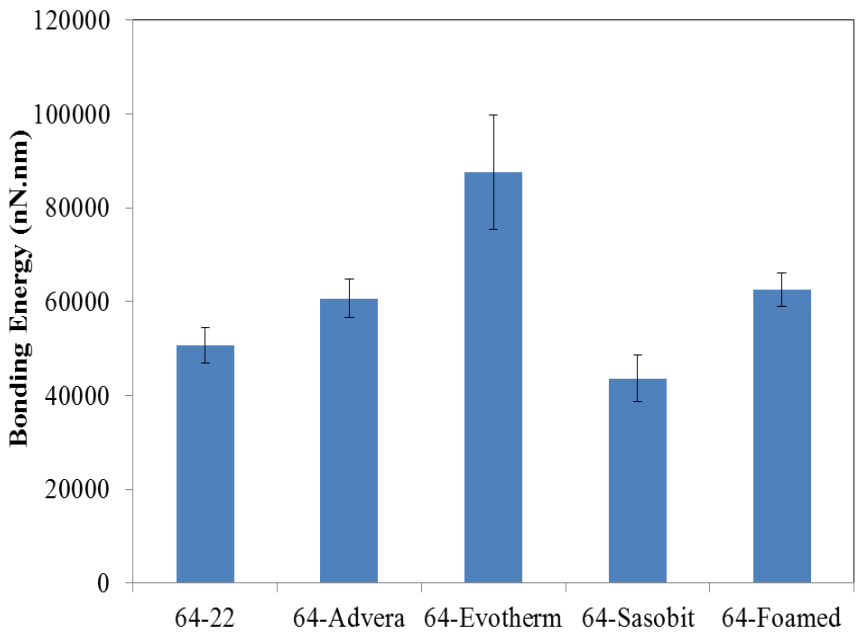
Healing Results: Wetting





Intrinsic Healing Results





Conclusions

- For the unconditioned samples, all WMA technologies had resulted in increasing the adhesive forces for both types of asphalt binders.
  - ✓ Foamed WMA had the highest improvement to these forces, while the Sasobit had the least. This result may explain the lower ITS values obtained due to the addition of the Sasobit.
- The addition of Sasobit resulted in a significant decrease in the cohesive forces for unconditioned samples.
- The Advera binder had the highest decrease after moisture conditioning. This is may explain the lower TSR values that Advera 64-22 mixture exhibited.

Conclusions

- In general, the Sasobit and Advera led to the largest reduction in the cohesive forces upon moisture conditioning.
- The ITS test results were found to depend more on the adhesive forces between the aggregate and binder as compared to the cohesive forces within the binder itself.
- All considered WMA technologies except Sasobit had resulted in improving the micro-crack closure rate of the considered asphalt binders.
- Only the Sasobit might adversely affect the intrinsic healing of the considered asphalt binders.

Acknowledgements

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- Special thanks to Mr. David Powers for his valuable contributions to this study.

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Thank you!!