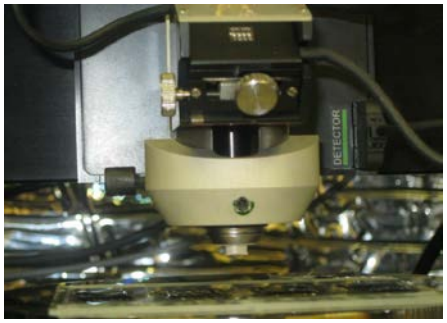
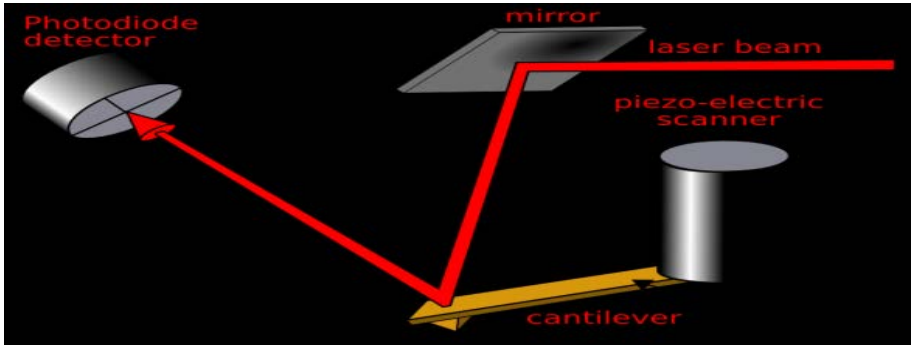
Micro-Mechanical Evaluation of the Interaction between RAS/RAP and Virgin Asphalt Binders





Munir Nazzal **Louay Mohammad**

FHWA Binder ETG Meeting
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Fall River, MA

Outline

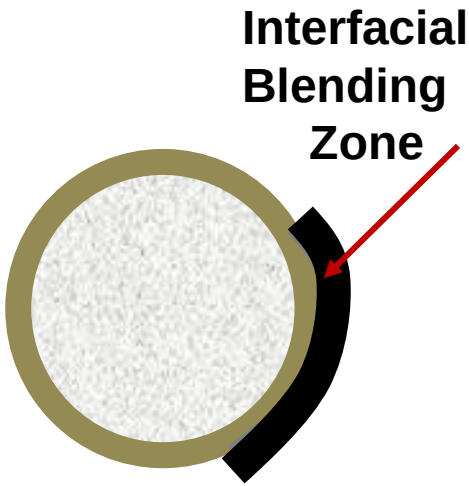
- Background
- Objectives
- AFM Testing
- AFM Testing Results
- Future Work
- Conclusions

Background

- Though the benefits of using RAS and higher amount of RAP in new mixes are high, it presents a concern that resultant mixture may be prone to more cracking.
- Recent studies indicated that the properties of this interfacial blending zone between RAP and virgin asphalt binder might dedicate the performance of the RAP asphalt mixtures.
- At the current time, the interaction between the RAS and virgin asphalt binder is unclear.

Background

- Examining the properties of the interfacial zone between RAP and virgin asphalt binder is imperative to understand the cracking resistance of mixes containing RAP/RAS and to identify the factors that affect it.



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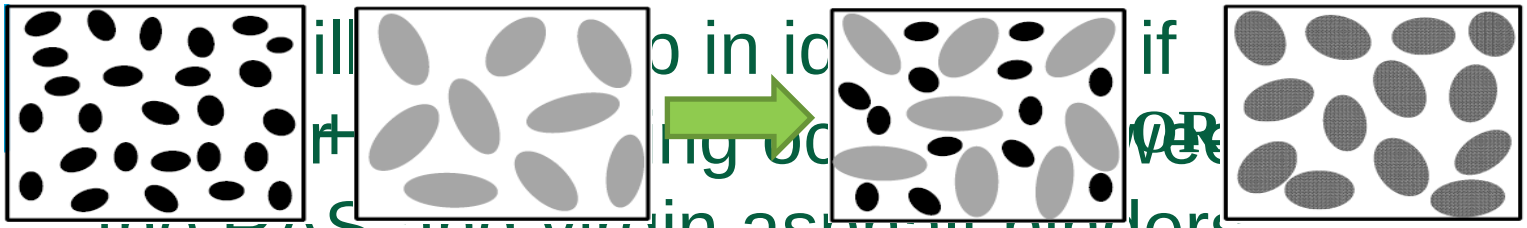
the RAS and virgin asphalt binders.



Virgin Asphalt **RAP /RAS** **Mixing** **Blending**

Objectives

- Study the interaction between RAP/RAS and virgin asphalt binders and evaluate the adhesive and micro-mechanical properties of the interfacial zone between these binders.
- Examine the effect of the properties of RAP and virgin asphalt binders on their blending.

Scope: Materials

- Three types of asphalt binders were considered in this study:
  - ✓ PG 58-28
  - ✓ PG 64-22
  - ✓ PG 64-28
- RAP materials with different rheological and mechanical properties were selected.
- Different tear off and manufacturing waste RAS materials were selected.
- RAP/RAS binders were extracted and recovered from using AASHTO T 164 and AASHTO T 170 procedure.

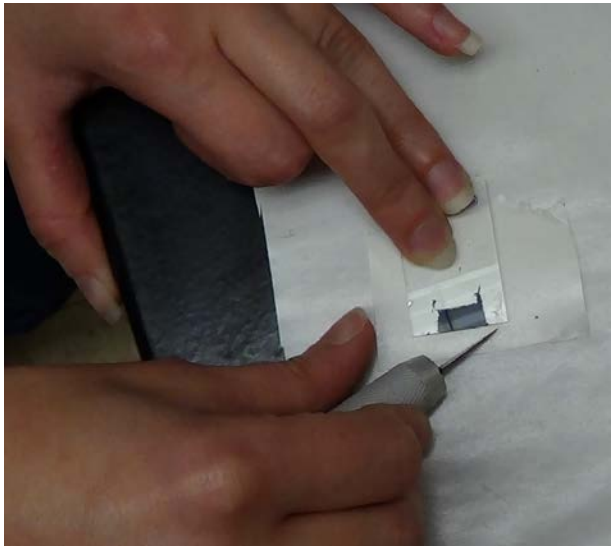
RAP Materials

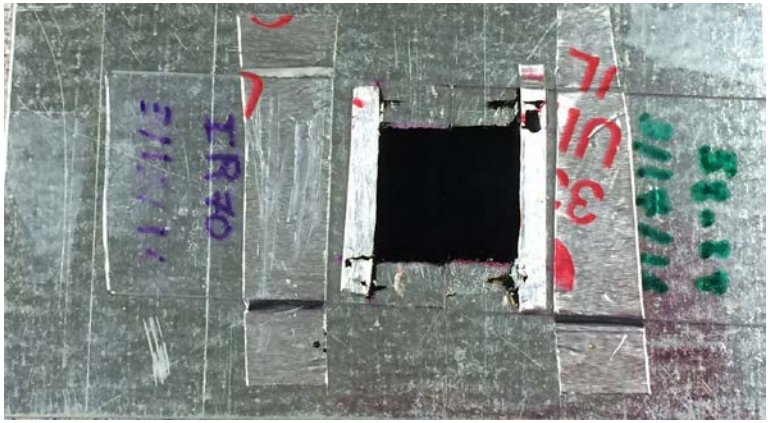
RAP ID	Viscosity* Pa*s	Continuous High Temperature Grade, °C	Continuous Low Temperature Grade, °C	
			BBR	ABCD
Composite	8,438	81.2	-19.8	-19.9
SR 7	2,015	96.8	-13	-14.45
IR-70	6,838	83.5	-19.1	-19.25
IR-90	15,311	80.2	-20.6	-21.5
US 33-2015	10,234	90	-16.1	-17.6
US 33-2014	8,623	89	-19.2	-16.75

RAS Materials

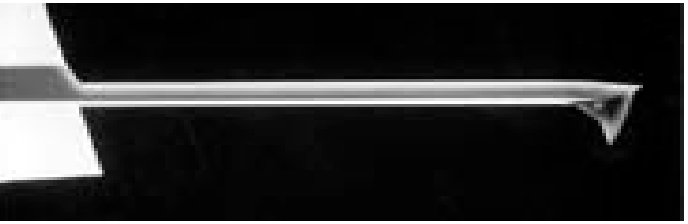
RAS ID	High Temperature Grade, ° C	Low Temperature Grade, ° C	
		BBR	ABCD
Tears offs-1	176.1	5.3	-
Tears offs-2	169.2	-	-
Manufacturing Waste	-	-	-

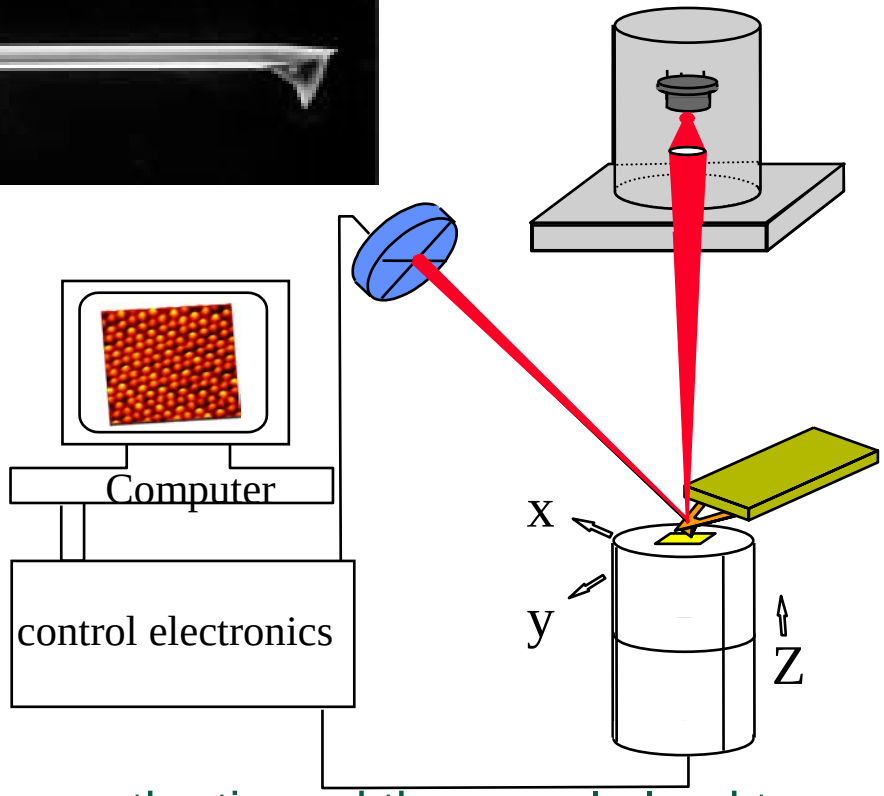
Sample Preparation

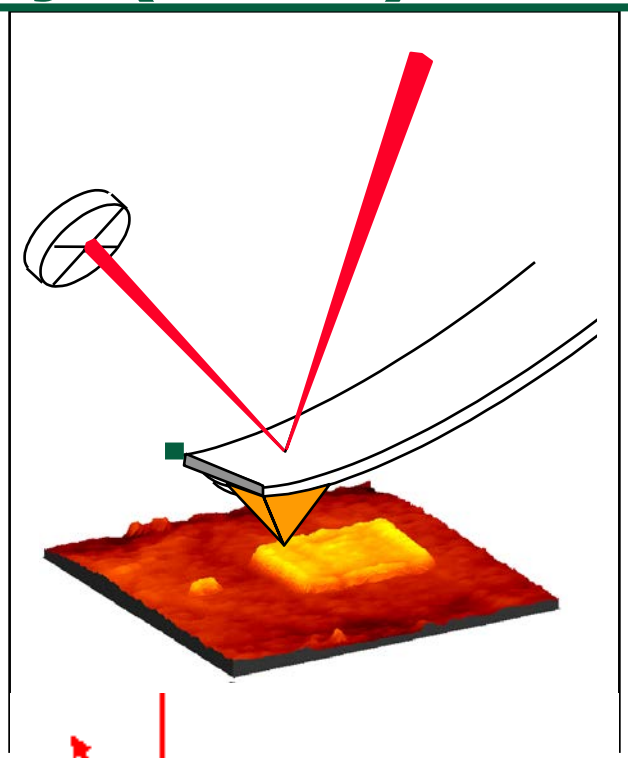


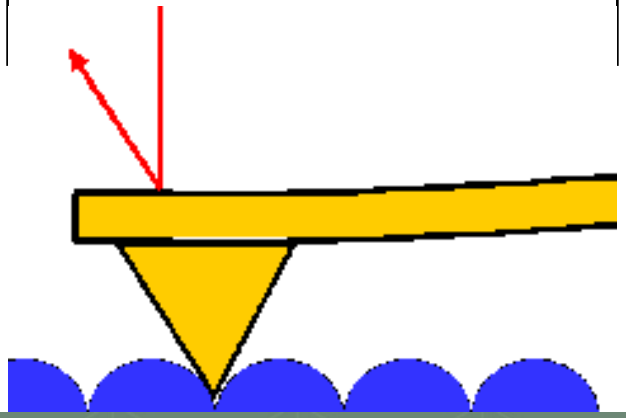


Atomic Force Microscopy (AFM)





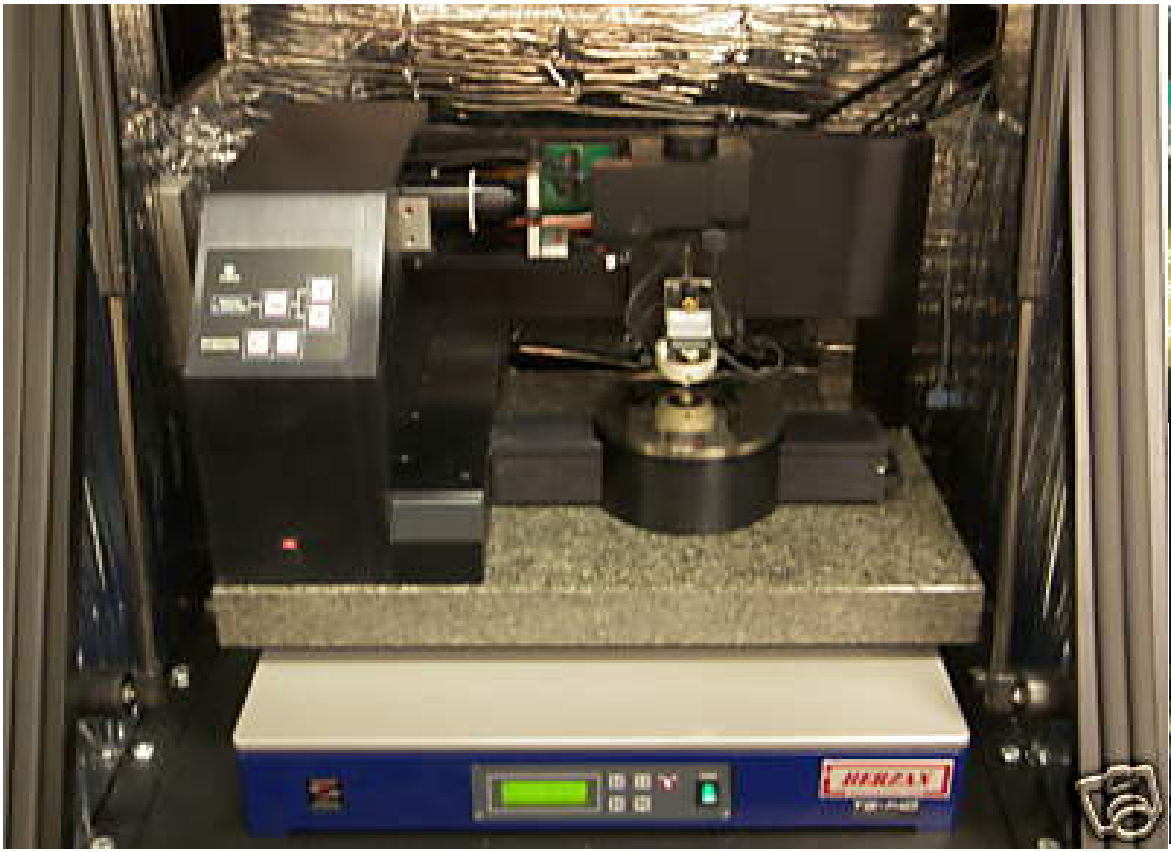


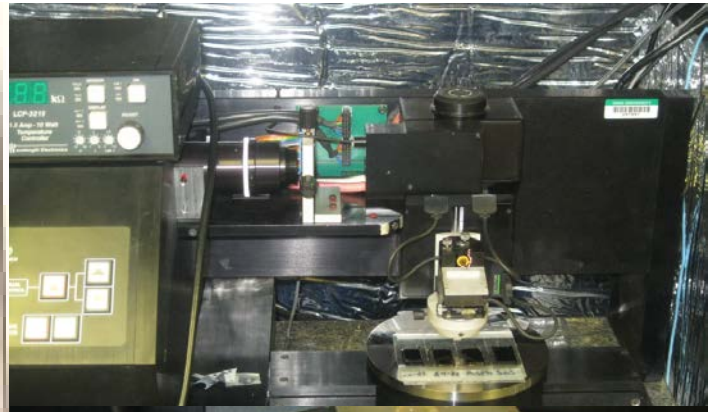


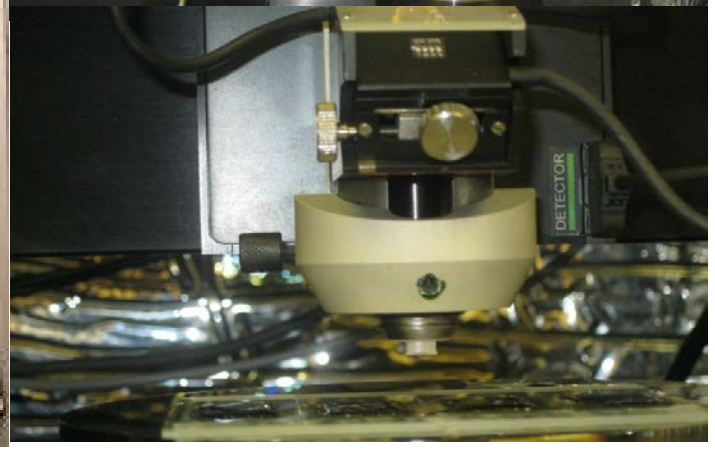
- Forces between the tip and the sample lead to a deflection of the cantilever.
- Deflection is measured using a laser spot reflected from cantilever collected by a detector

Atomic Force Microscopy (AFM)

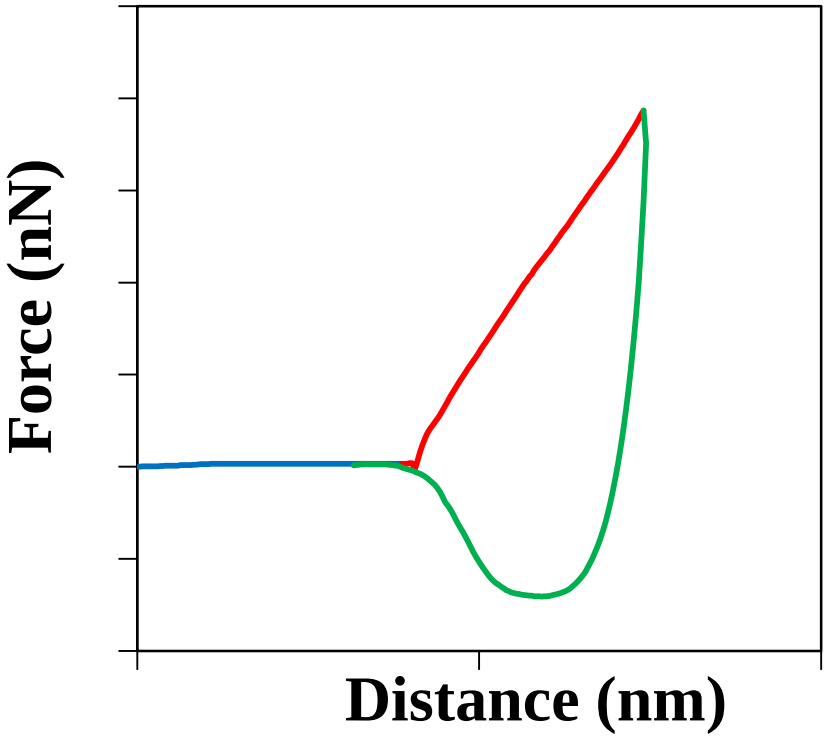
- Agilent 5500 LS AFM was used in this research

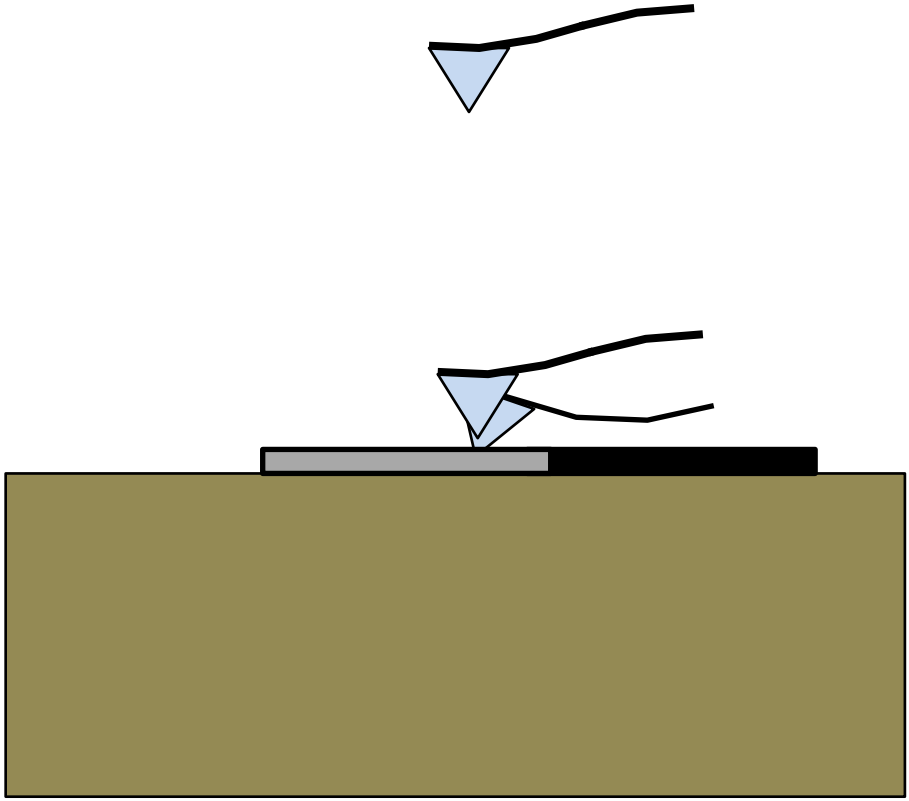






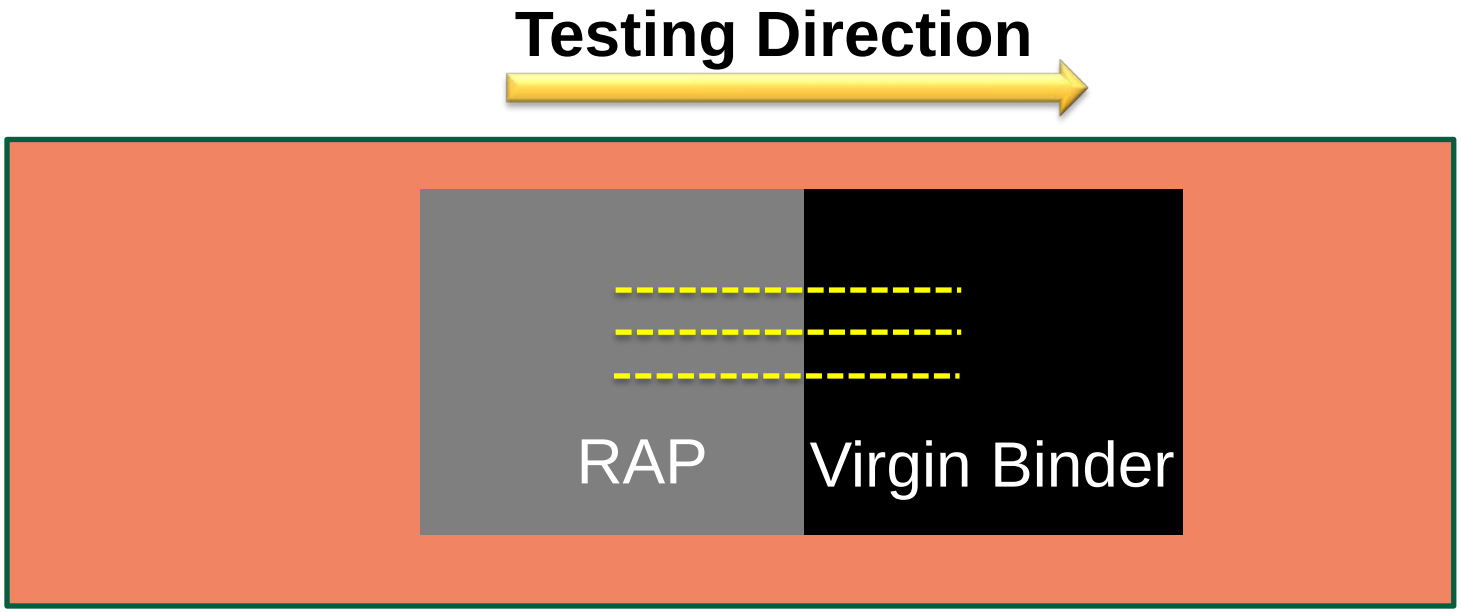
AFM Force Spectroscopy





- 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



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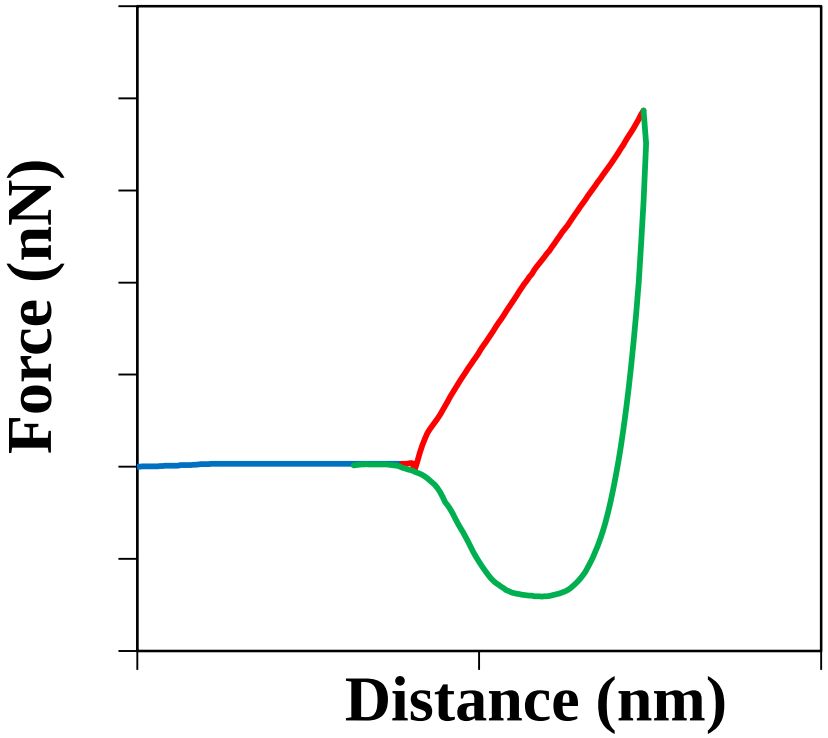

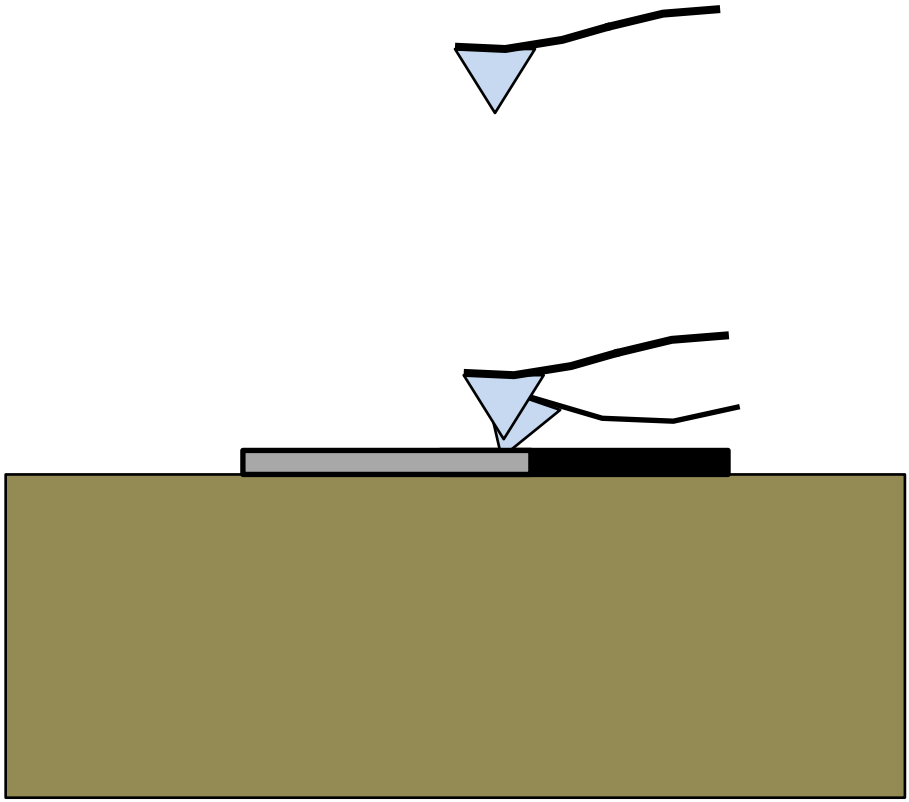

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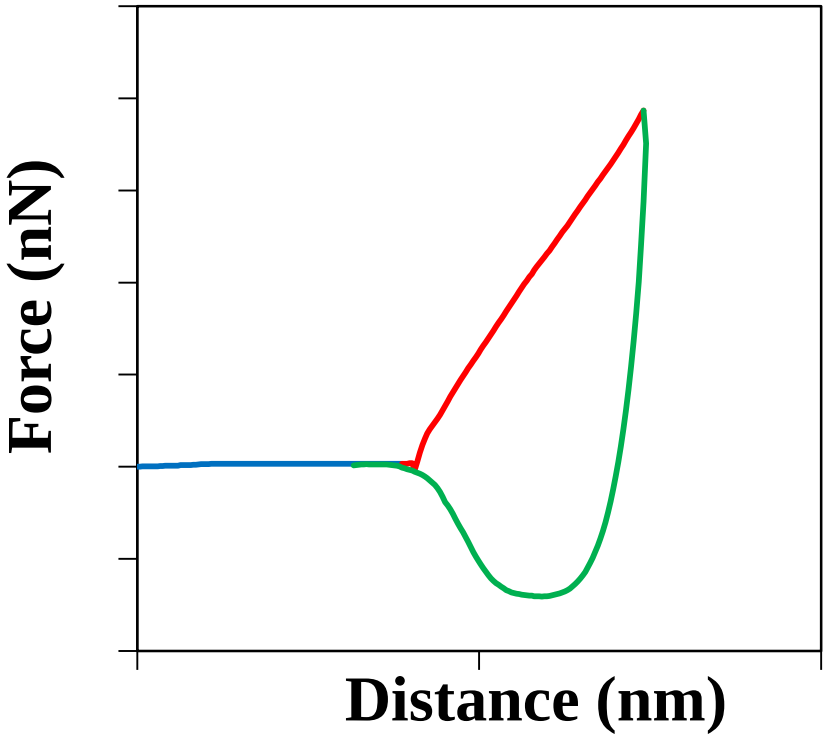

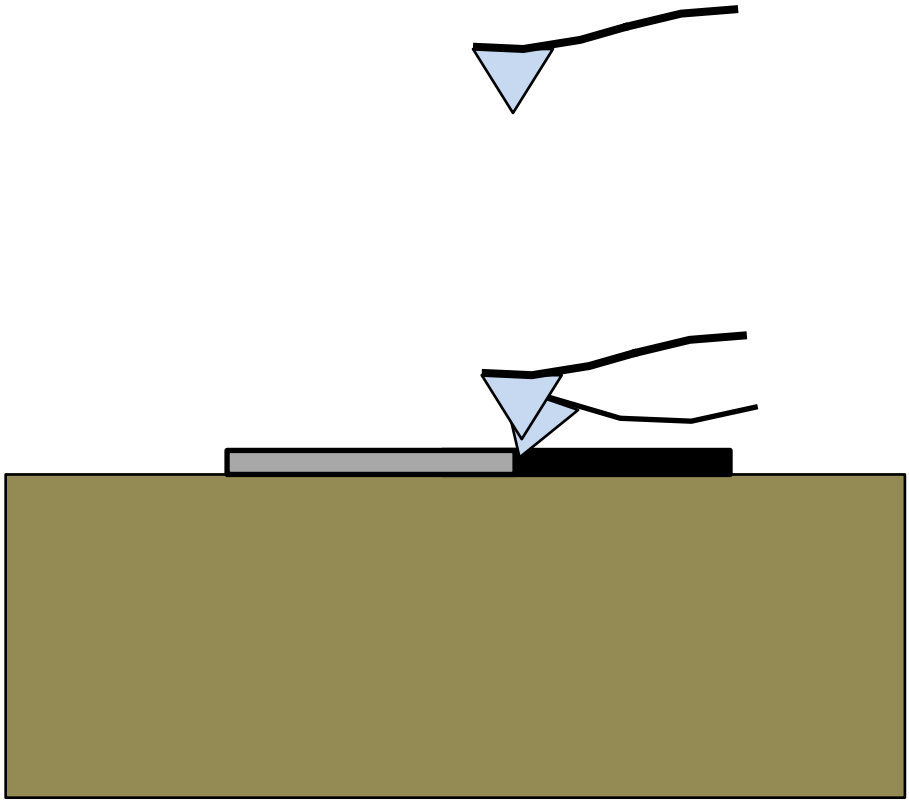

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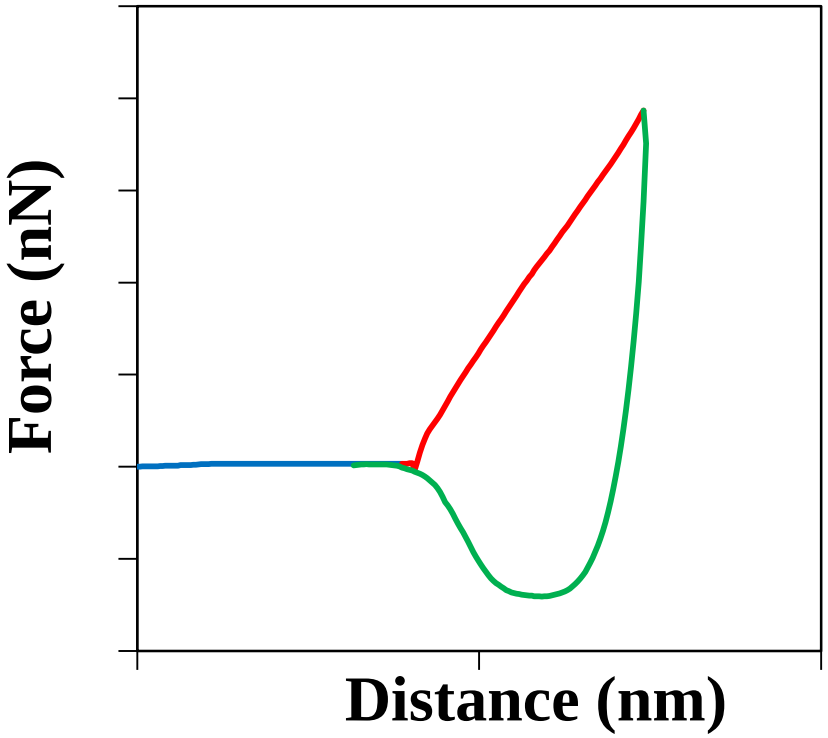
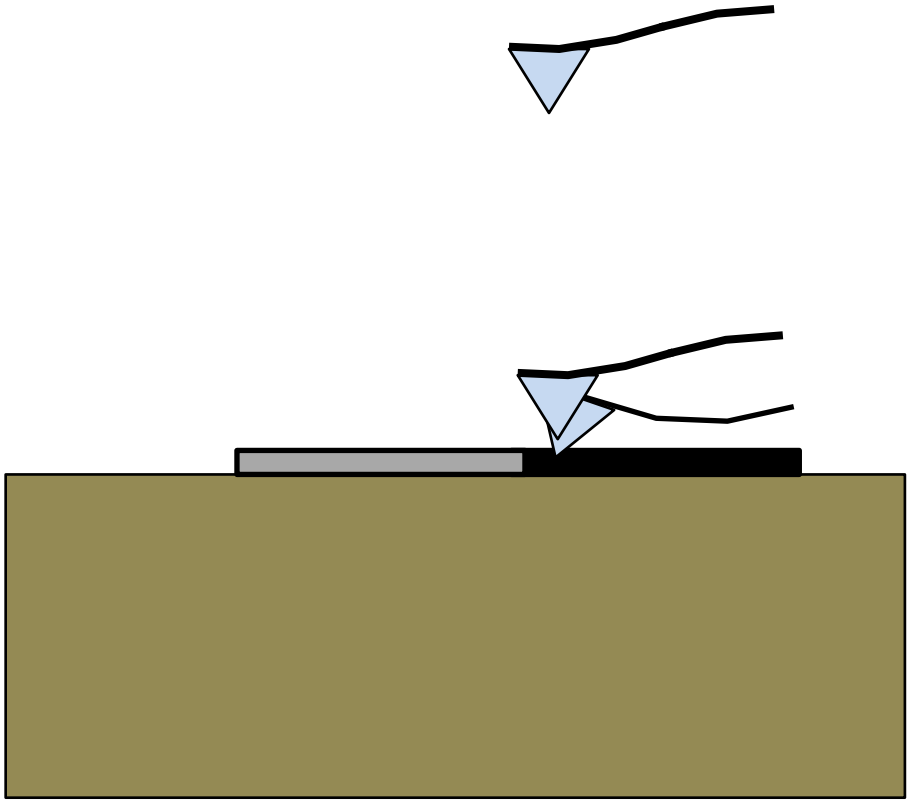
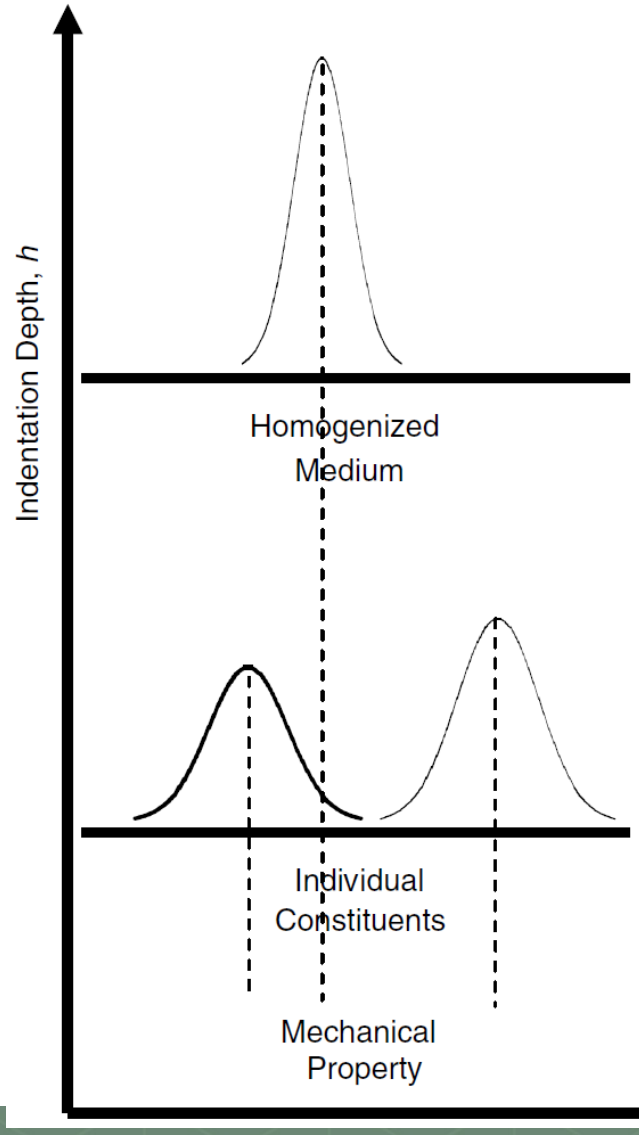


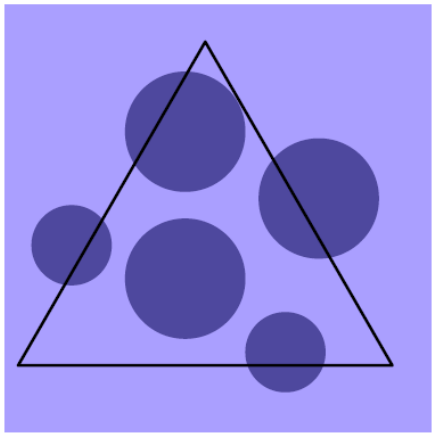


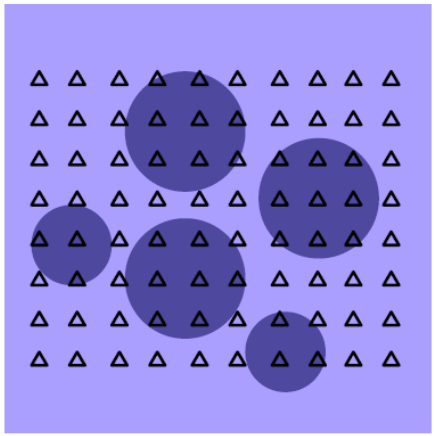
- The sample is probed at a fixed spot on the surface.
- The measurement is performed as an approach-retraction cycle
- The total force exhibited at the tip during the process is monitored

Indentation Depth

- The indentation depth should be selected to minimize the surface effect.
- Tests should be carried out with a grid of a constant size.



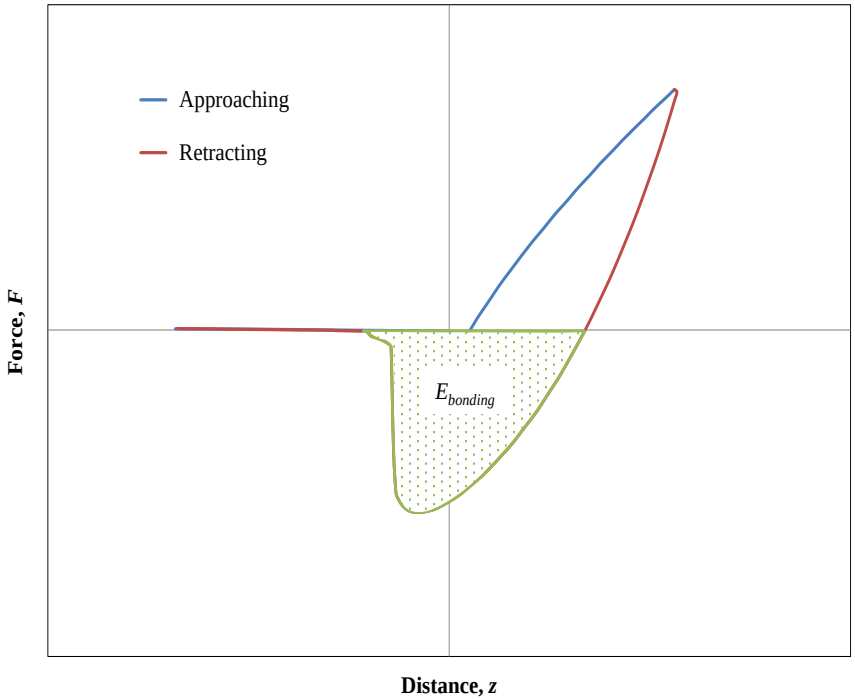




After Constantinides &Ulm(2007)

AFM Force Spectroscopy Results

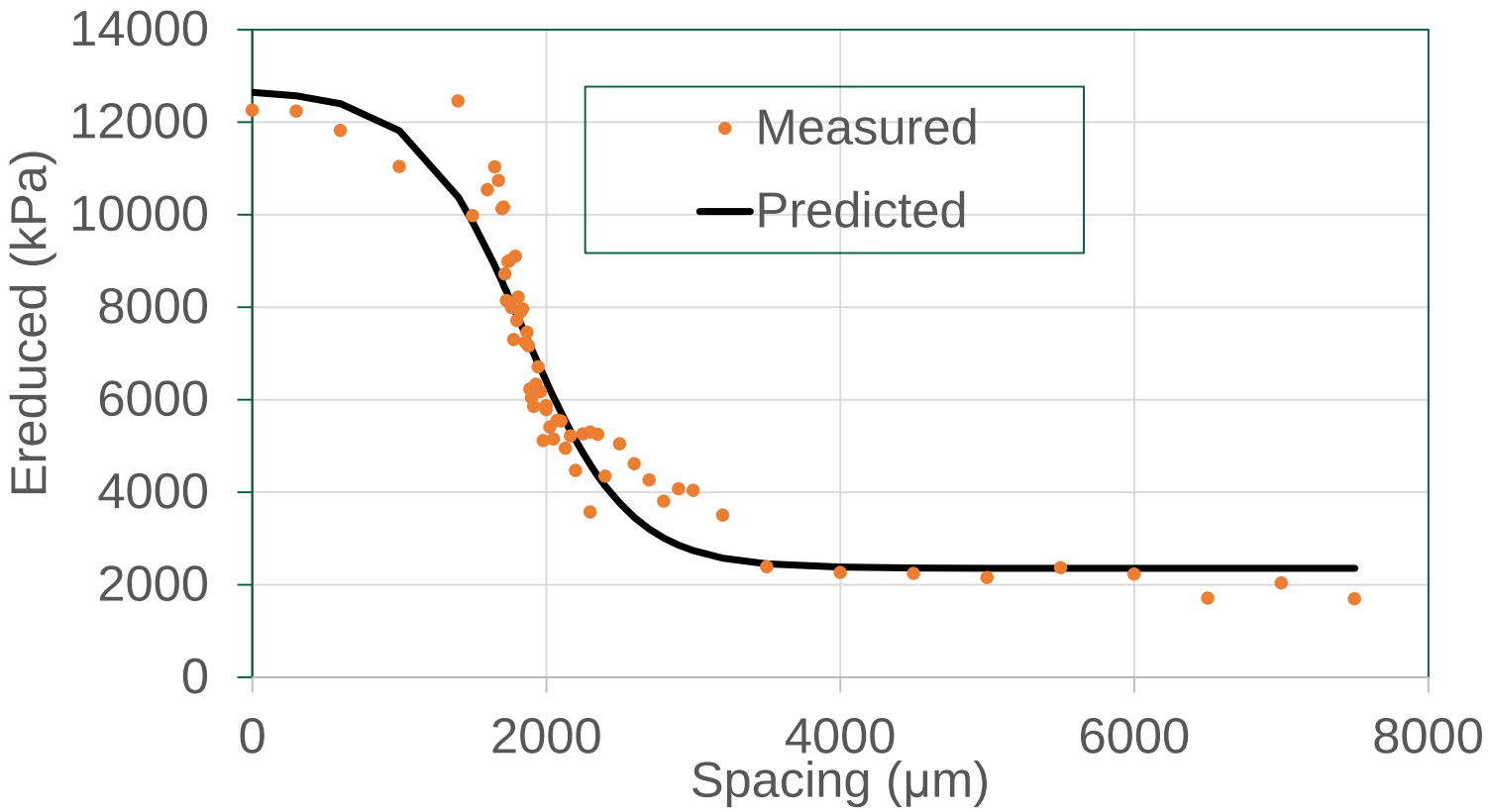
- The adhesion properties o the binders were obtained based on the total adhesion energy needed t separate the tip from the asphalt sample.
- The energy, $E_{bonding}$ can be estimated by integration :



$$E_{bonding} = \int_{z_o}^{z_1} F dz \approx \frac{\Delta z}{2N} \sum_{i=1}^{N} [F(z_{i+1}) + F(z_i)]$$

AFM Test Results

$$E_{reduced} = \frac{A1}{1+e^{k(x-x0)}} + A_2$$



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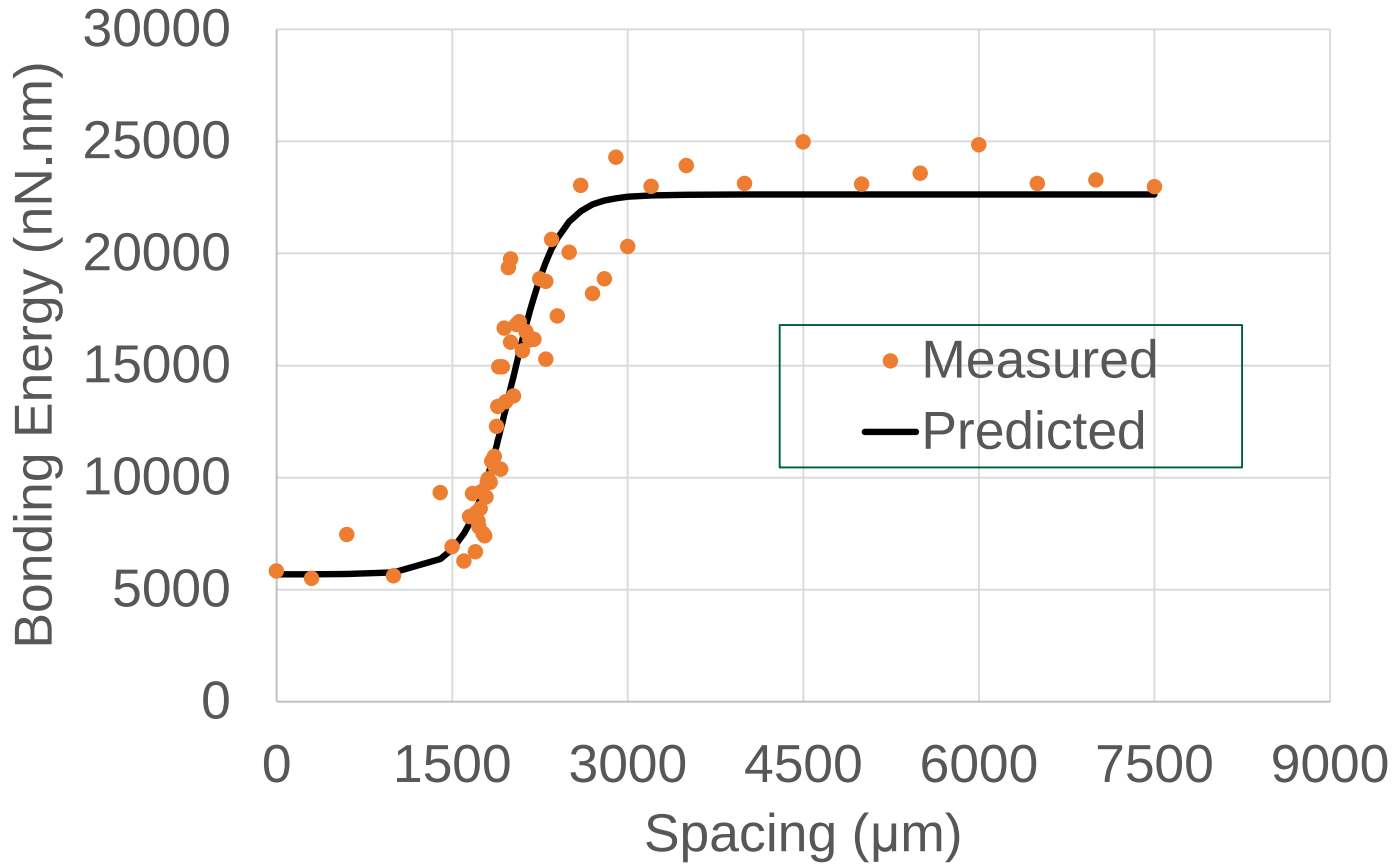
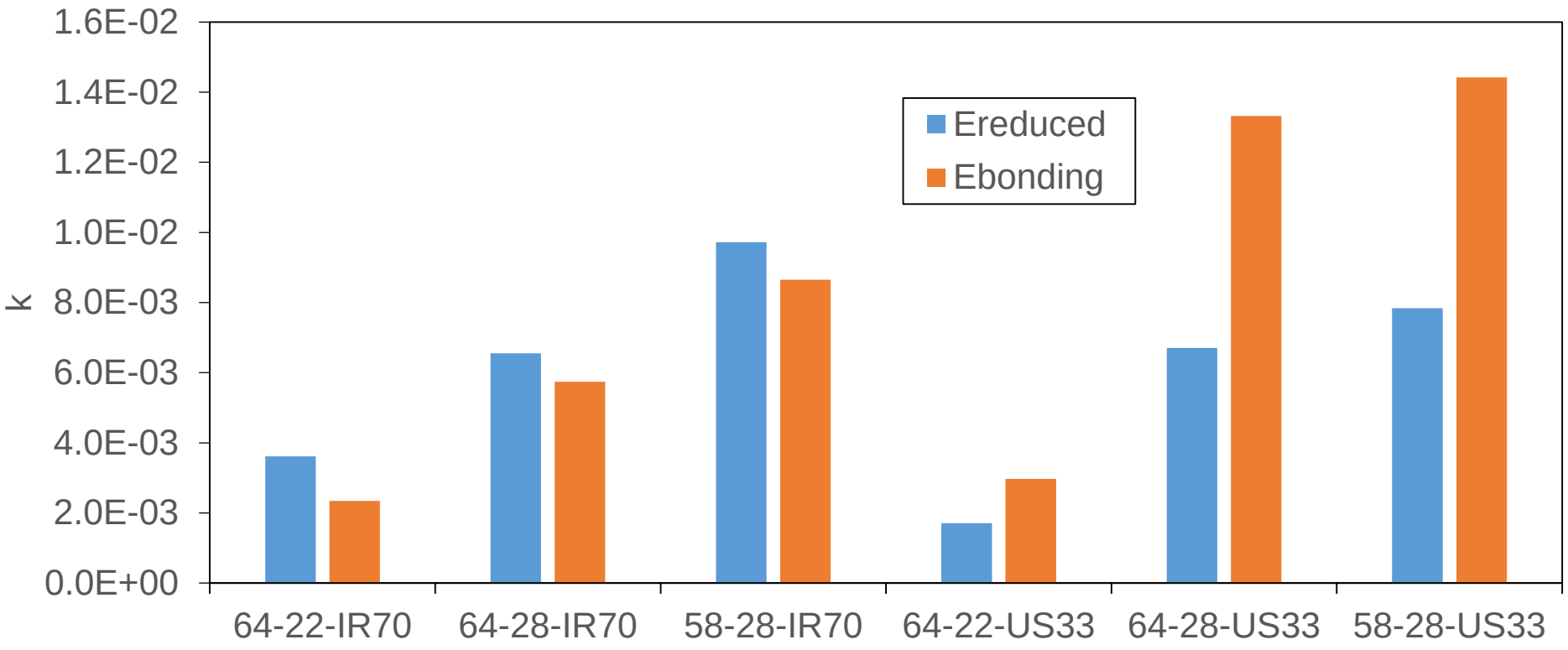
$$\mathrm{BE} = \frac{A1}{1+e^{-\boldsymbol{k}(x-x0)}} + A_2$$

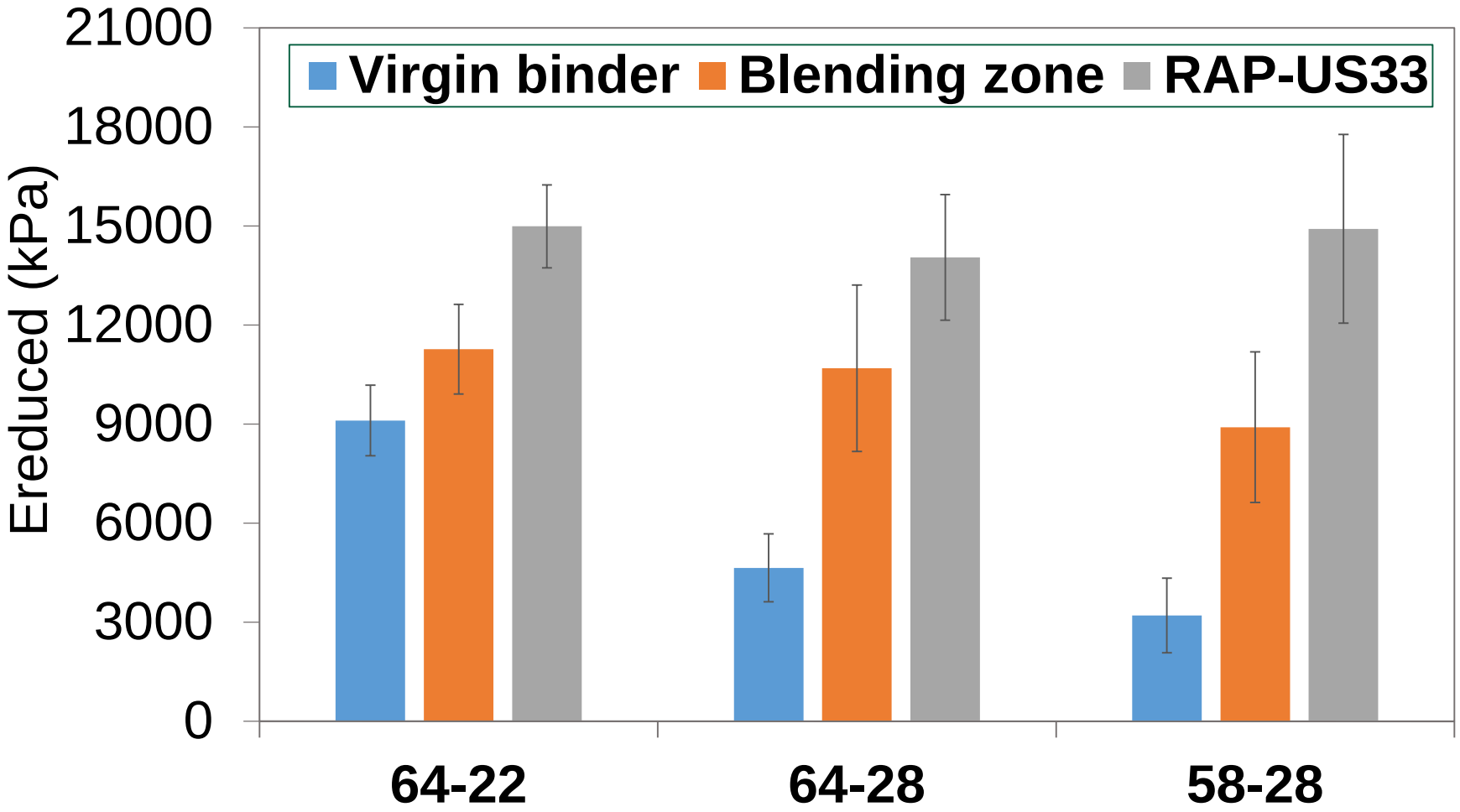


AFM Test Results

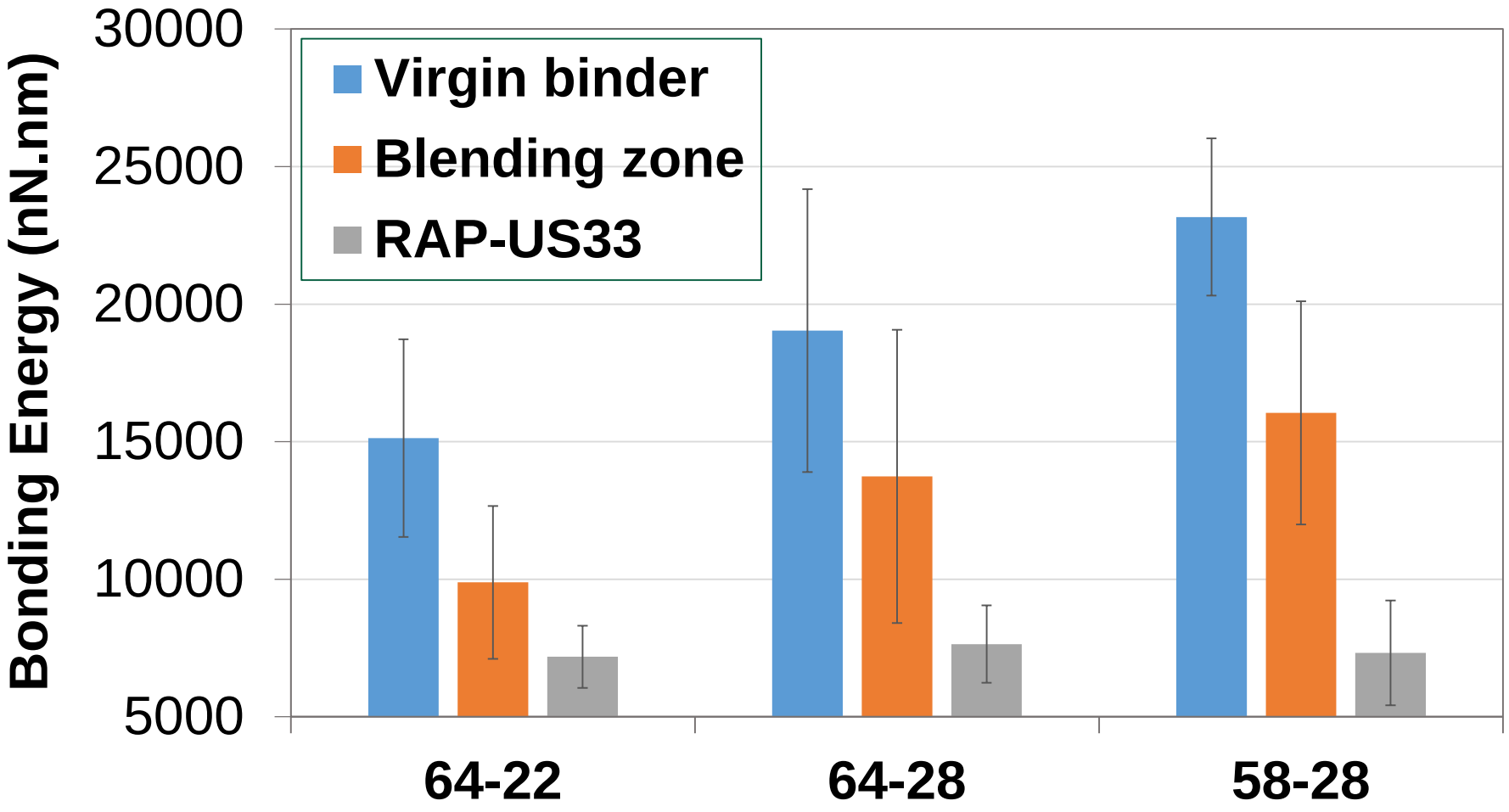
$$E_{reduced} = \frac{A1}{1+e^{k(x-x0)}} + A_2 \qquad E_{bonding} = \frac{A1}{1+e^{-k(x-x0)}} + A_2$$



AFM Test Results-Ereduced



AFM Test Results-Bonding Energy



AFM Test Results- Ereduced

Effect	F-value	P-value
RAP binder	65.64	<.0001
Virgin binder	48.91	<.0001
RAP binder*Virgin binder	7.47	0.0006
Grouping of Blending Zone		
Combination	**$E_{reduced}$ (KPa)**	**Letter Group**
US33 + PG64-22	11270	A
US33 + PG64-28	10691	A
IR70+ PG64-22	10176	B
US33 + PG58-28	8907.78	B
IR70 + PG64-28	8248.20	C
IR70 + PG58-28	7997.67	C

AFM Test Results- Bonding Energy

Effect	F-value	P-value
RAP binder	0.55	0.4604
Virgin binder	89.66	<.0001
RAP binder*Virgin binder	2.10	0.1234
Grouping of Blending Zone		
Combination	**Bonding energy estimate (nN.nm)**	**Letter Group**
IR70 + PG58-28	16730	A
US33 + PG58-28	16046	A
US33 + PG64-28	13739	B
IR70 + PG64-28	12989	B
IR70+ PG64-22	10754	C
US33 + PG64-22	9887.51	C

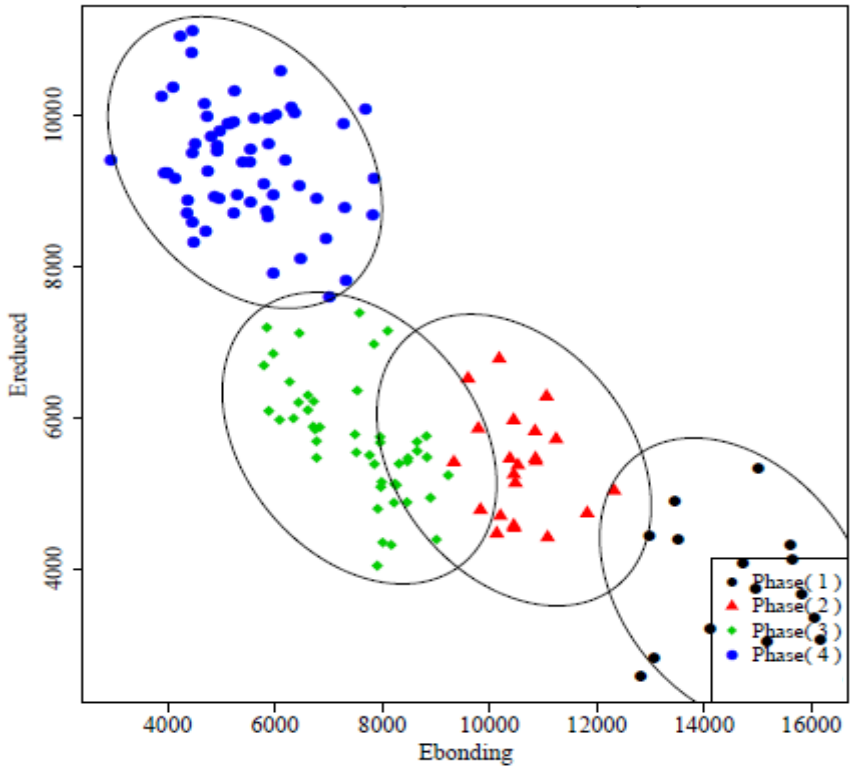
AFM Test Results-RAP Concentration

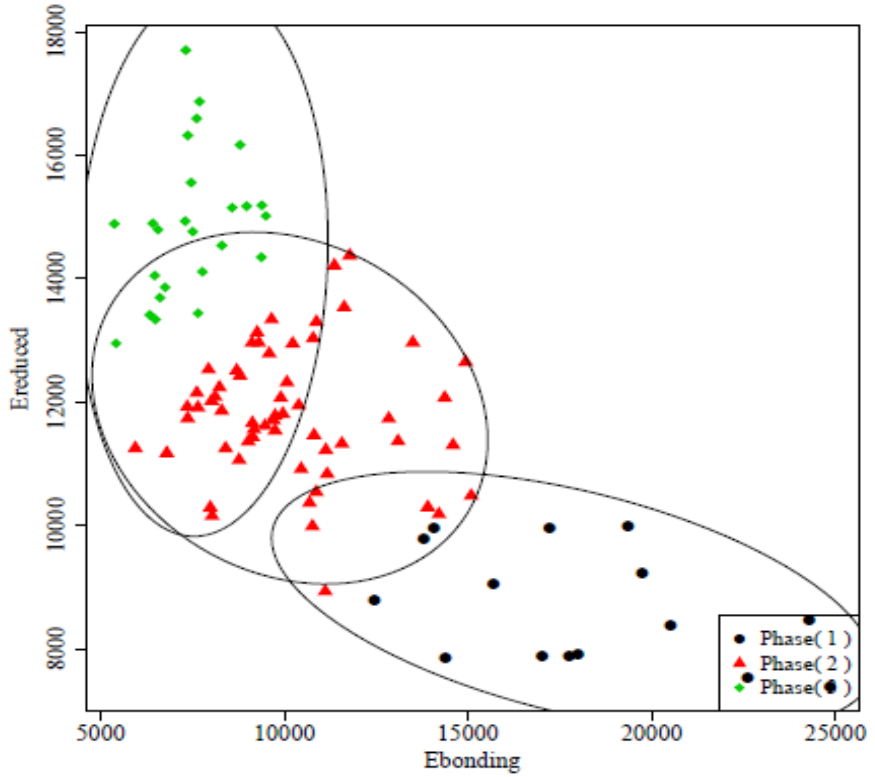
$$E_{blend} = \frac{E^{\alpha}_{RAB} \cdot E_{VB}}{E^{\alpha}_{RAB}} \qquad BE_{blend} = \frac{E^{\alpha}_{RAB} \cdot E_{VB}}{E^{\alpha}_{RAB}}$$

Combination	α based on Ereduced	α based on Bonding Energy
RAP-IR70 + PG64-22	0.4298	0.4604
RAP-IR70 + PG64-28	0.6548	0.3738
RAP-IR70 + PG58-22	0.6552	0.3415
RAP-US33 + PG64-22	0.4274	0.5709
RAP-US33 + PG64-28	0.728	0.4339
RAP-US33 + PG58-28	0.5926	0.3188

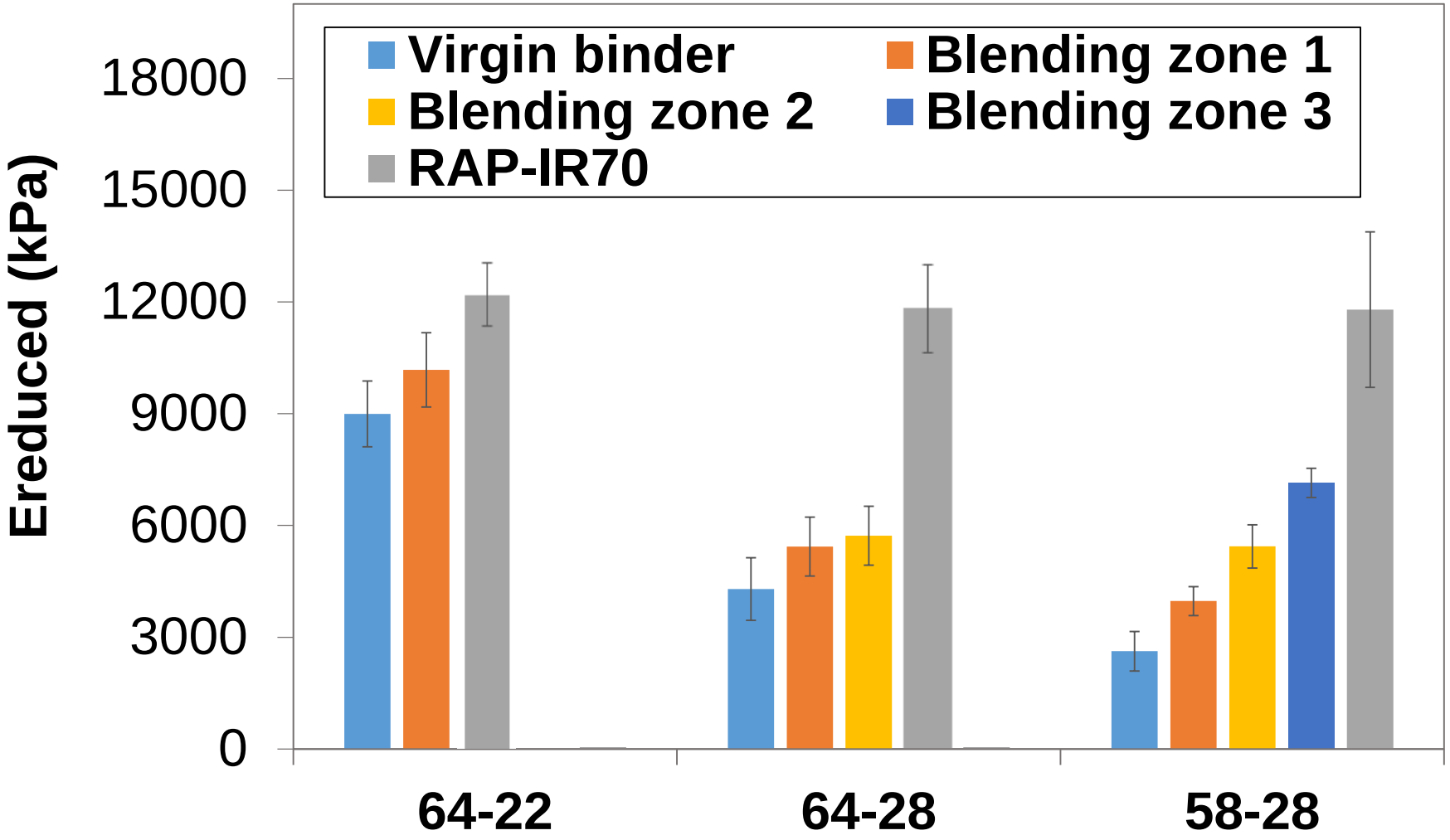
Cluster Analysis

- Cluster analysis is performed to determine number of phases in the interfacial zone.

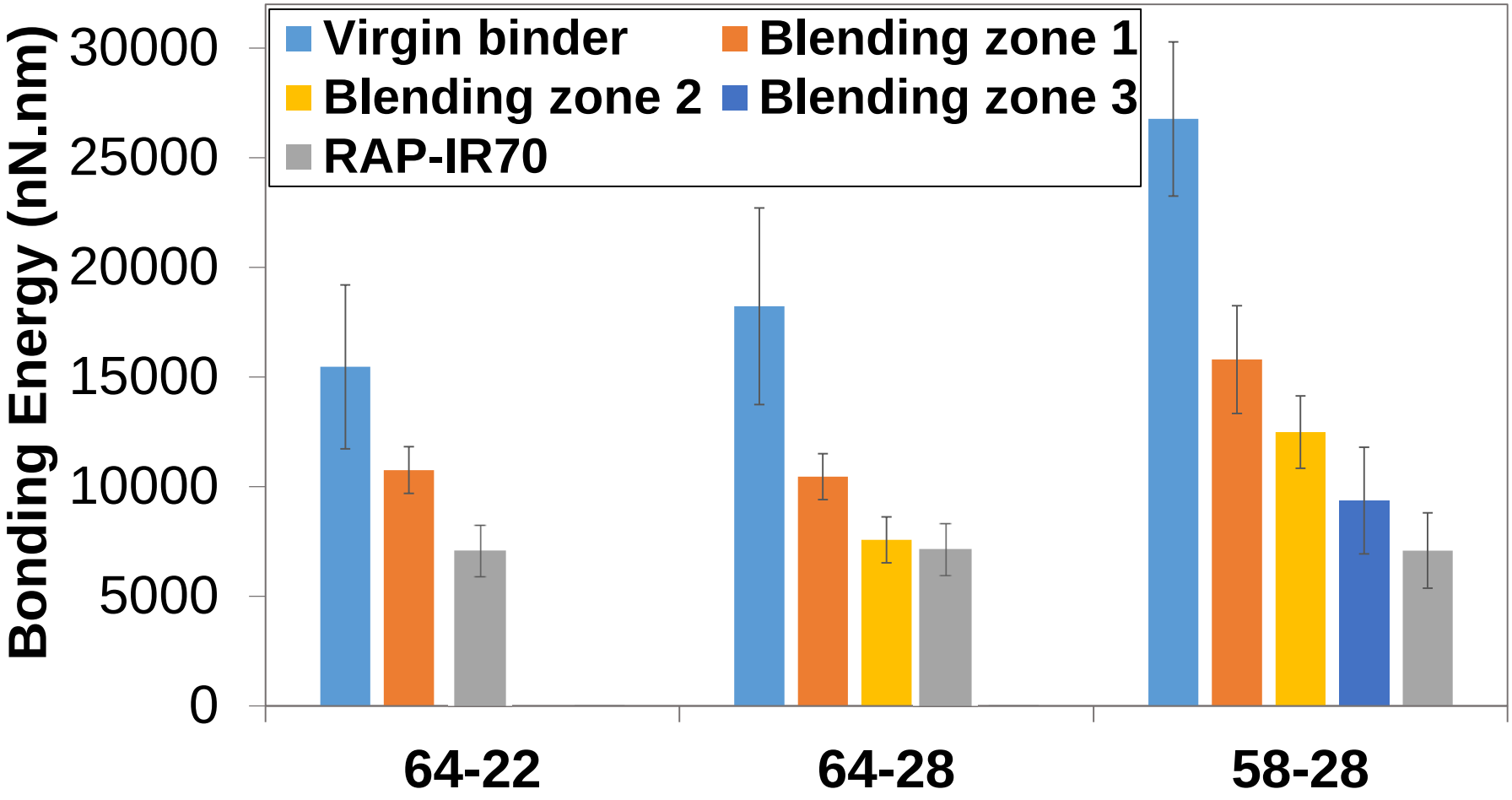




AFM Test Results-Ereduced



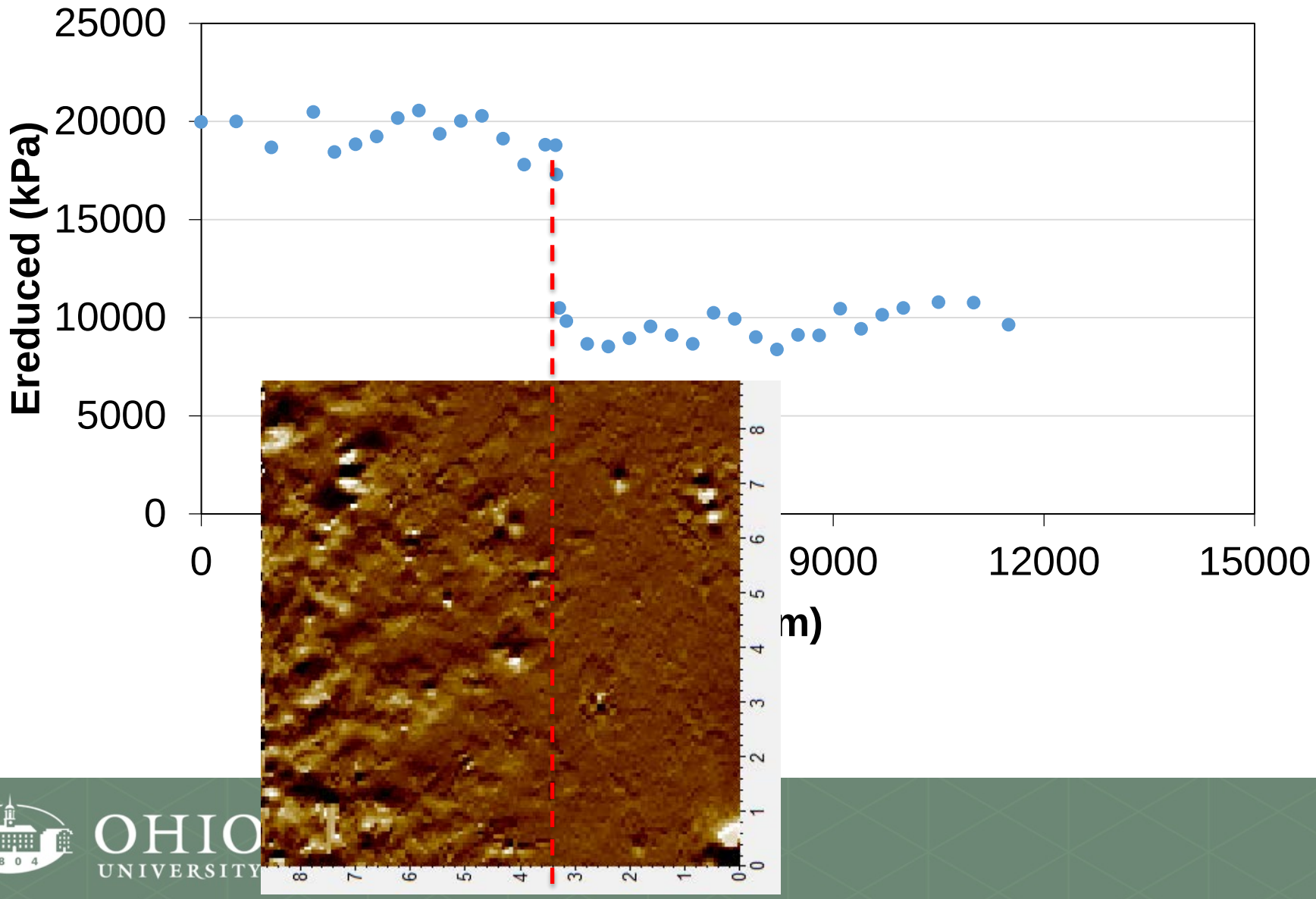
AFM Test Results- Bonding Energy



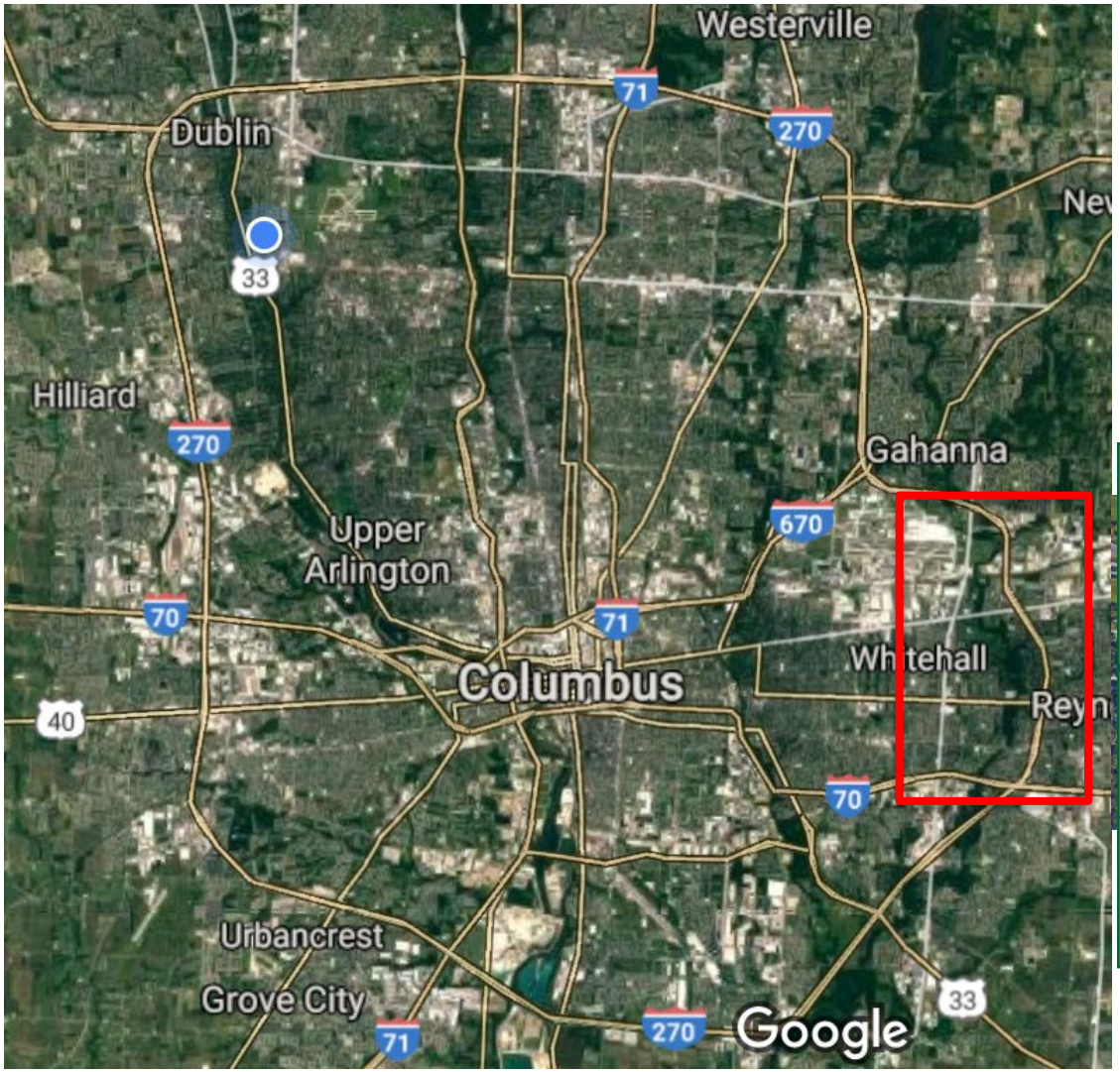
RAS Materials

RAS ID	High Temperature Grade, ° C	Low Temperature Grade, ° C	
		BBR	ABCD
Tears offs-1	176.1	5.3	-
Tears offs-2	169.2	-	-
Manufacturing Waste	-	-	-

AFM Test Results- RAS



RAP Testing at Interstate 270



- Existing Pavement from IR 270 was milled, processed, and used in the new mixture for the overlay.

RAP ID	High Temperature Grade, ° C
IR-270 (TCE)	78.1
IR-270 (Toluene)	79.7

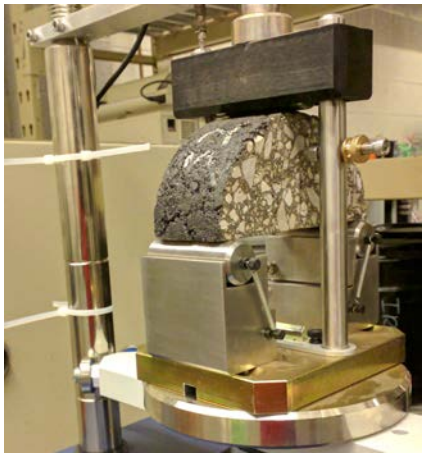
Mixtures Testing

- Cores from intermediate and surface course mixtures were collected.
- Plant produced samples of intermediate and surface course mixtures were collected
- Aggregates, RAP and binders used in producing the field mixes were obtained to prepare and test:
  - ✓ Control mixture (no RAP)
  - ✓ Control mixture with 25%RAP, 35% RAP, 50%RAP
  - ✓ Control mixture with RAS
  - ✓ Control mixture with RAS and RAP

Mixtures Testing

Mix Testing

- **Low Temp Cracking** → **ACCD**
- **Fatigue Cracking** → **SCB**
- **Durability** → **AASHTO T283**



Conclusions

- The AFM force spectroscopy results showed that the RAP binders blended with virgin binders in a blending zone.
- The blending zone properties varied based on the virgin binder and RAP binder being used.
- The RAP and virgin asphalt binders properties significantly affected the reduced modulus of the blending zone.
- The adhesive bonding of the blending zone was mainly affected by the virgin binder being used.

Thank you!!