# EVALUATING CHANGES IN RHEOLOGICAL PROPERTIES OF BLENDED BINDERS

## Conventional Binder with Aged-Hardened Rubberized Binder
## Rubberized Binder with Aged-Hardened Conventional Binder


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# Outline

- Introduction
- Objectives
- Experimental Design
- Testing Results
- Conclusions

# Introduction

- **Rubberized hot-mix asphalt (RHMA) pavement has been increasingly used in California over the last 10 to 20 years**
  - Reach the end of their design lives, will be milled off and added to RAP stockpile
- **Currently, the amount of RAP used in new HMA varies between 15 and 25 percent**

# Why Use Rubberized Asphalt Concrete (RAC) in California?

- **Law-Assembly Bill 338**

  "Requires Caltrans (DOT) to use 35% RAC on its highway construction and repair projects"

- **Cost**

  Half the thickness of RAC will typically provide the same fatigue & reflective cracking life as full thickness dense-graded hot-mix asphalt (HMA) for overlays.

| Type | Hot Mix ($/ton) |
|---|---|
| Conventional-DG | 79 - 99 |
| RAC-GG | 91-99 |

2013 Contract Cost Data, A Summary of Cost by Items for Highway Construction Projects. State of California, Business, Transportation and Housing Agency,

# Why Use Rubberized Asphalt Concrete (RAC) in California?

- **Other benefits**
  1. Not Contributing to Tire Stockpiles
  2. Use less virgin materials compared to HMA
  3. Less GHG emissions on both material production and construction phases
  4. Quiet

Wang, T., et al. UCPRC Life Cycle Assessment Methodology and Initial Case Studies for Energy Consumption and GHG Emissions for Pavement Preservation Treatments with Different Rolling Resistance. No. UCPRC-RR-2012-02. 2012.
Lu, Qing, et al. "Investigation of Noise and Durability Performance Trends for Asphaltic Pavement Surface Types: Three-Year Results." Institute of Transportation Studies (2009).

# Current Challenges

- Currently, Caltrans **does not permit** the use of any reclaimed asphalt pavement (RAP) in any kind of RAC

- Also, since RAC has been used in CA for about 30 years, **more and more rubberized RAP has been generated**

- What are the effects of using rubberized RAP in new HMA mixes?
- What are the implications of using RAP in new RHMA mixes?

# Research Objectives

## Investigate the effects of incorporating

1. Rubberized RAP into asphalt concrete
2. RAP into rubberized asphalt concrete

## Methodology

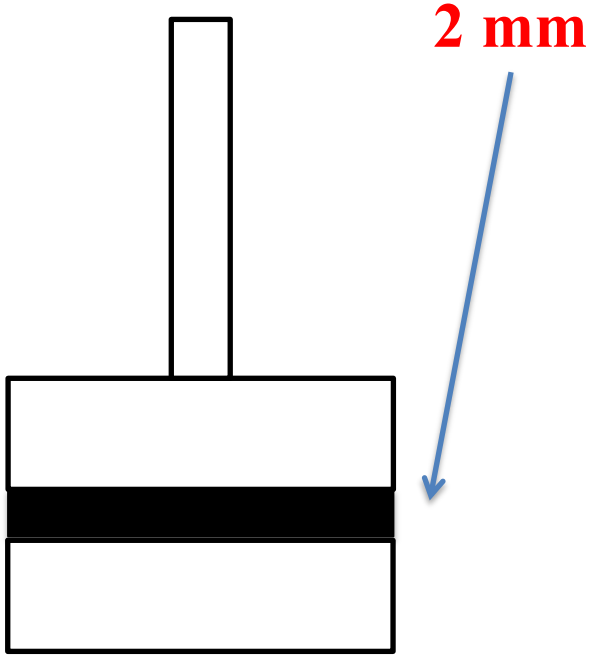
- Asphalt binders' rheological properties

# Experimental Design

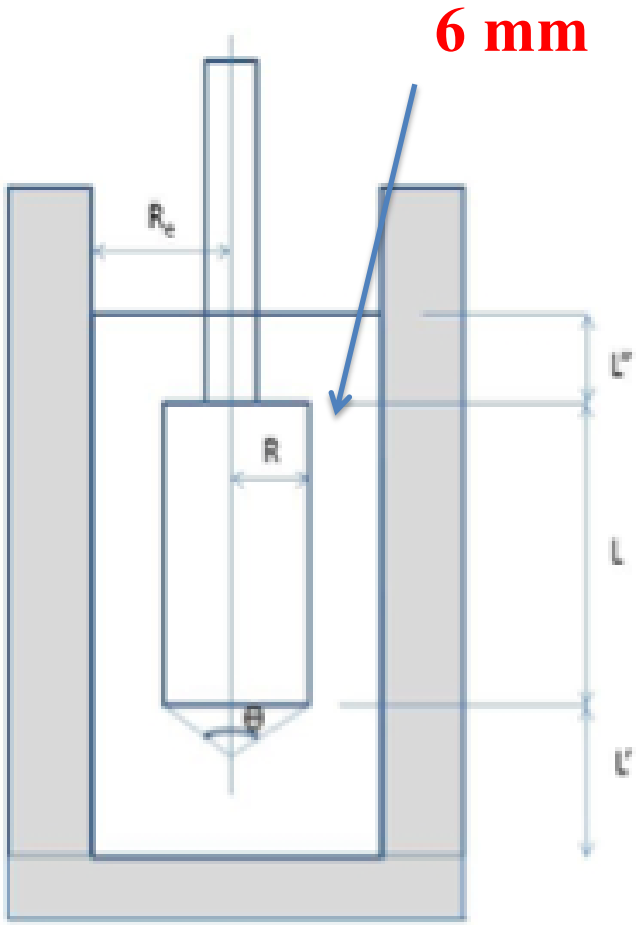
- **Aged rubberized binder cannot be satisfactorily extracted from RRAP**
  - Artificially aged binders were used to simulate the extraction binders

- **The properties of field-blend rubberized binder used in California cannot idea to accurately measured with a traditional parallel plate system**
  - *Relatively large crumb rubber particles (passing mesh #8)*
  - *Extremely high viscosity*
  - Concentric cylinder was used to measure the rheological properties of binders

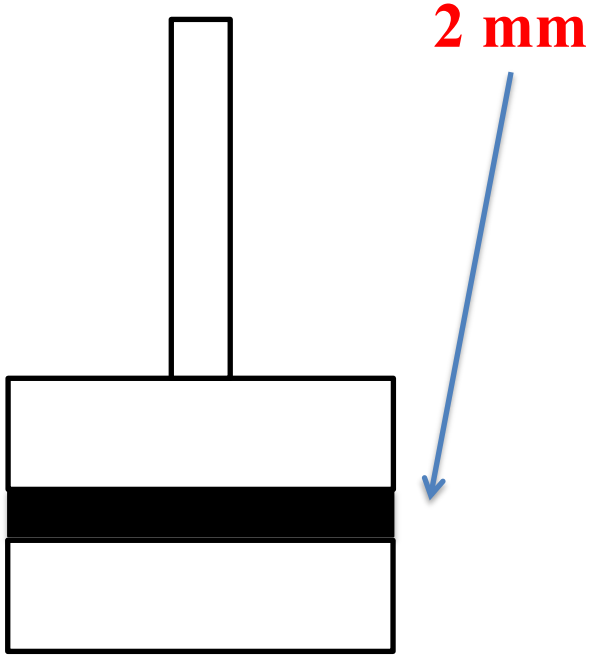
# Parallel Plate




# Concentric Cylinder



## Parallel Plate




## Concentric Cylinder

# Material Collection & Preparation

- **One conventional binder (PG64-16)**
- **One rubberized binder (laboratory blended)**

## Rubberized binder preparation

- Base binder: PG 64-16 (same conventional binder)
- Rubber content: 18 percent by weight of total binder
- Grinding type: ambient
- Extender oil: four percent by weight of base binder

**Blend in a mixer for 60 minutes at approximately 190˚C**

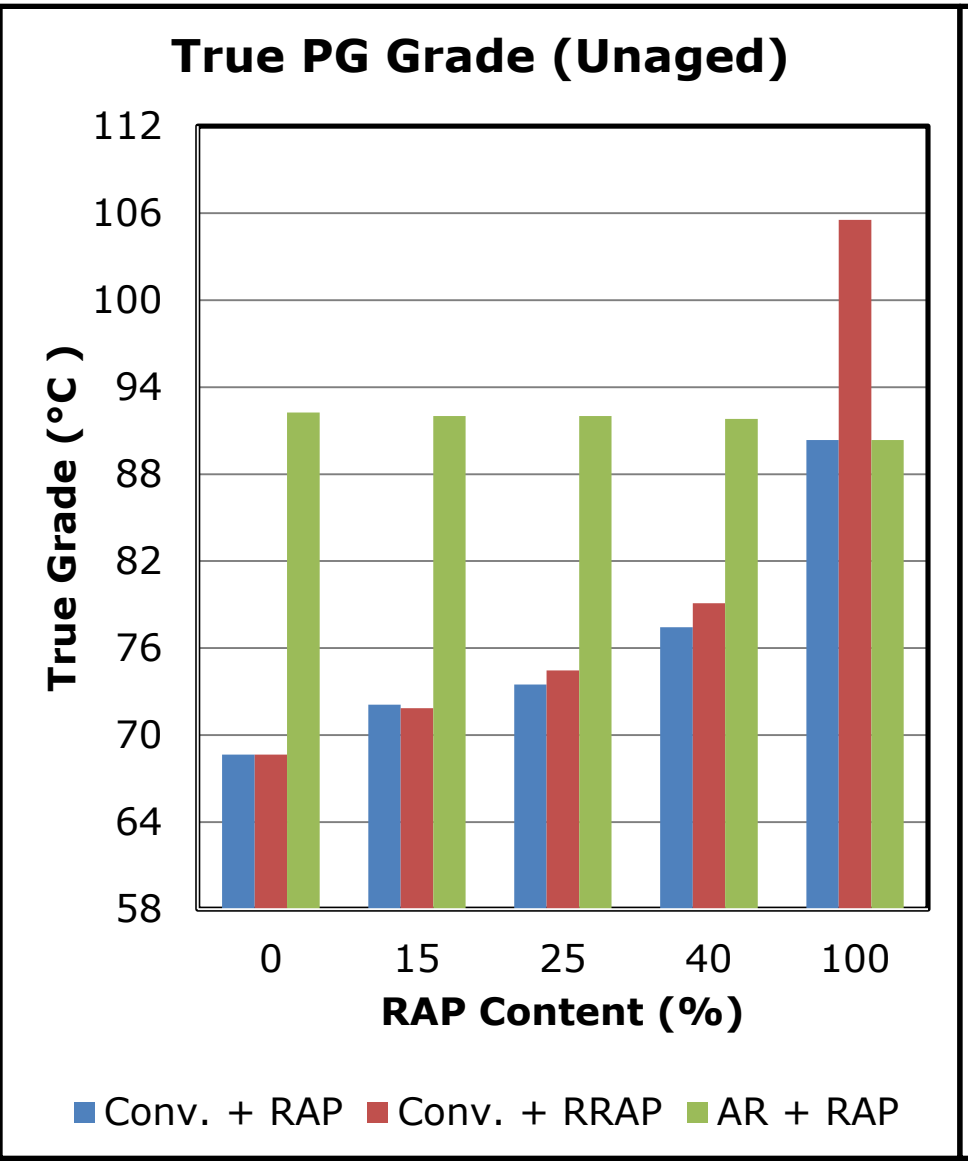

OMEGA

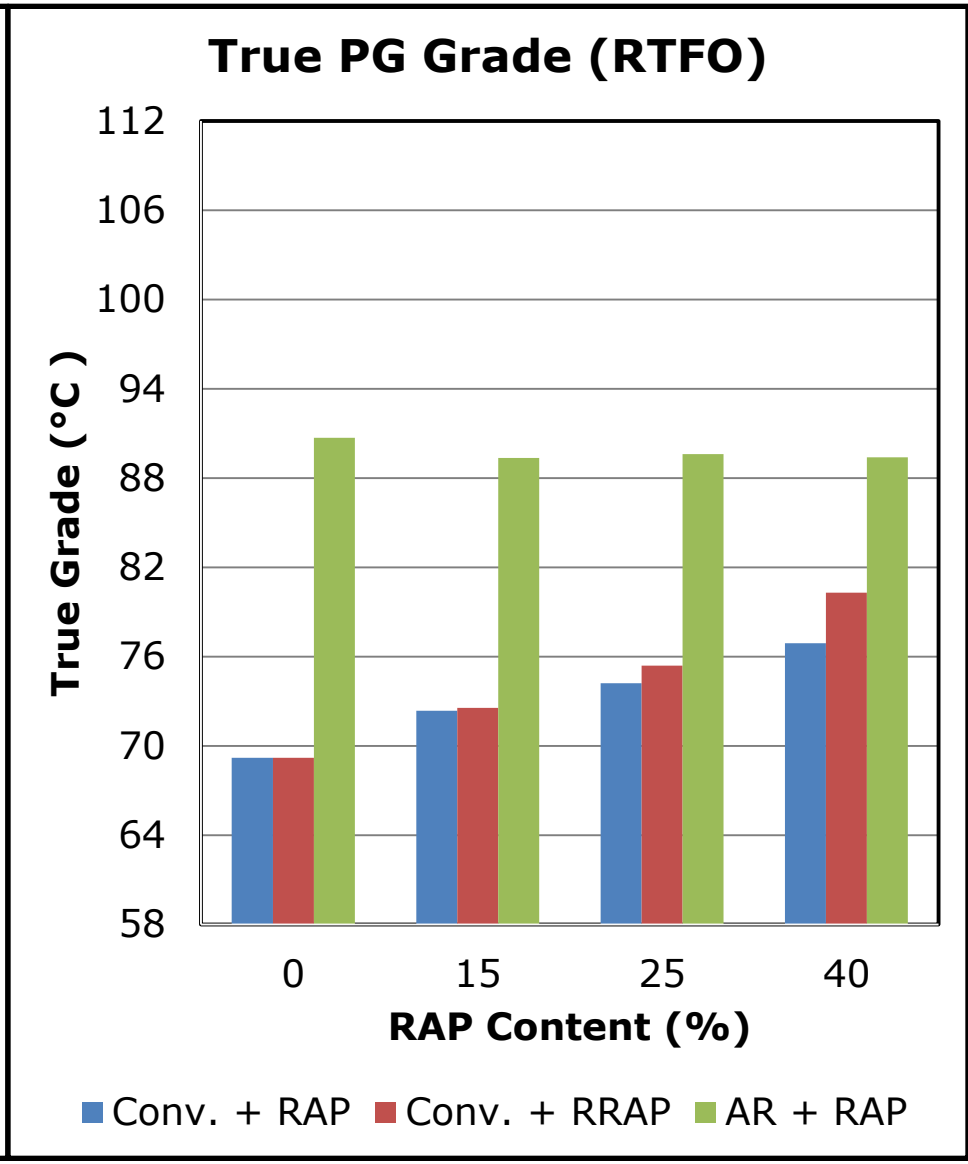
# Artificial RAP/RRAP Binders

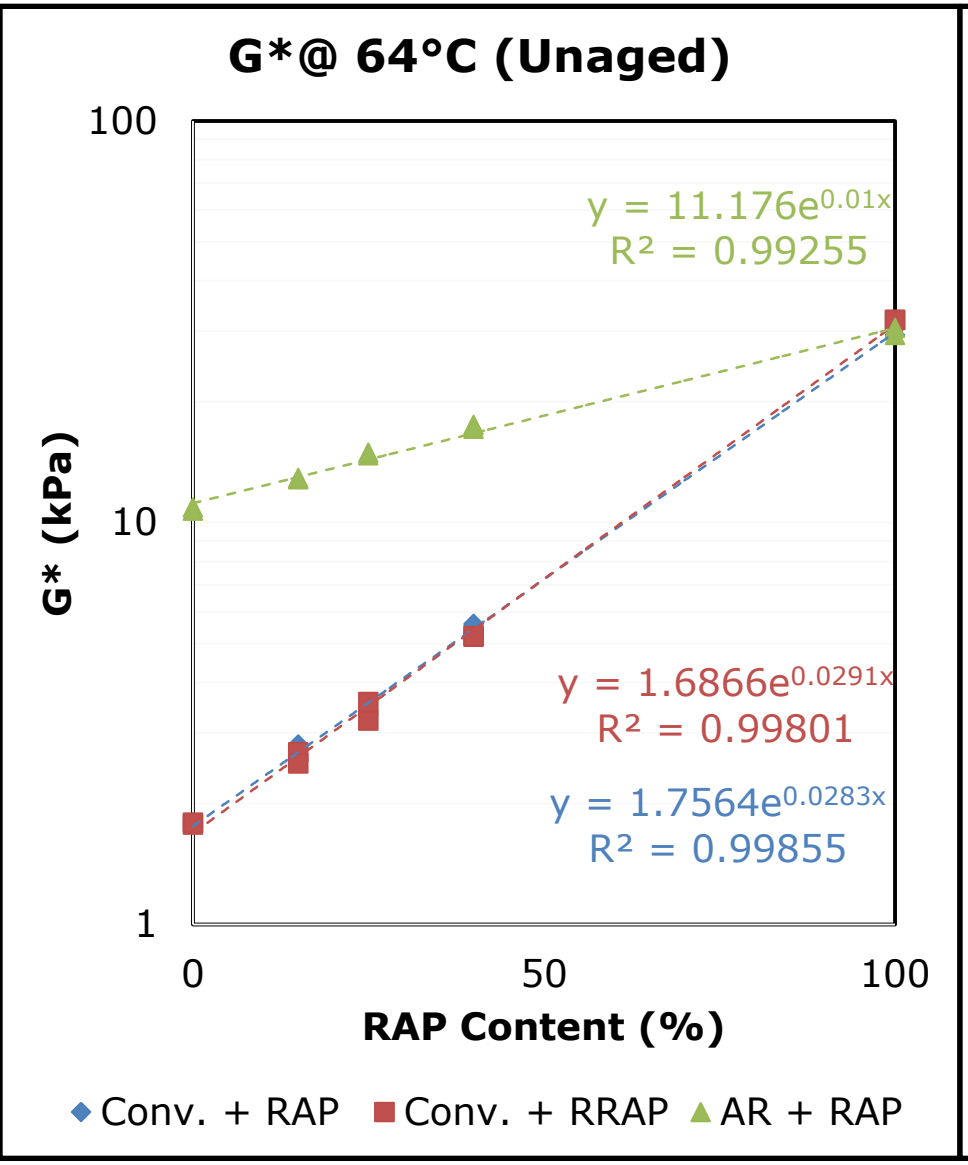
- The artificial RAP and R-RAP binders were prepared in a Pressure Aging Vessel (PAV) for 40 hours at 100˚C.

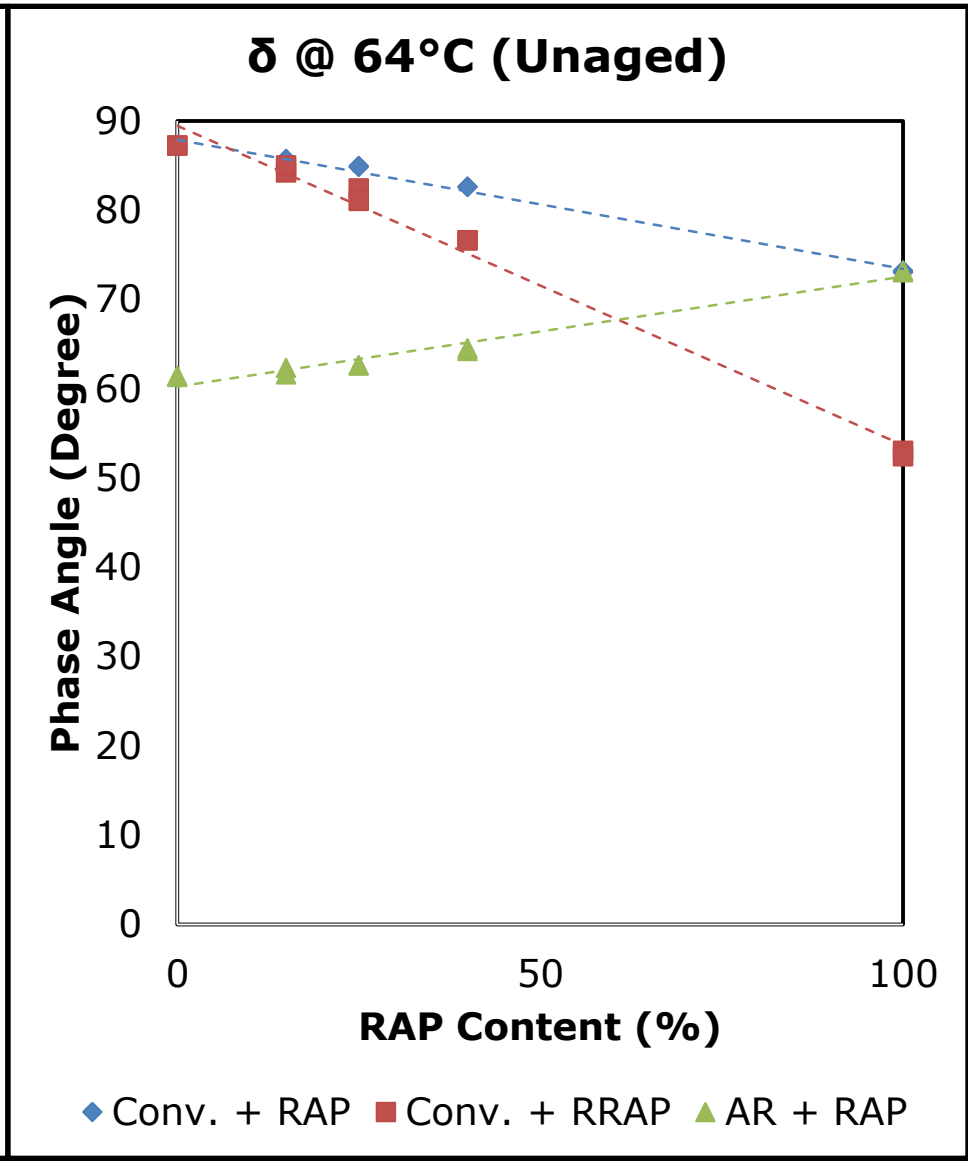
Artificial R-RAP

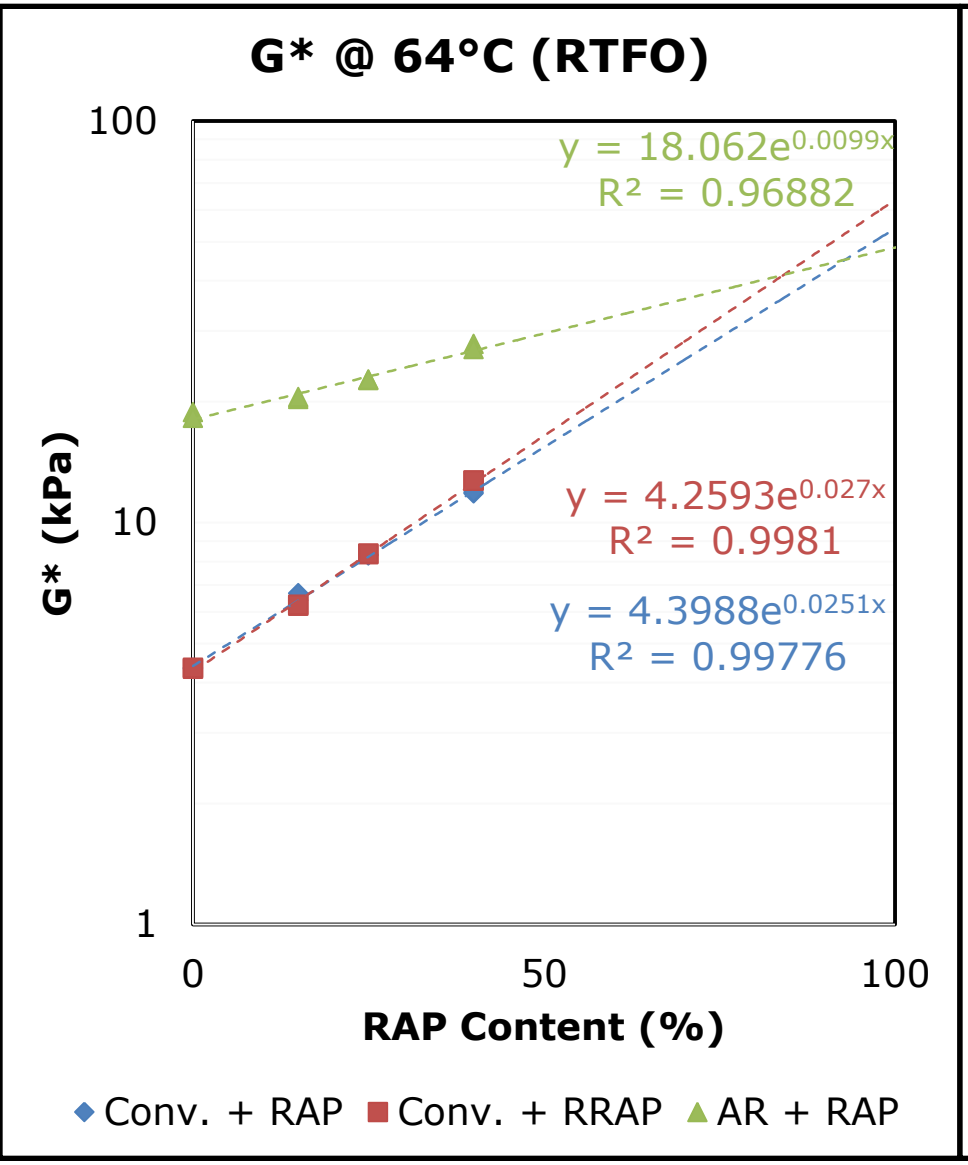
# RESULTS & CONCLUSIONS

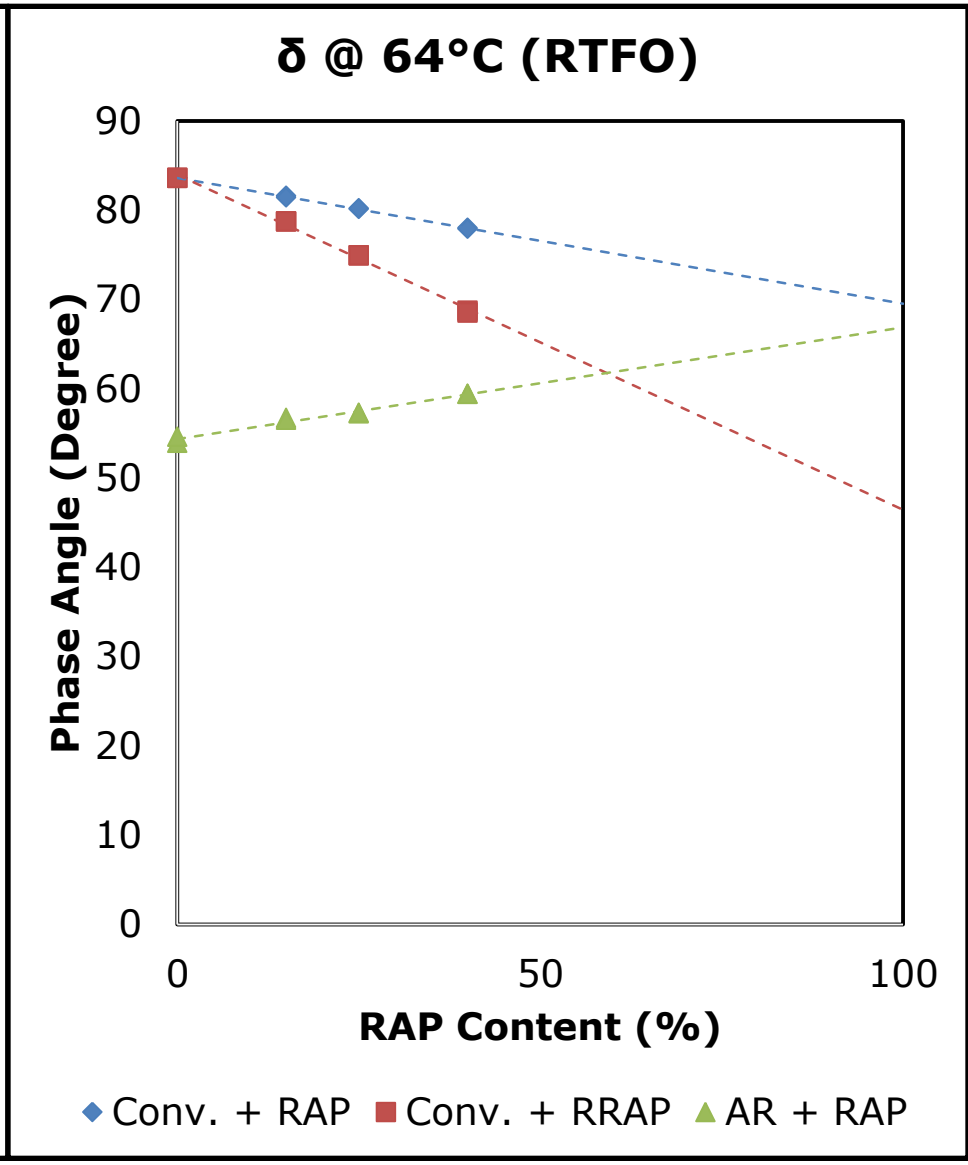

True PG Grade (Unaged)
True Grade (°C )
112
106
100
94
88
82
76
70
64
58
0
15
25
40
100
RAP Content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP

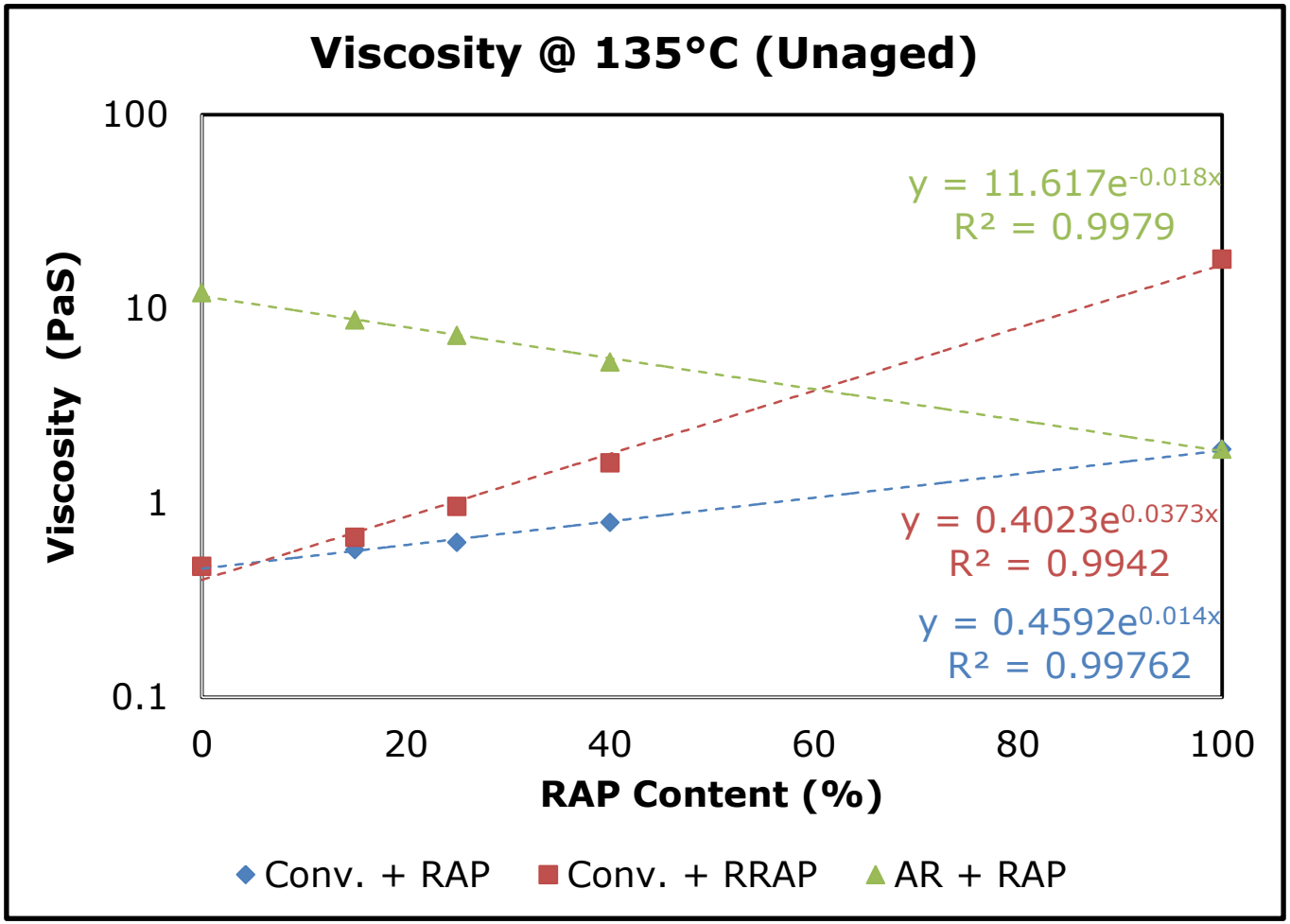

True PG Grade (RTFO)
True Grade (°C )
112
106
100
94
88
82
76
70
64
58
0
15
25
40
RAP Content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP

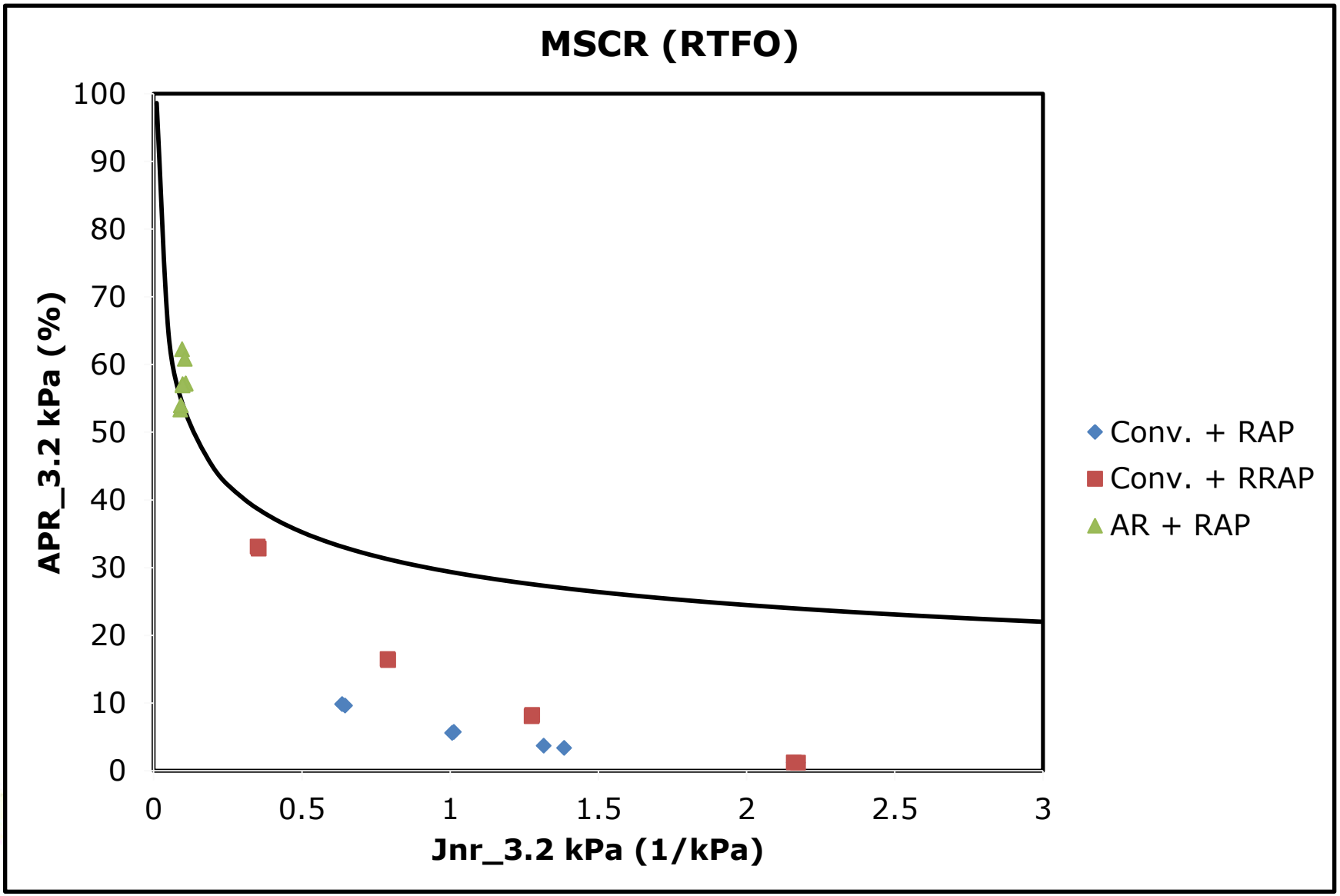

G*@ 64°C (Unaged)
100
10
1
G* (kPa)
y = 11.176e0.01x
R² = 0.99255
y = 1.6866e0.0291x
R² = 0.99801
y = 1.7564e0.0283x
R² = 0.99855
0
50
100
RAP Content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP

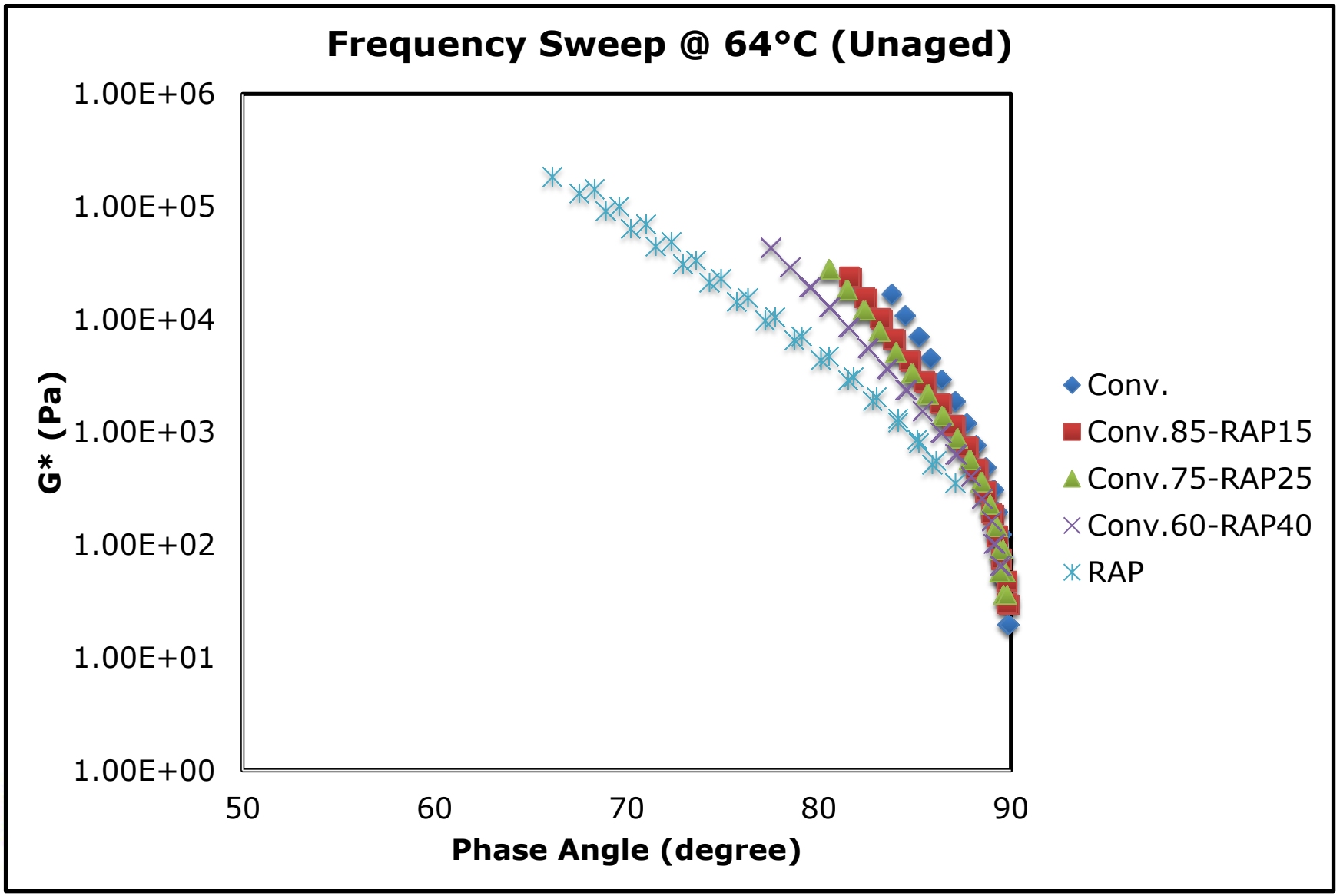

δ @ 64°C (Unaged)
90
80
70
60
50
40
30
20
10
0
Phase Angle (Degree)
0
50
100
RAP Content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP

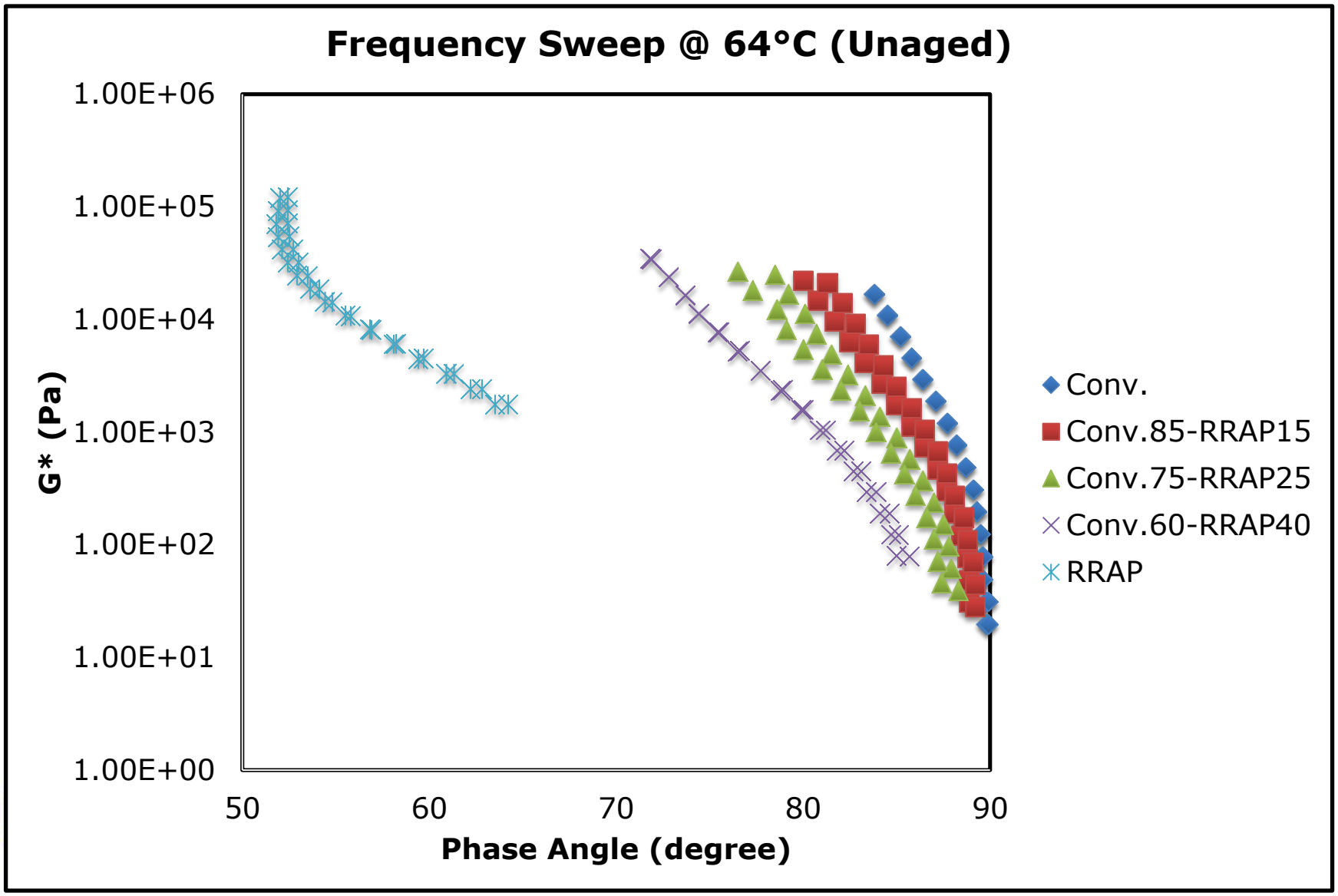

G* @ 64°C (RTFO)
100
10
1
G* (kPa)
y = 18.062e0.0099x
R² = 0.96882
y = 4.2593e0.027x
R² = 0.9981
y = 4.3988e0.0251x
R² = 0.99776
0
50
100
RAP Content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP

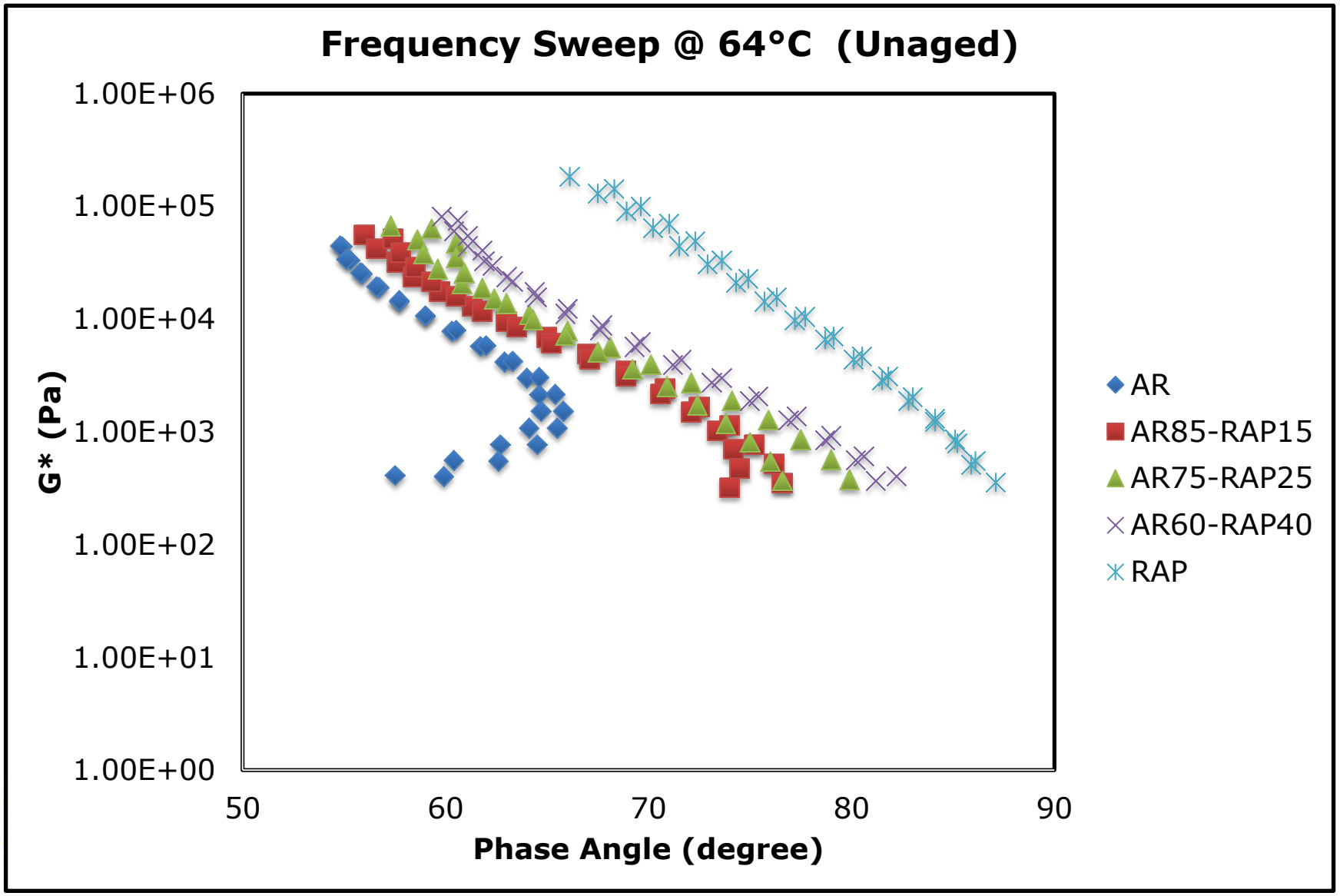

δ @ 64°C (RTFO)
90
80
70
60
50
40
30
20
10
0
Phase Angle (Degree)
0
50
100
RAP Content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP

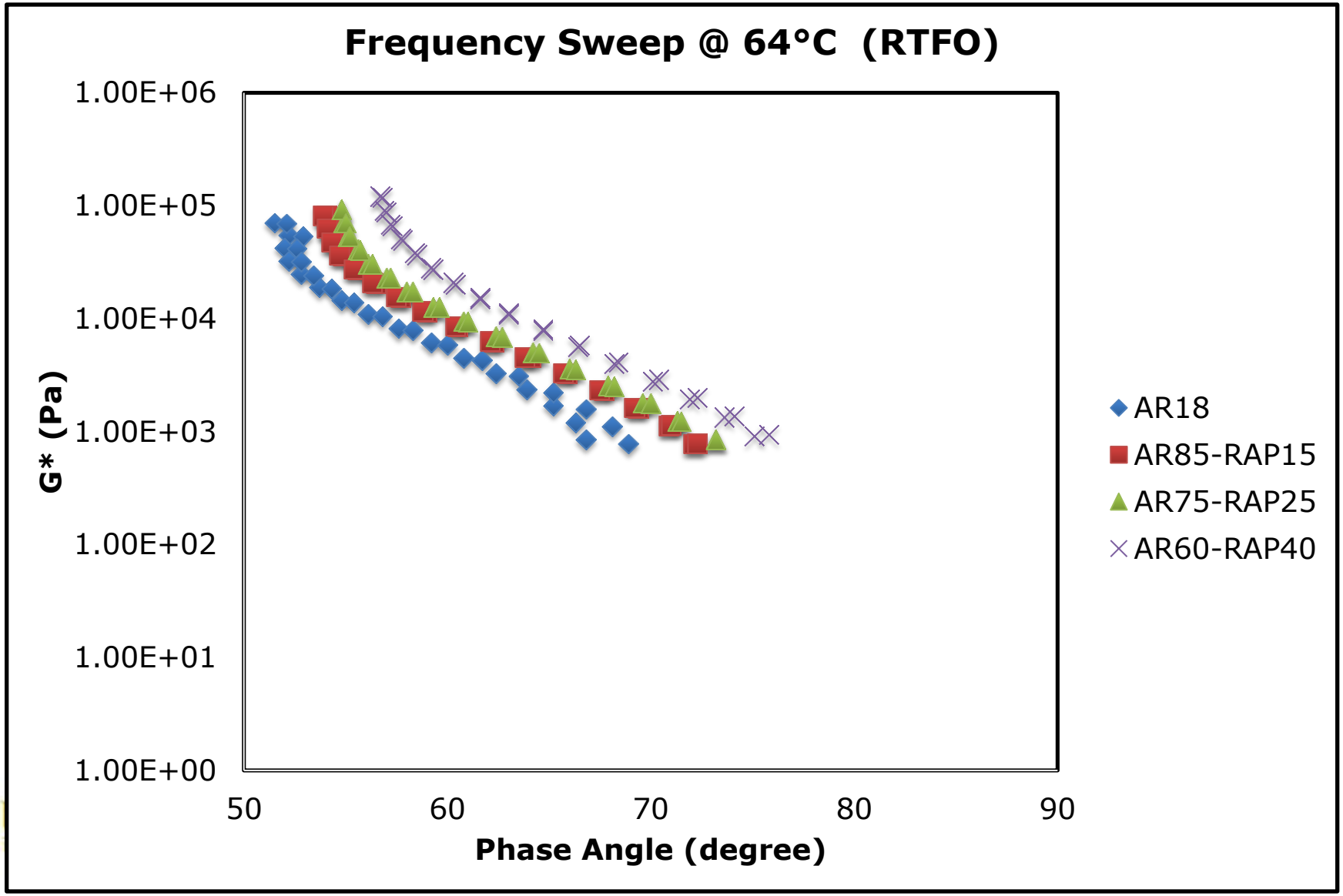

Viscosity @ 135°C (Unaged)
Viscosity (PaS)
100
10
1
0.1
0
20
40
60
80
100
RAP Content (%)
y = 11.617e-0.018x
R² = 0.9979
y = 0.4023e0.0373x
R² = 0.9942
y = 0.4592e0.014x
R² = 0.99762
Conv. + RAP
Conv. + RRAP
AR + RAP

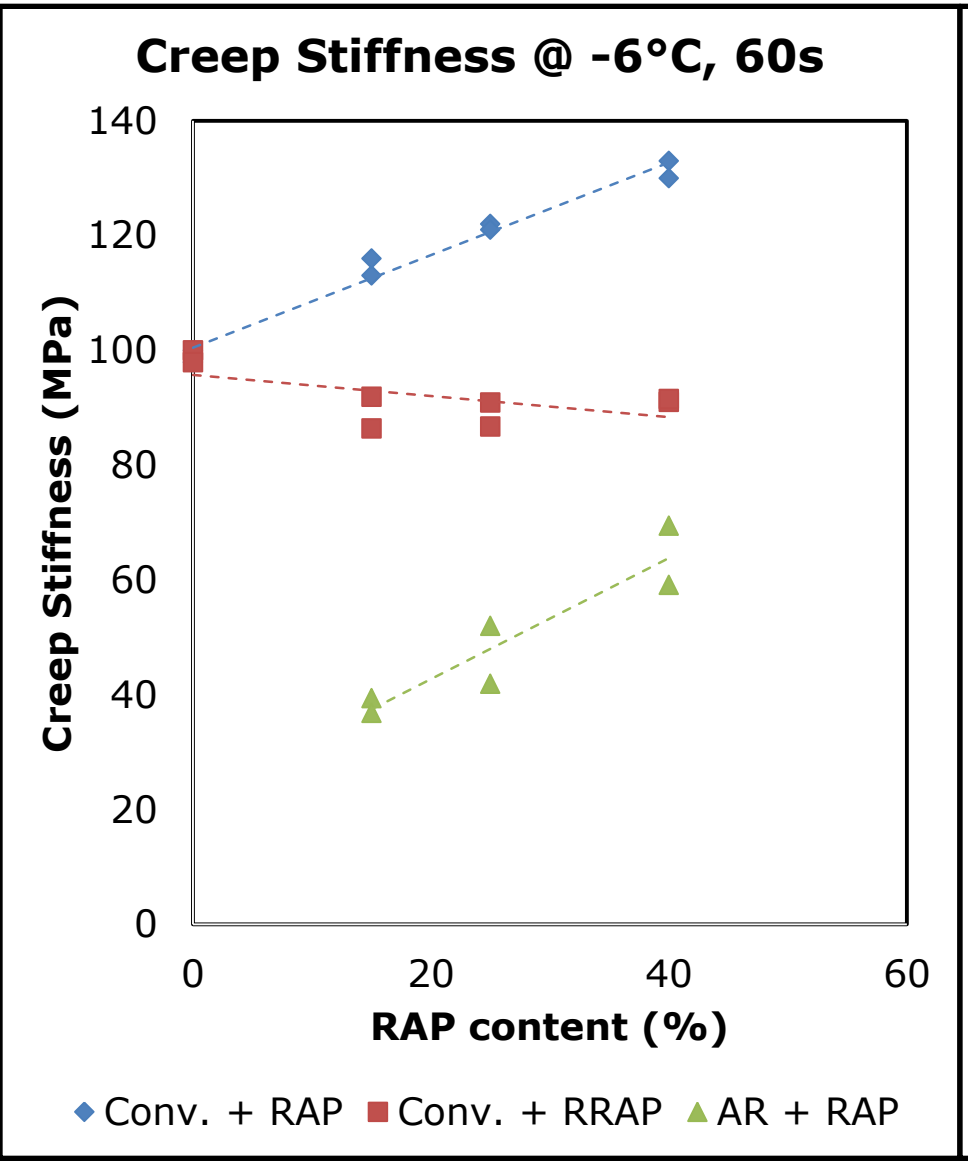

MSCR (RTFO)
APR_3.2 kPa (%)
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
Jnr_3.2 kPa (1/kPa)
Conv. + RAP
Conv. + RRAP
AR + RAP

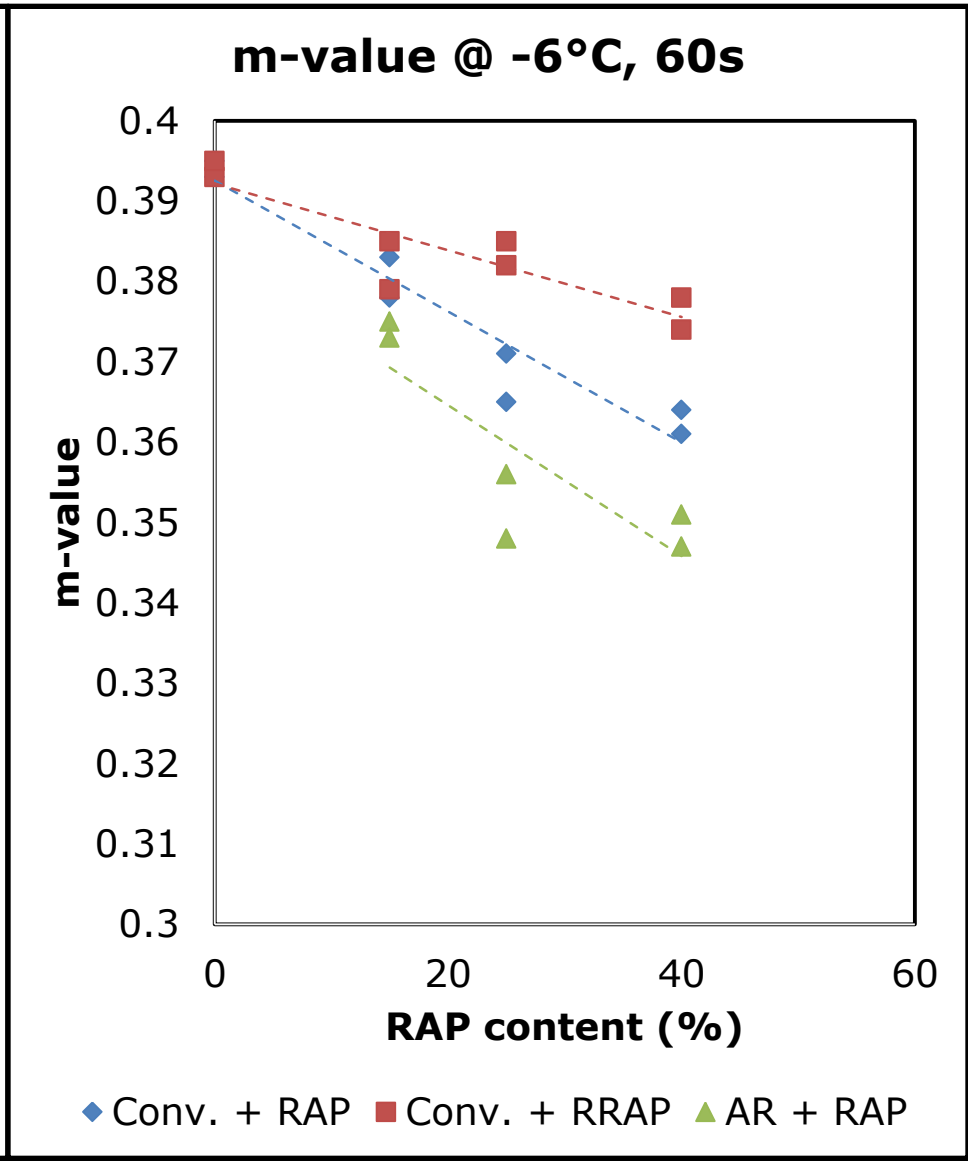

Frequency Sweep @ 64°C (Unaged)
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
G* (Pa)
50
60
70
80
90
Phase Angle (degree)
Conv.
Conv.85-RAP15
Conv.75-RAP25
Conv.60-RAP40
RAP


Frequency Sweep @ 64°C (Unaged)
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
G* (Pa)
50
60
70
80
90
Phase Angle (degree)
Conv.
Conv.85-RRAP15
Conv.75-RRAP25
Conv.60-RRAP40
RRAP


Frequency Sweep @ 64°C (Unaged)
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
G* (Pa)
50
60
70
80
90
Phase Angle (degree)
AR
AR85-RAP15
AR75-RAP25
AR60-RAP40
RAP


Frequency Sweep @ 64°C (RTFO)
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
G* (Pa)
50
60
70
80
90
Phase Angle (degree)
AR18
AR85-RAP15
AR75-RAP25
AR60-RAP40


Creep Stiffness @ -6°C, 60s
Creep Stiffness (MPa)
140
120
100
80
60
40
20
0
0
20
40
60
RAP content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP


m-value @ -6°C, 60s
m-value
0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.3
0
20
40
60
RAP content (%)
Conv. + RAP
Conv. + RRAP
AR + RAP

# Conclusions

- **Using concentric cylinder geometry on DSR accurately captures the changes between different blended binders.**
- **Rubberized binders are more elastic compared to conventional binders.**
- **Rubberized binders are less temperature susceptible than conventional binders.**
- **MSCR provides a better indication of rutting resistance than high temperature PG for rubberized binders.**

# Conclusions

- **RRAP provides better rutting and low temperature cracking resistance compared to RAP on conventional binders containing RAP.**

- **RAP has little effect on rutting resistance but negative effects on low temperature cracking resistance.**

# Acknowledgements

**Prof. John Harvey**
**UCPRC**



# Thank you