

Characterizing RAP Binder Properties through Impact Resonance Testing of Asphalt Mixtures

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**Mansour Solaimanian, Ph.D., P.E.
Ilker Boz
Penn State University**



Outline

- 1 Current Practice in RAP Binder Characterization
- 2 What is the Impact Resonant Test (IRT)?
- 3 Testing Asphalt Concrete with IRT
- 4 Results and Data Analysis
- 5 Application Methodology



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- 1 **Current Practice in RAP Binder Characterization**
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RAP USAGE

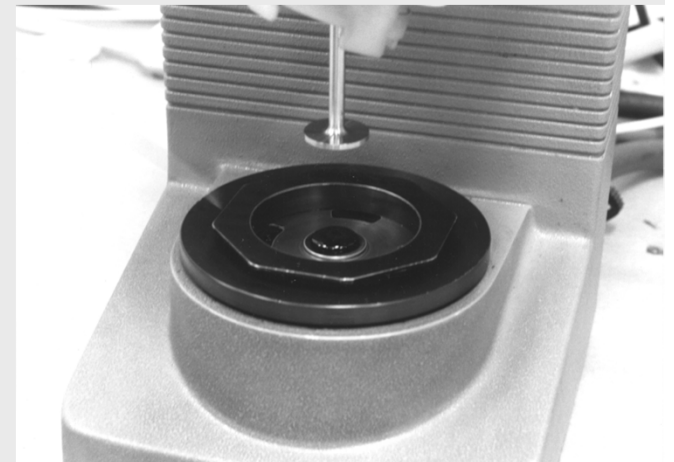
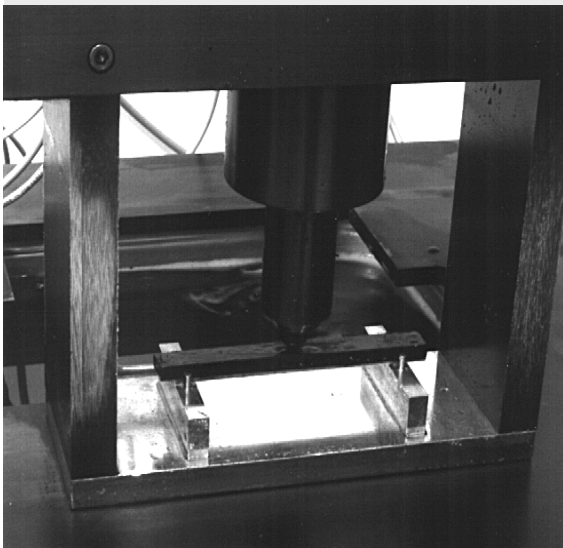
- Approximately 66.7 million tons of RAP recycled in 2011.



- #1 Recycling product in USA
(NAPA and FHWA, 2011).

Process for RAP Binder Characterization

- Common practice for determination of RAP binder properties?
 - Binder Extraction
 - Binder Recovery
 - Rheological Testing to Grade



Process for RAP Binder Characterization?

- Concerns:
 - Time consuming.
 - Environmental concerns.
 - Possibility of change in binder properties.



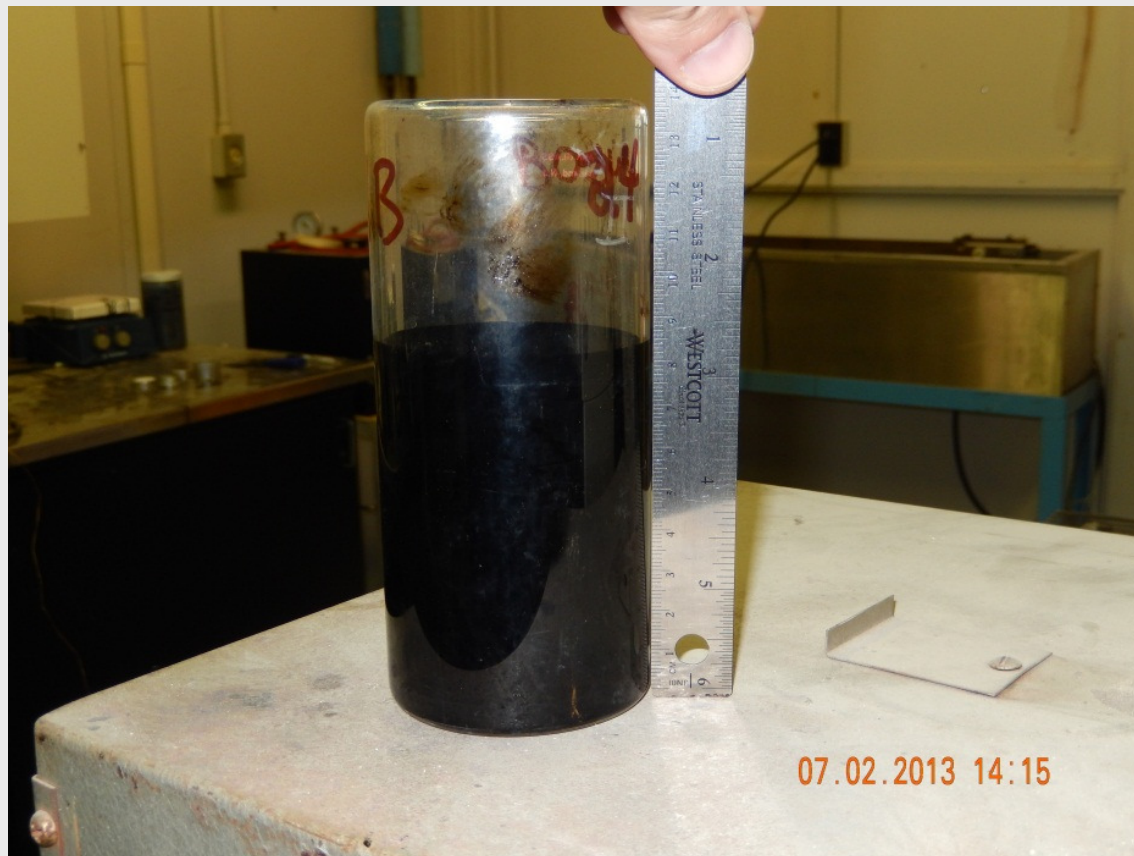
Binder Recovered from RAS Too Stiff to Pour

190°C



Binder Recovered from RAS

Right after RTFO aging: binder not covering the entire bottle

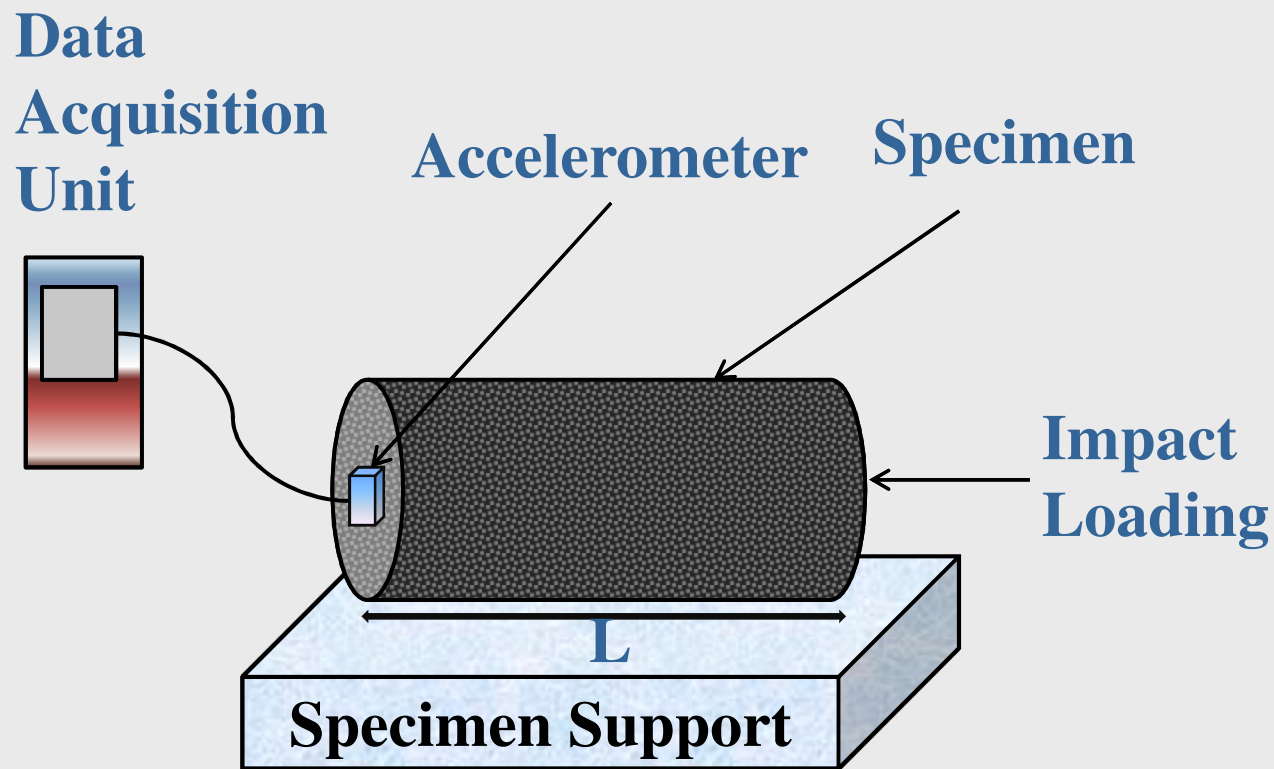


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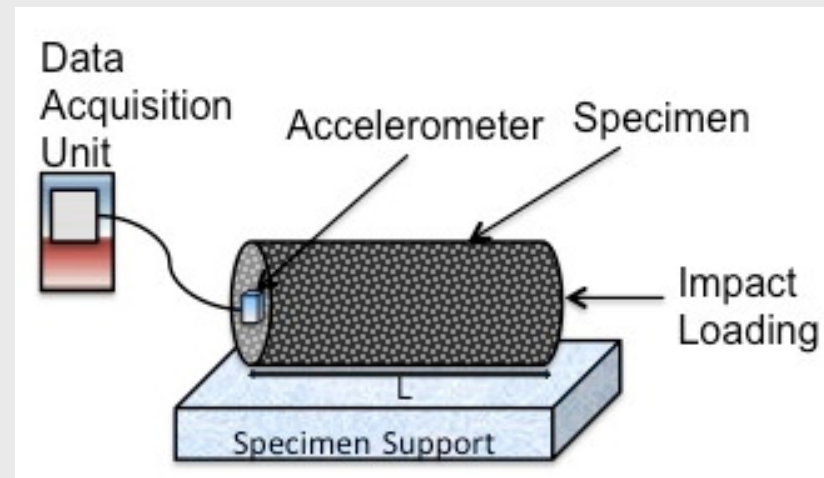
An Alternative The Impact Resonance Test



An Alternative

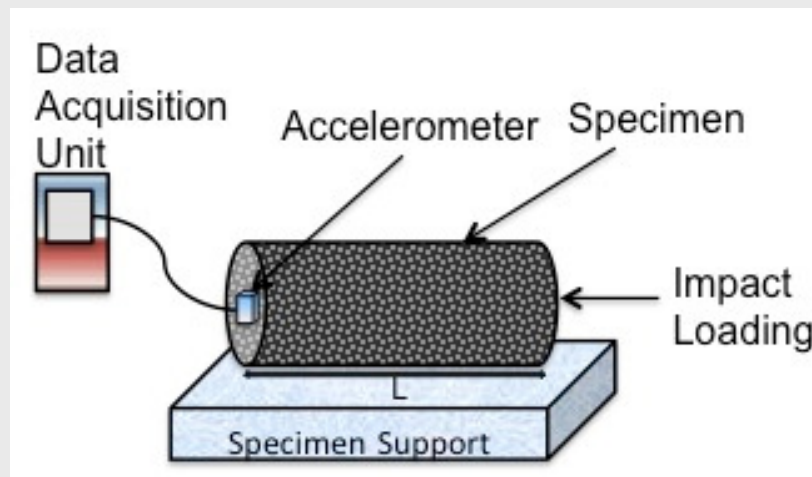
The Impact Resonance Test

- What Do We Consider A Good Testing Protocol?
 - Simple
 - Fast
 - Inexpensive
 - Repetitive
 - Reliable



The Impact Resonance Test Fundamentals

- A non-destructive technique
- Capture material properties from resonant frequencies
- Capture the vibration amplitude and the rate of attenuation
- Relating these parameters to the material properties.

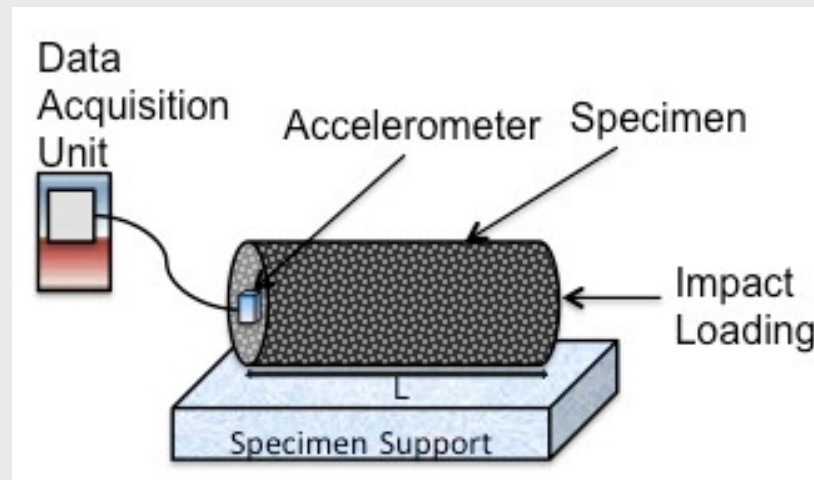


The Impact Resonance Test

Applications

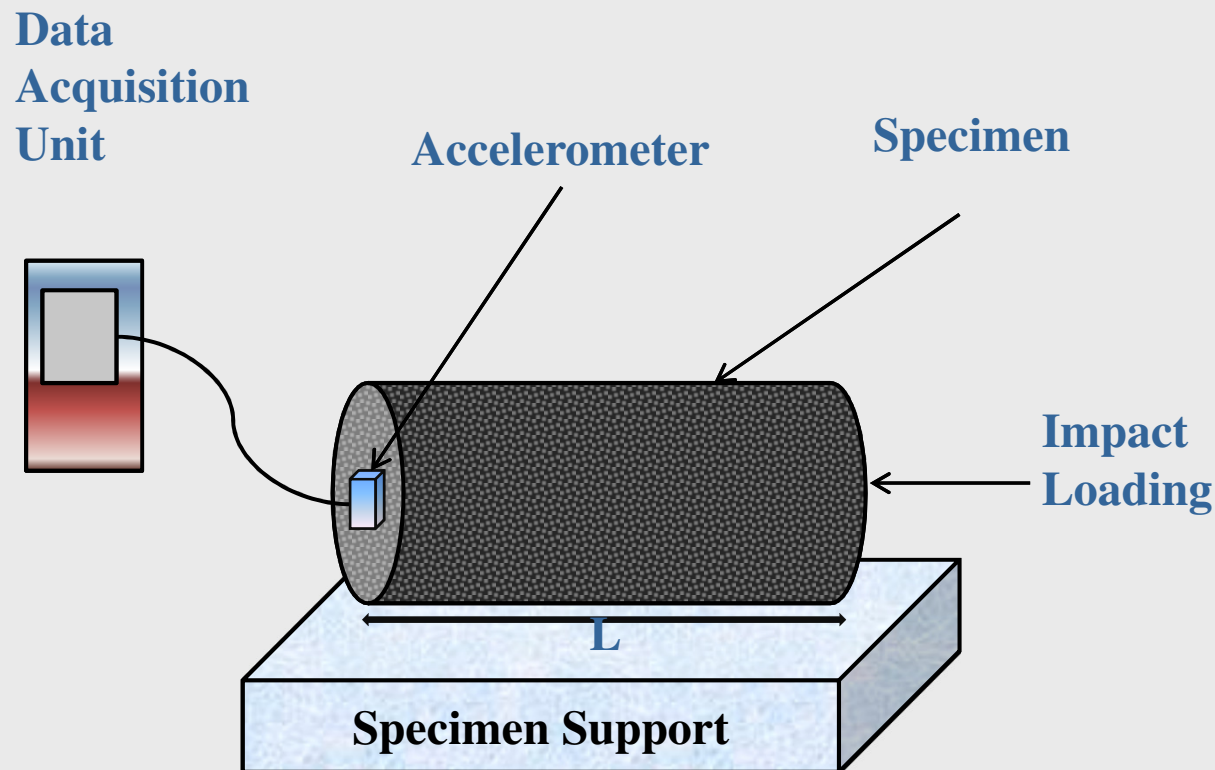
- Has been used in determination of engineering properties of a wide range of materials:

Concrete, Soil, Wood, and Ceramic...



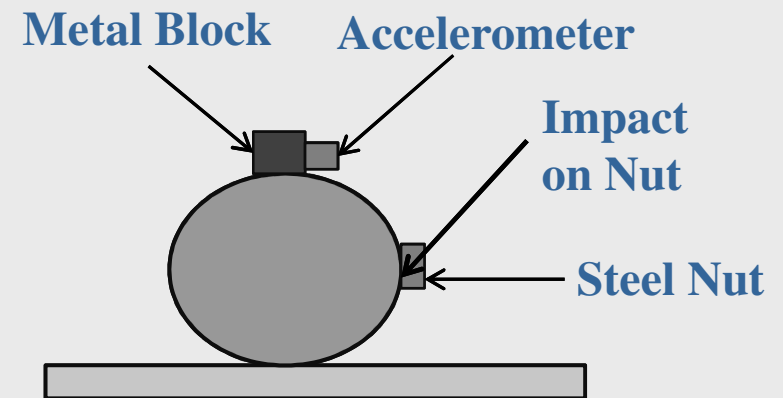
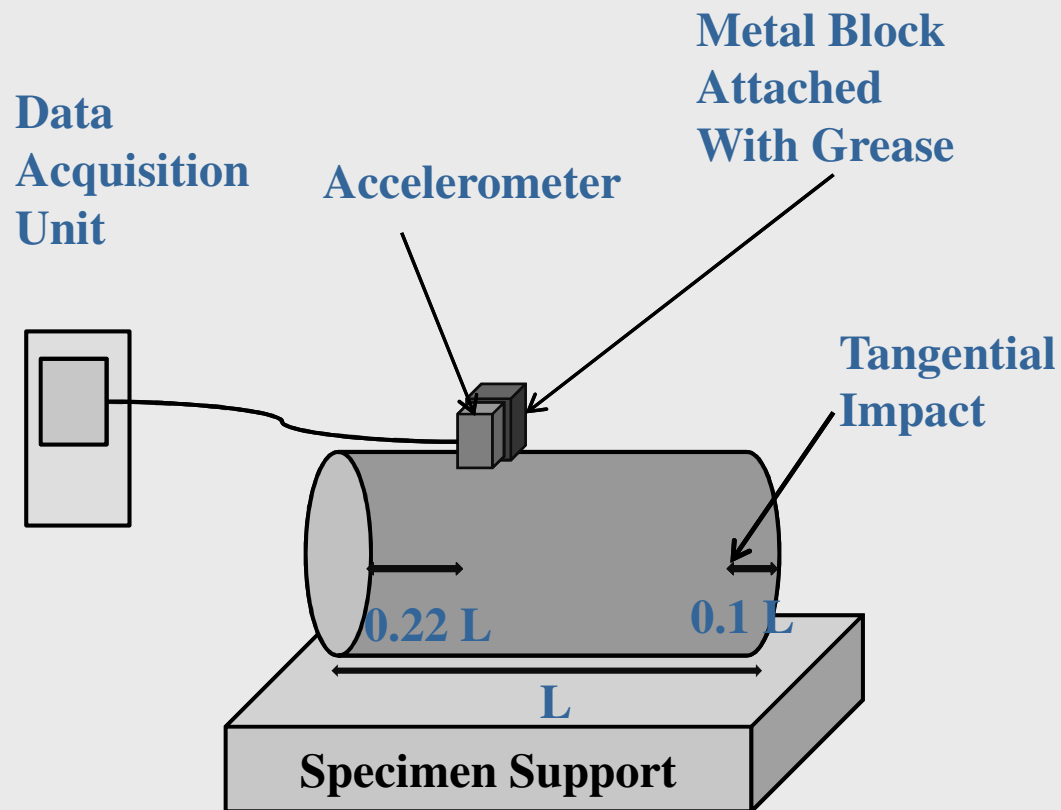
The Impact Resonance Test

- Longitudinal Mode of Testing



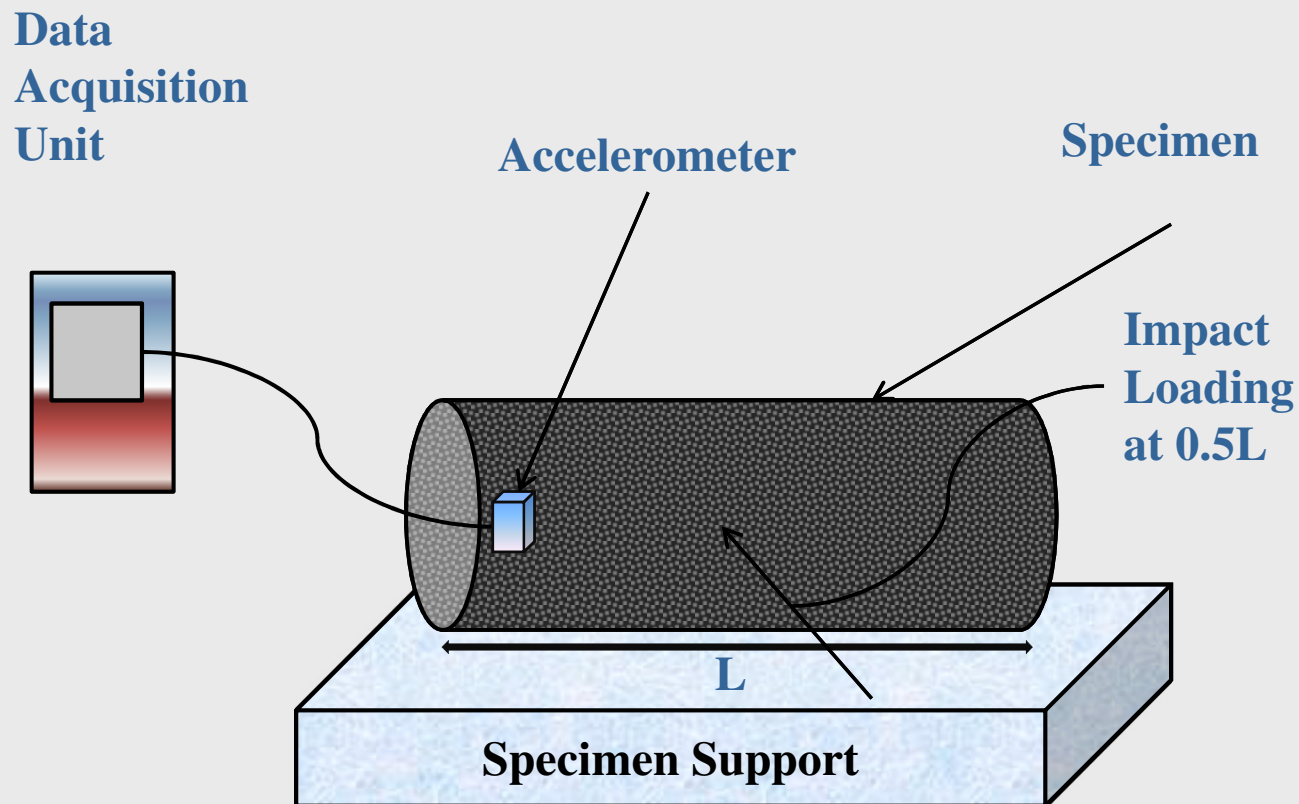
The Impact Resonance Test

■ Torsional Mode of Testing

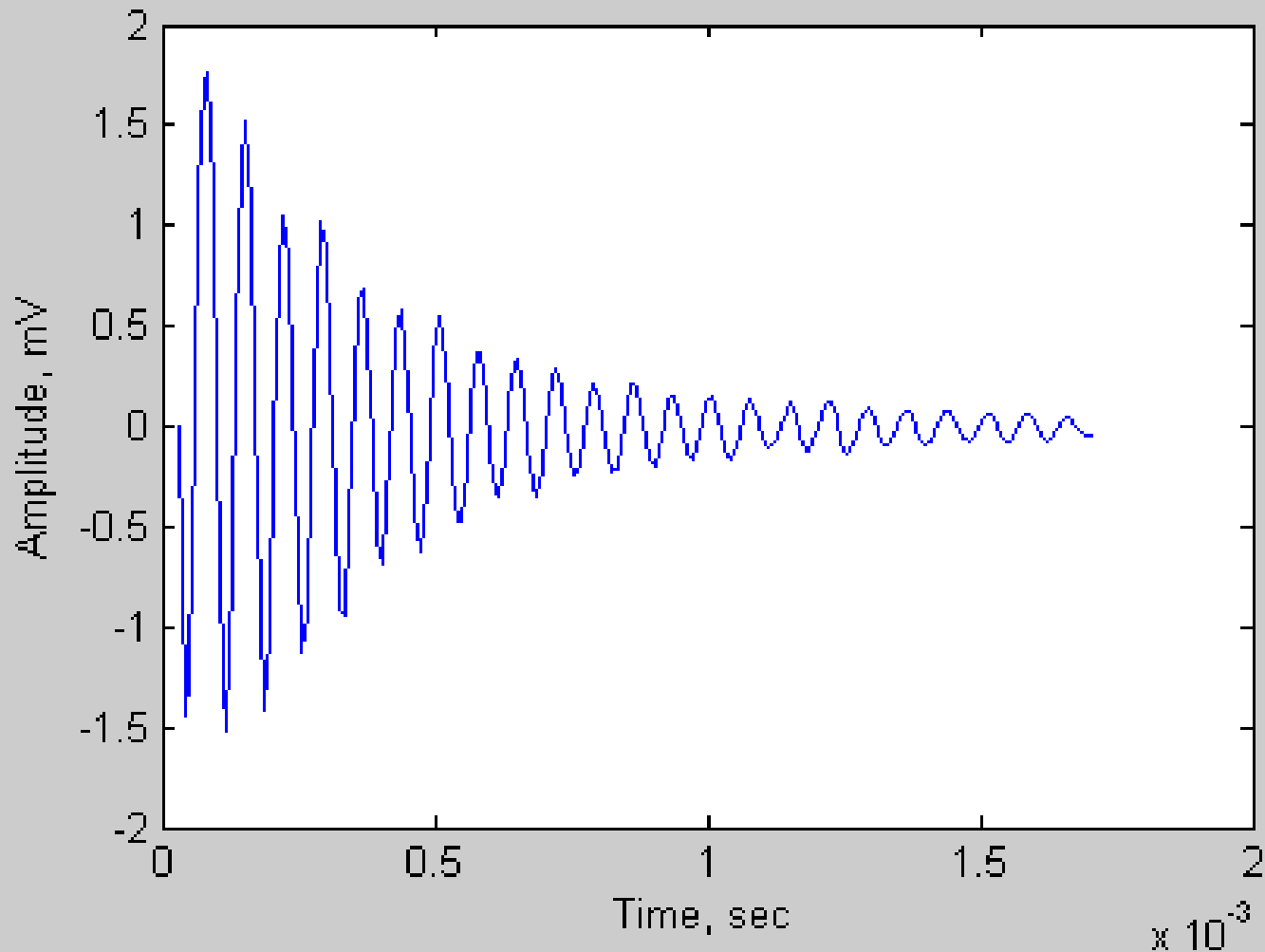


The Impact Resonance Test

- Transverse Mode of Testing



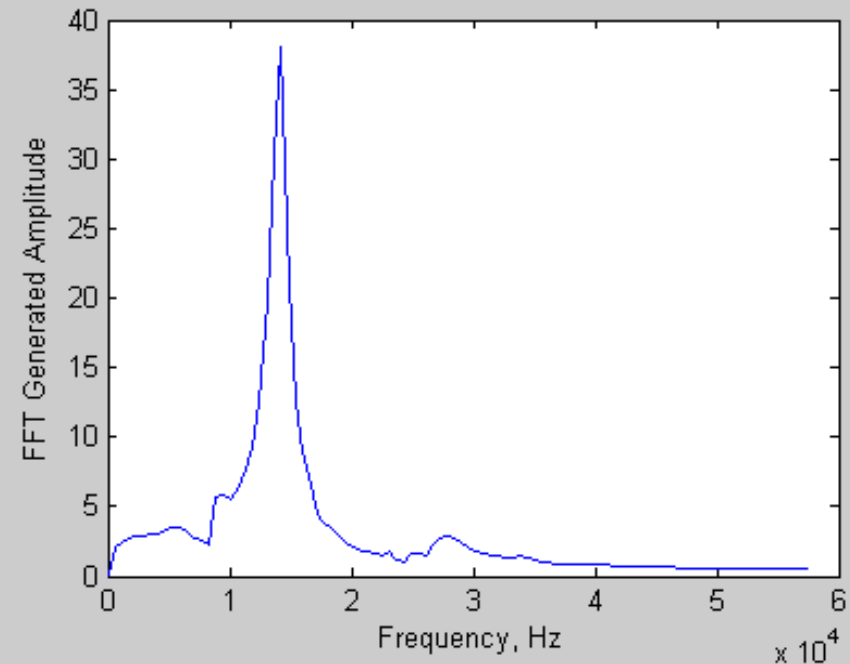
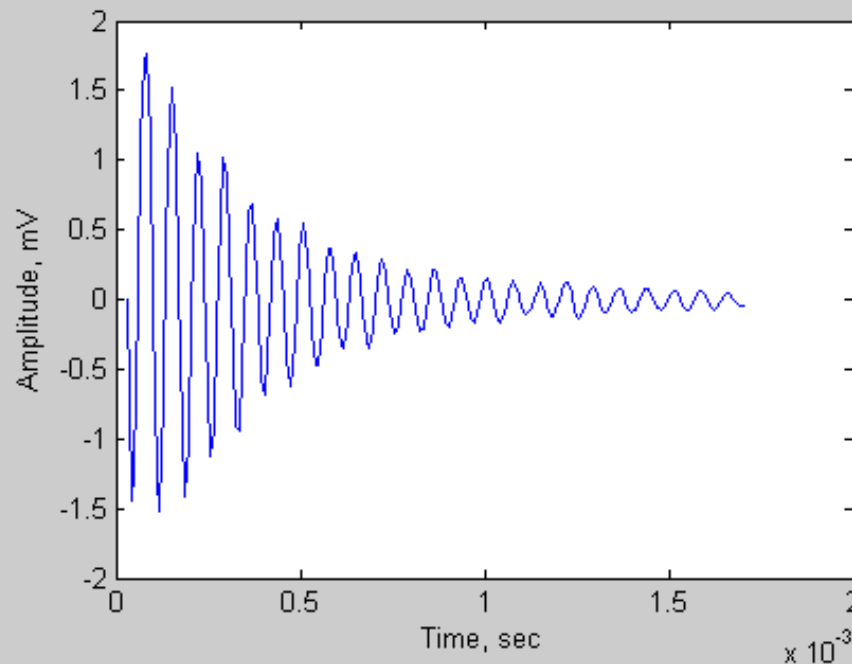
The Impact Resonance Test Response



The Impact Resonance Test Response

Time Domain

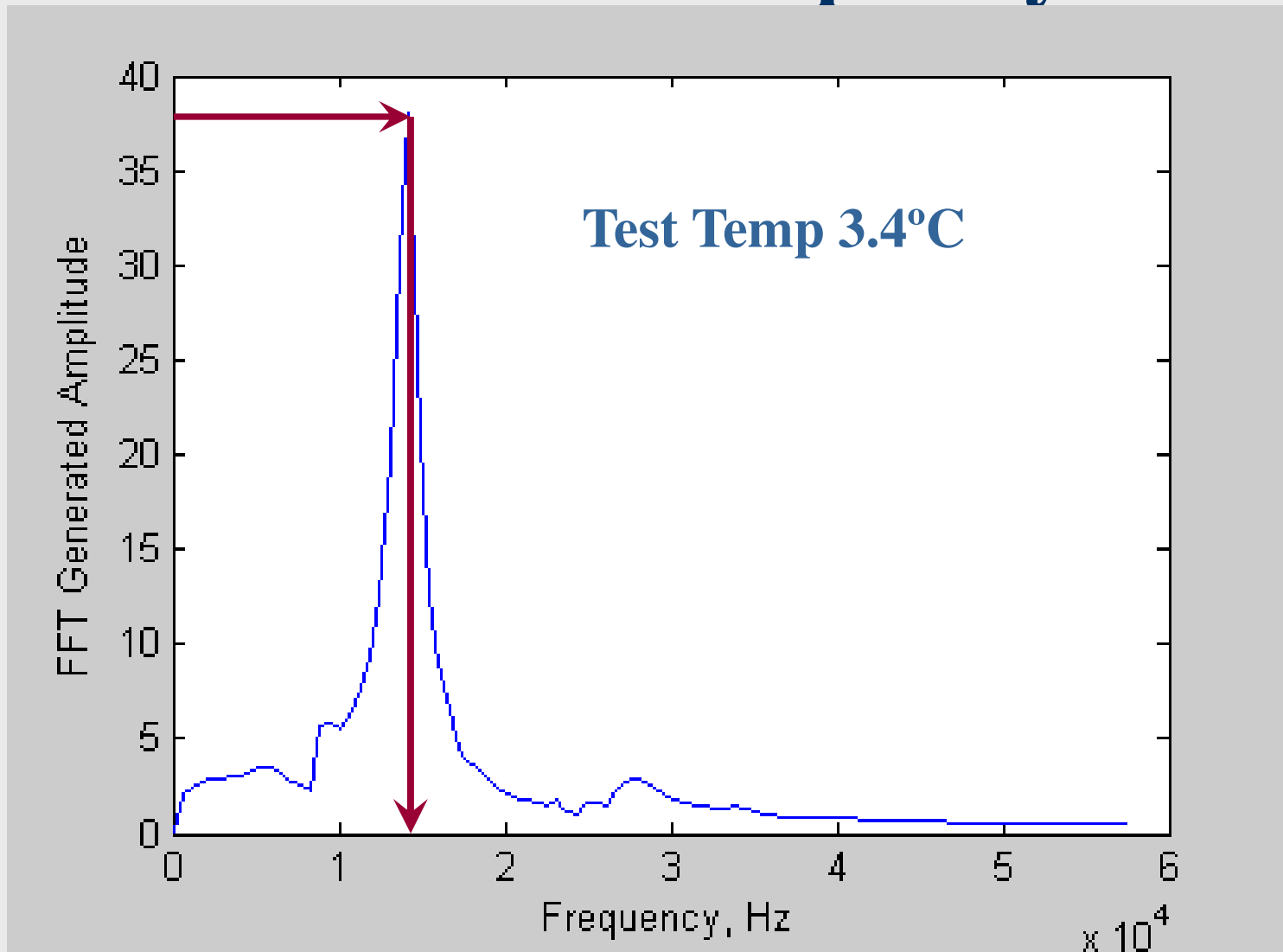
Frequency Domain



FFT



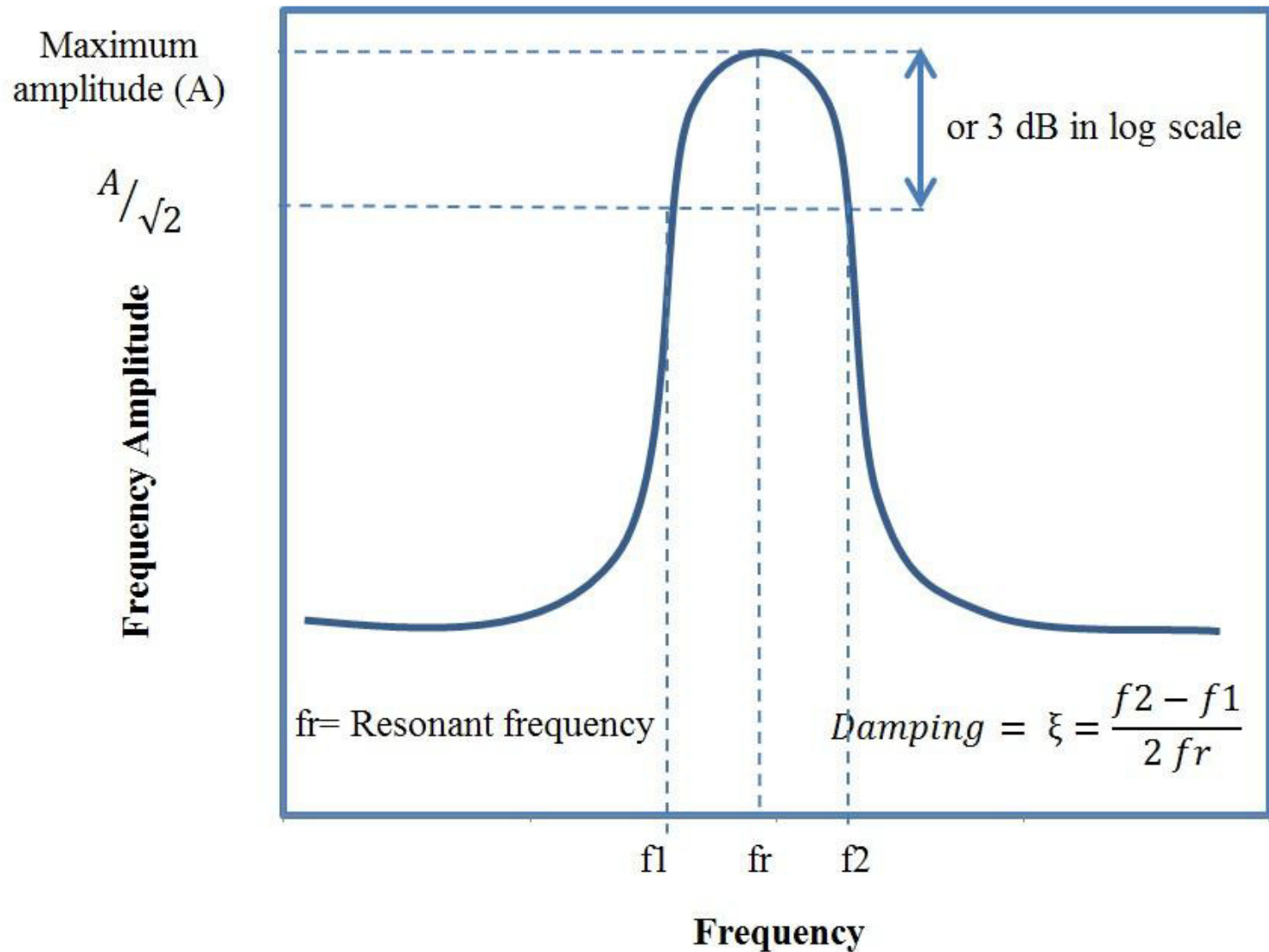
Resonance Frequency



Frequency Domain



Damping Calculations



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The Impact Resonance Test

- In Asphalt Concrete: considerable attention in the last two decades
 - Determination of Elastic Properties: Poisson's Ratio and Elastic Modulus (Whitmoyer and Kim, 1994).
 - Evaluation of Healing and Fatigue Behavior (Daniel and Kim, 2001).
 - Dyn. Mod. Master Curve Construction (Kim and Lee, 1995, Kweon and Kim, 2006, La Croix et al., 2009, and Ryden, 2011).



The Impact Resonance Test



The Impact Resonance Test

Component	Type	Characteristics
Data Acquisition Unit	-	Sampling Rate: 8.6 μ s (116 kHz)
Accelerometer	Piezoelectric	Freq. Range: 100 to 100,000 Hz
Impact Hammer	Allen Wrench	Diameter: 4.8 mm Weight: 21.1 grams
Supporting Mat	Sponge Rubber	40 cm x 32 cm x 2.5 cm



Experimental Program

- Materials:
 - One source of virgin aggregate.
 - One source of RAP.
 - Three different binder grades.
 - PG58-28
 - PG64-22
 - PG76-22



Experimental Program

- Two Stages of Work:
 - I: Does IRT differentiate among different binder grades?
 - II: Determine RAP binder high temperature properties.



Experimental Program (Virgin Aggregate)

- Six specimens made of 100% virgin aggregates with three different binder grades.
 - 5.4% Binder content.
 - Mix/Compact at 154°C.
 - Compacted size: D=150 mm, H=135mm
 - Saw-cut and cored: D=60 mm, H=120 mm
- Four hours of conditioning at target temperature in an environmental chamber.
- Test with IRT at 4, 10, 25 and 35°C



Experimental Program (Virgin Aggregate)

- Six specimens made of 100% virgin aggregates with three different binder grades.



Experimental Program (RAP Study)

- 100% RAP Specimens
 - Three batches for Gradation/Binder Content.
 - Three batches prepared for test specimens.
 - Mix/Compact at 135°C.
 - Compacted size: D=103 mm, H=123.6 mm.
 - Tested with IRT at a Range of Temperatures.

- Specimens with PG Binders
 - Total of six RAP batches from burn-off
 - Two batches used for loss compensation.
 - Four batches Used for Blending with Binders
 - Mix/Compact at 135°C.
 - Compacted size: D=103 mm, H=123.6 mm.
 - Test with IRT at a Range of Temperatures.



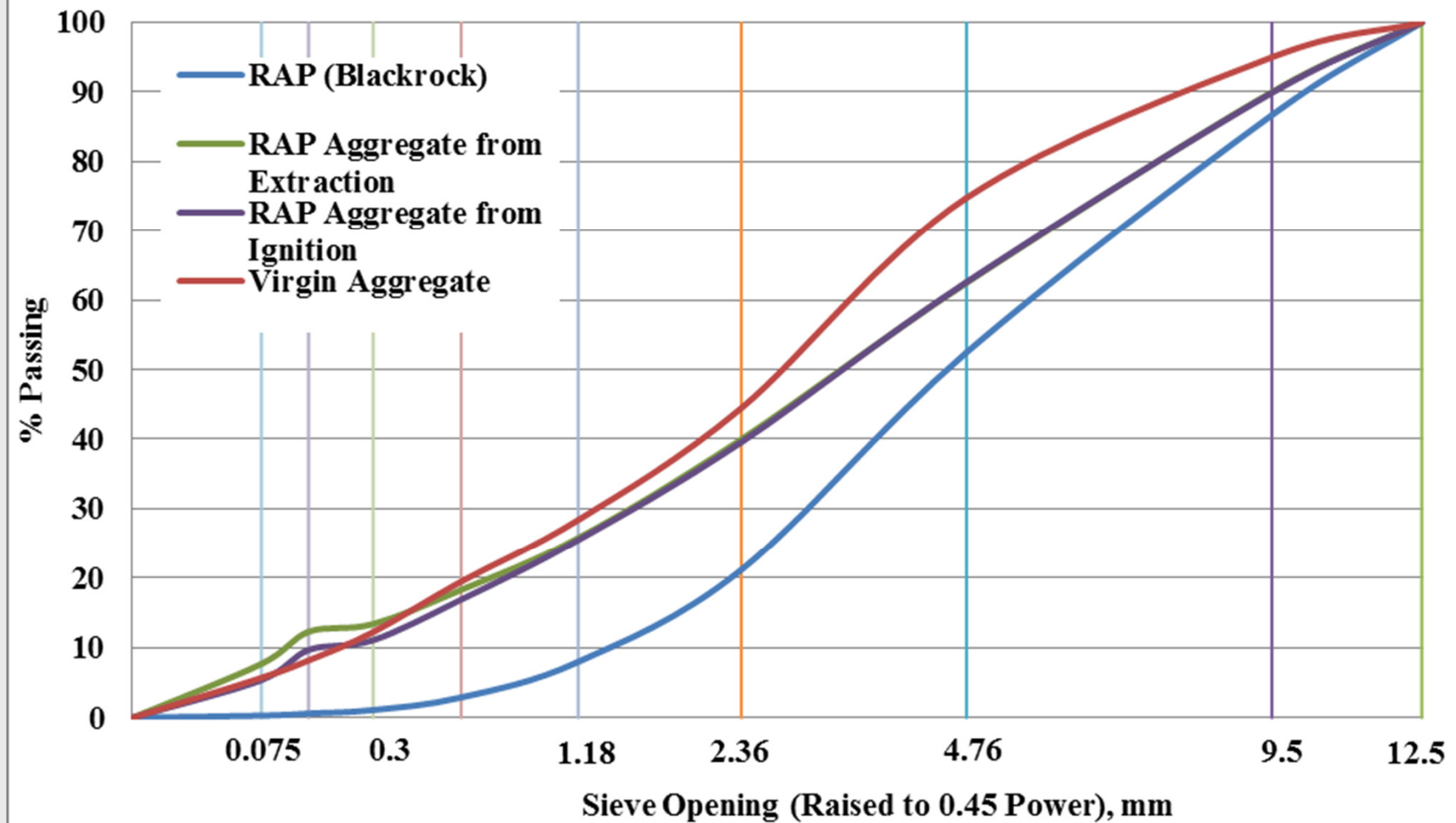
Experimental Program (RAP Study)

■ Material Characterization

- RAP stockpile gradation, “black rock”
- RAP binder content and aggregate gradation through recovery and extraction.
- RAP aggregate gradation through ignition oven.
- RAP moisture and theoretical specific gravity determination.



Experimental Program



Experimental Program (RAP Study)



Scalped RAP

Heated RAP (135°C, 2hrs)



100% RAP Specimen
(123 mm tall)

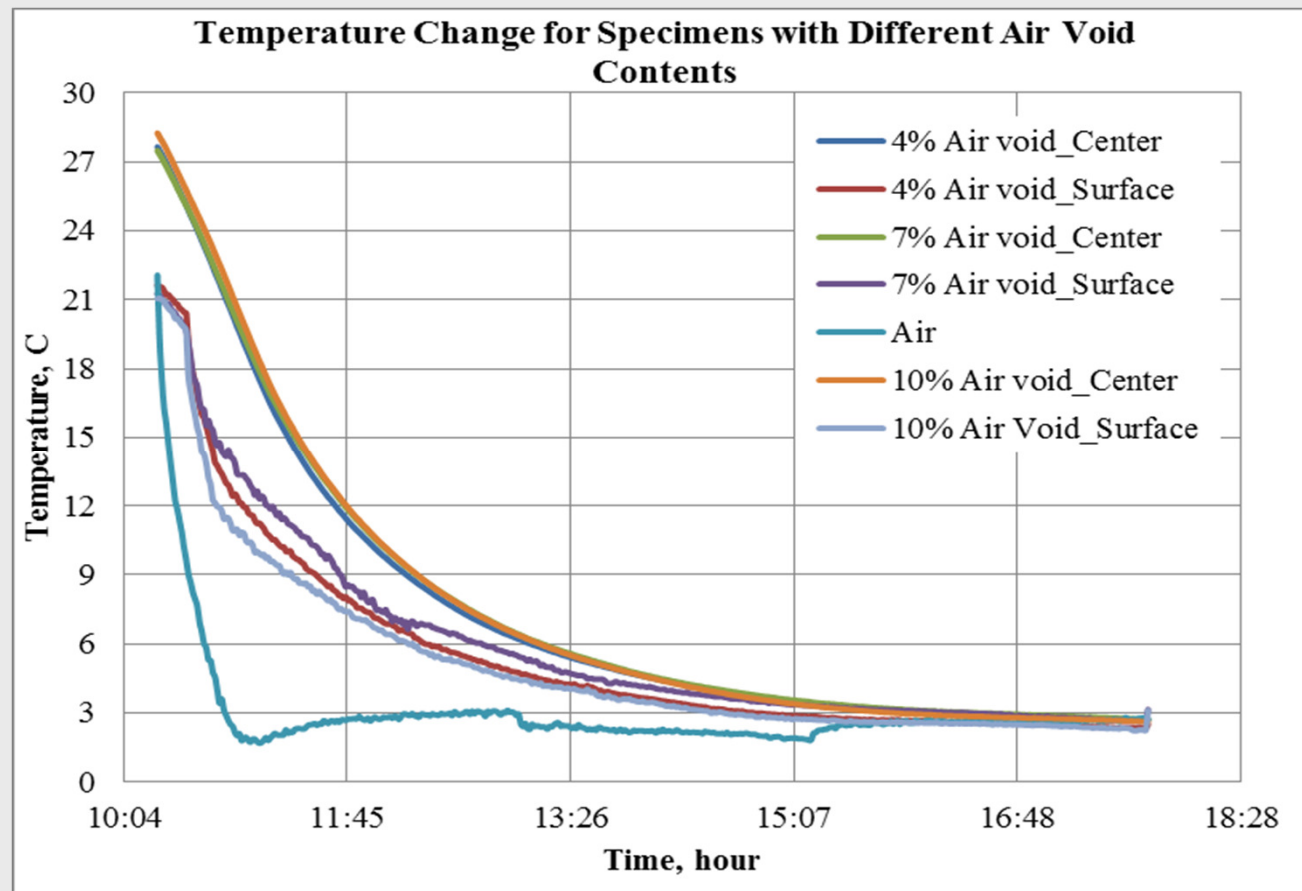


100% RAP Specimen Ready to Test



Experimental Program

■ Establishing Temperature Conditioning Time



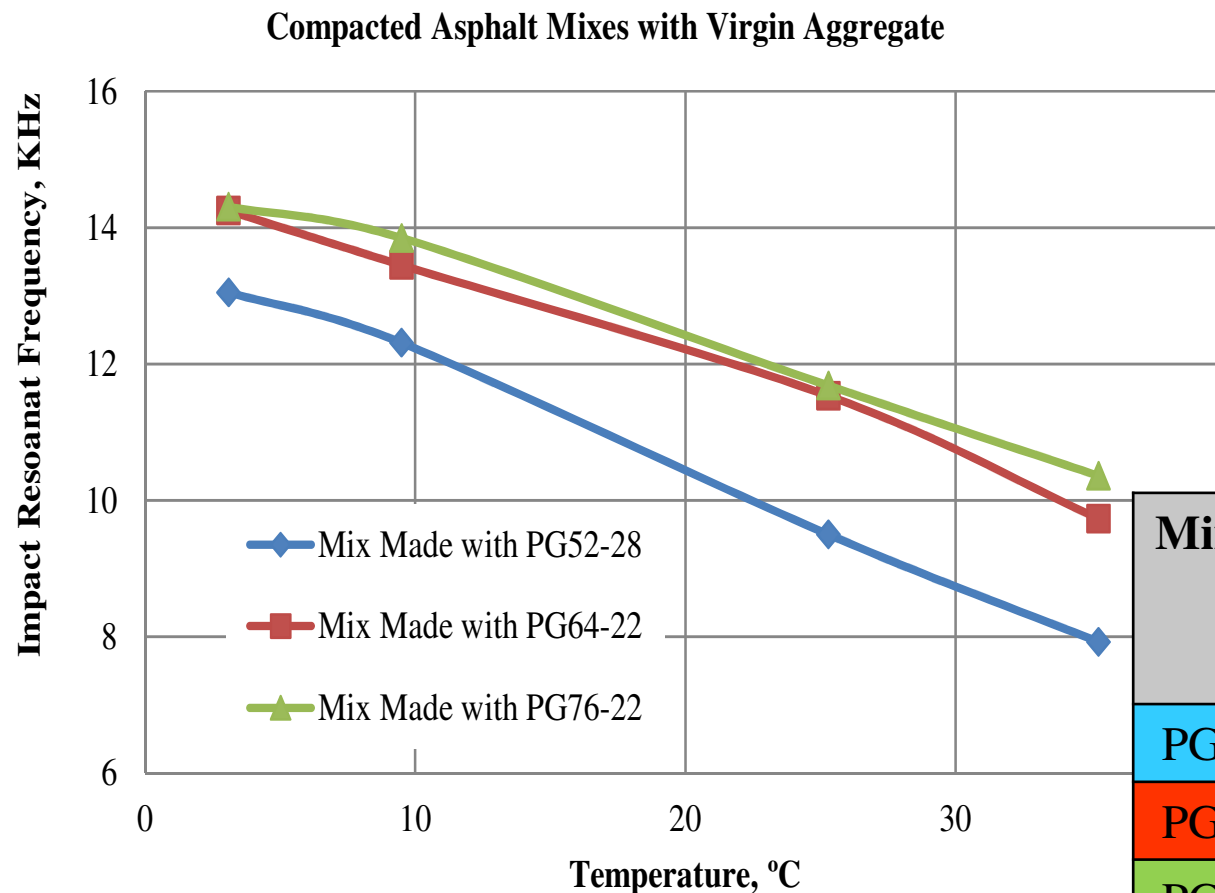
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IR Test Results

■ Mixes with Virgin Aggregate

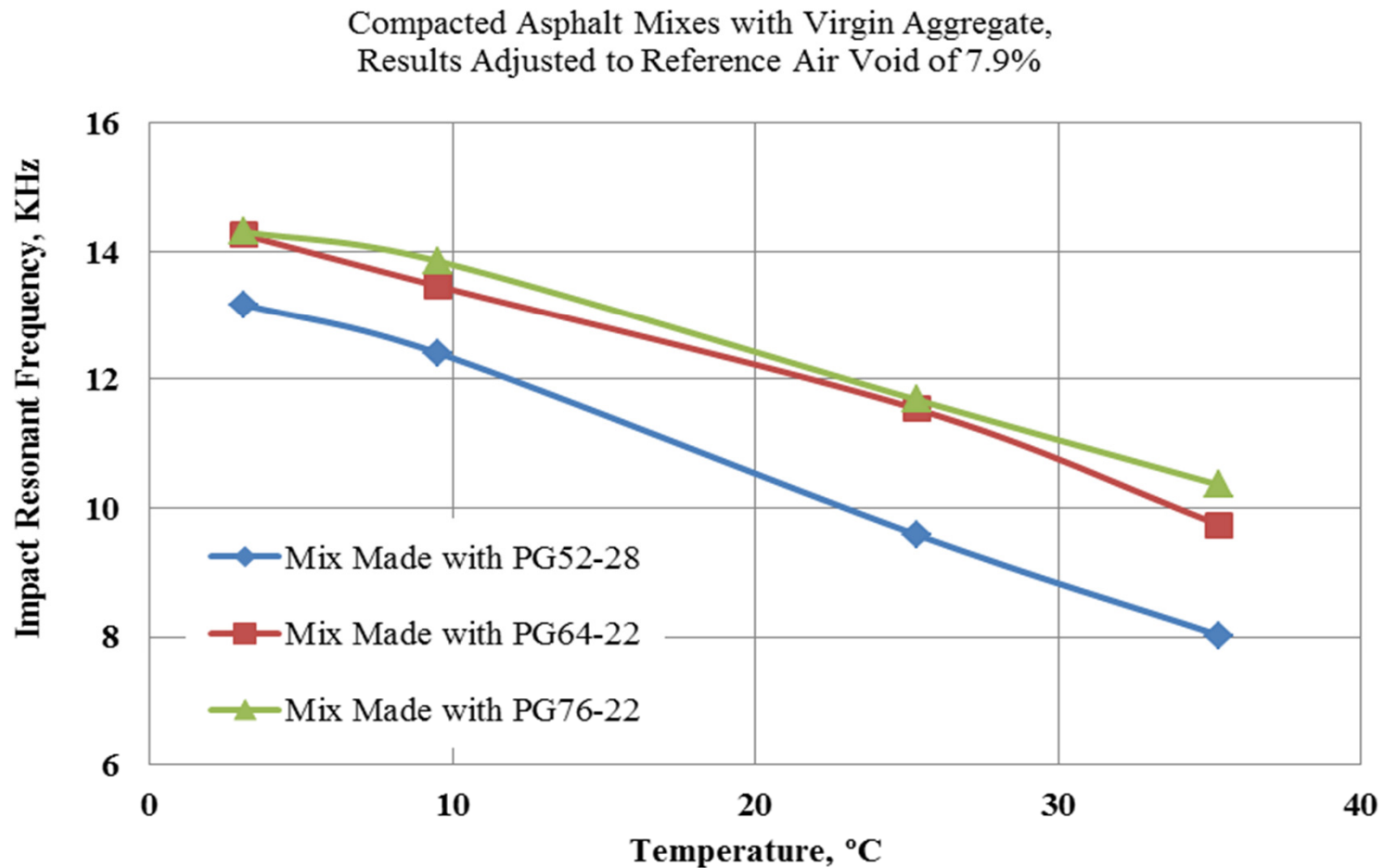


Mix with	Compacted Specimen		Avg. Void, %
	1	2	
PG52-28	8.2	8.4	8.3
PG64-22	7.9	8.1	8.0
PG76-22	8.0	7.9	7.9



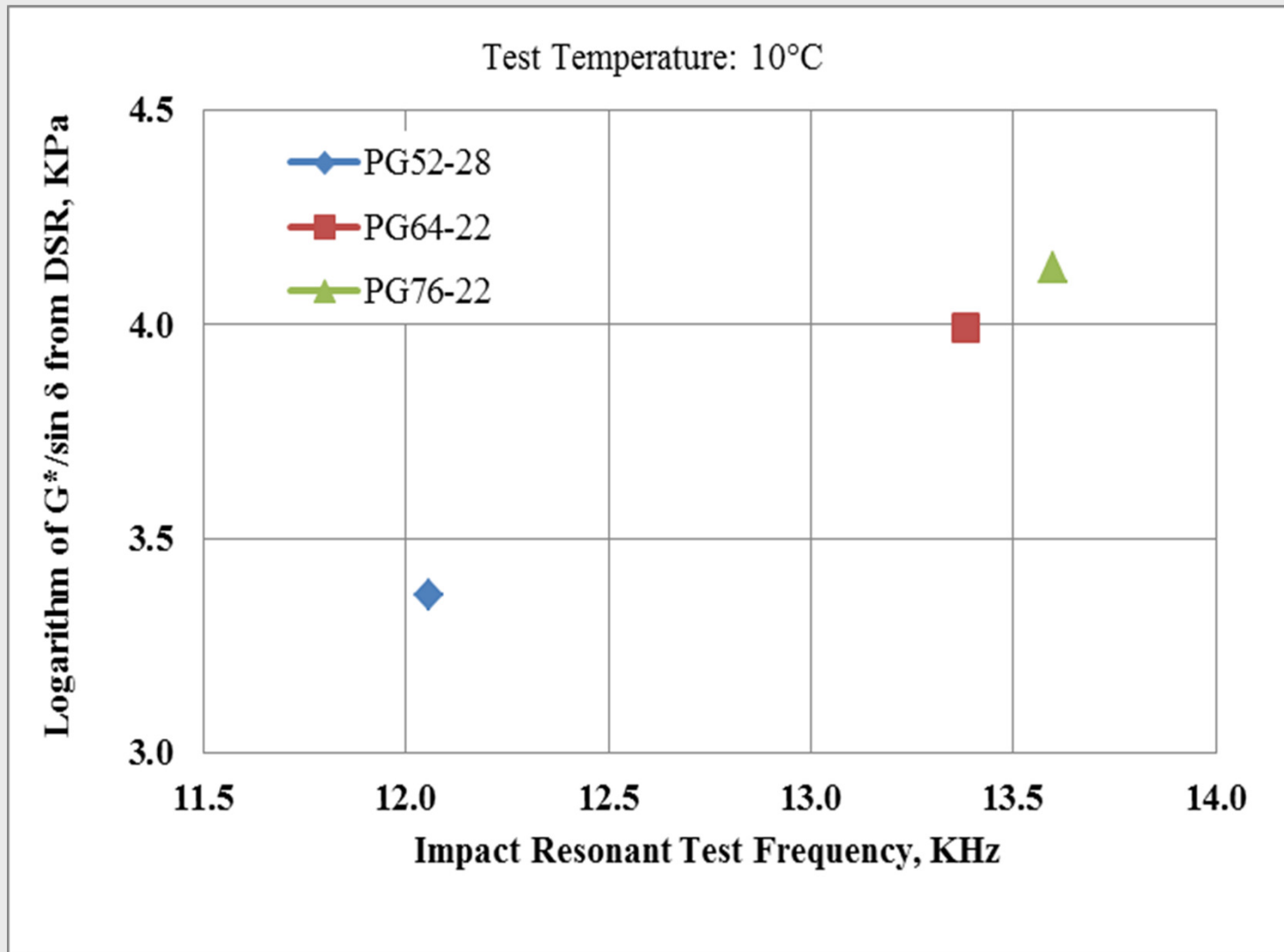
IR Test Results

■ Mixes with Virgin Aggregate



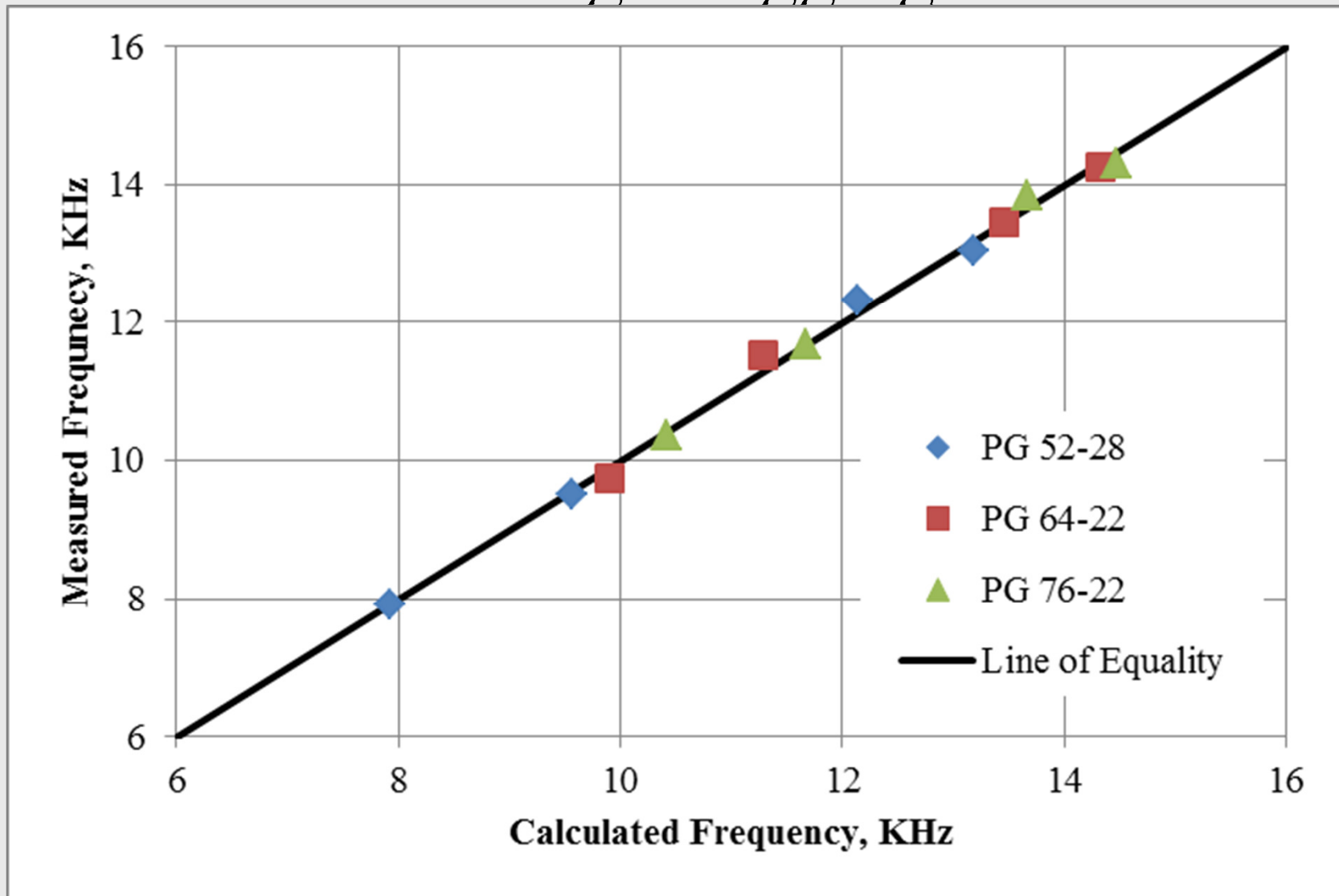
IR Test Results

■ Mixes with Virgin Aggregate



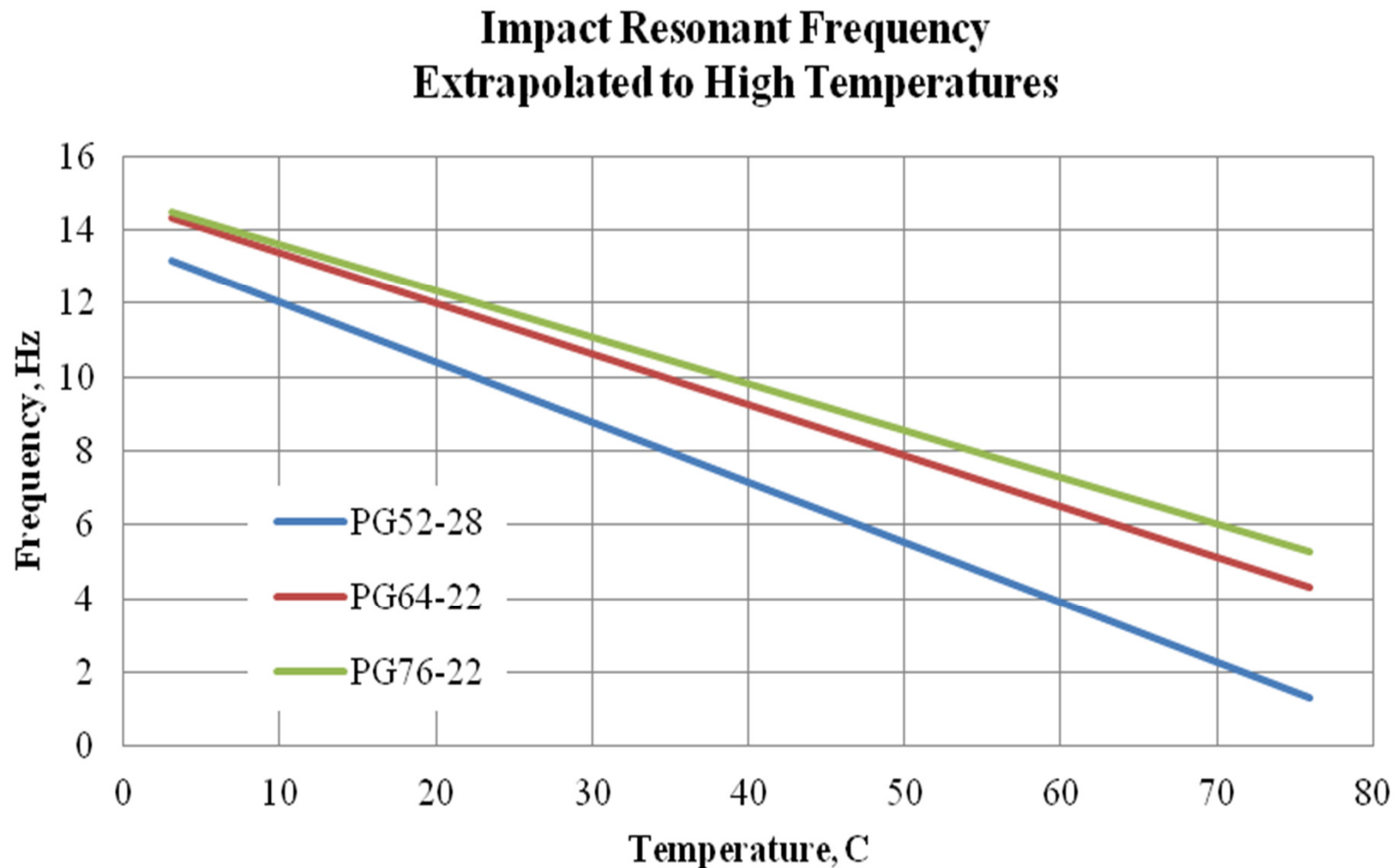
IR Test Results

■ Mixes with Virgin Aggregate



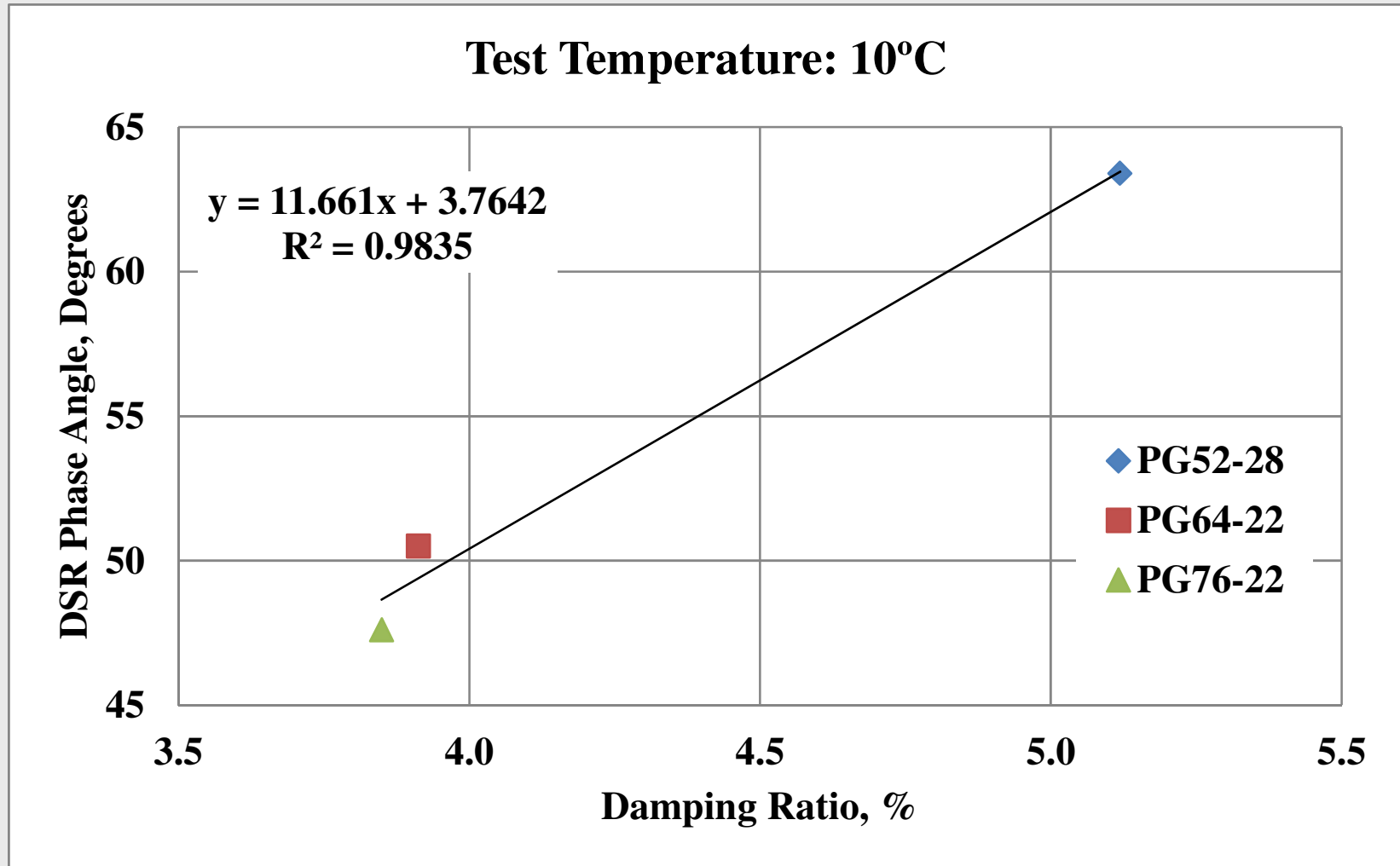
IR Test Results

- Mixes with Virgin Aggregate



IR Test Results

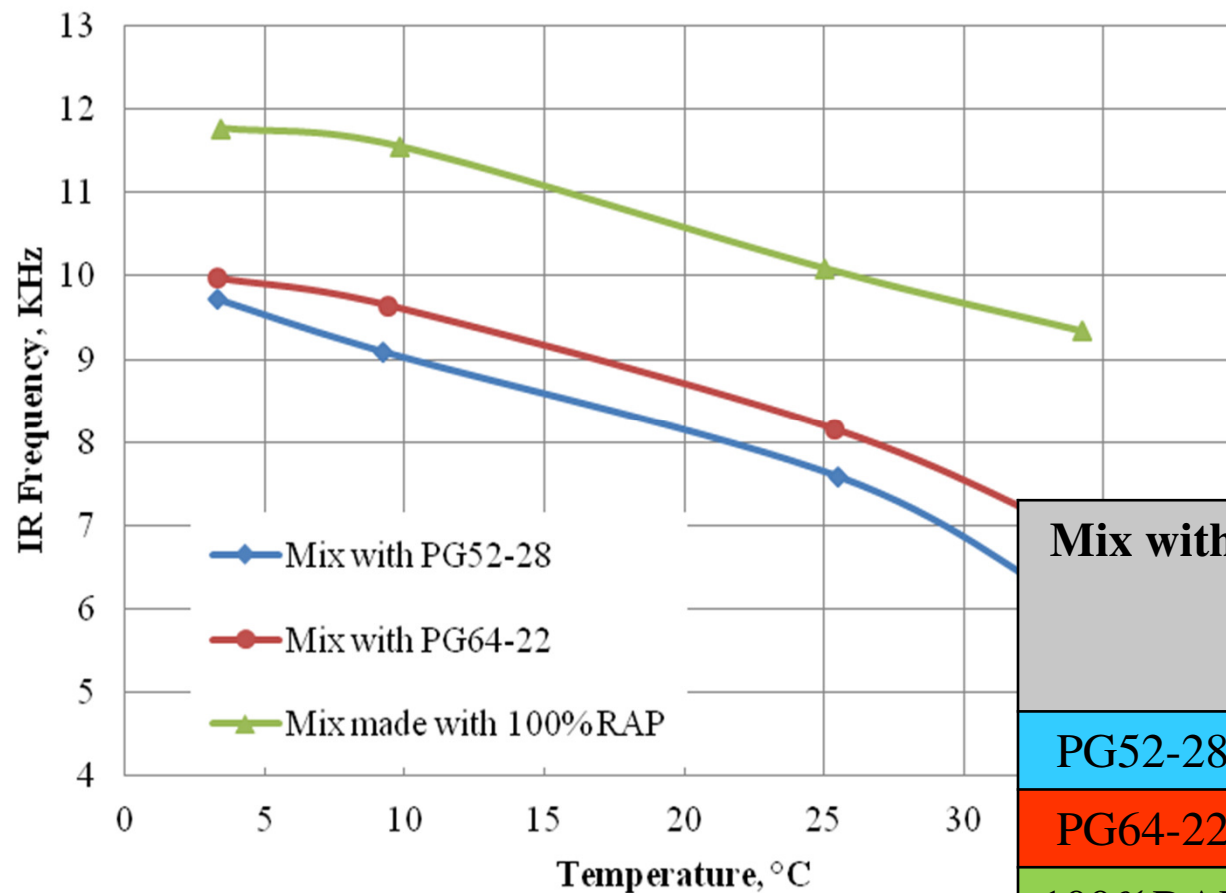
■ Mixes with Virgin Aggregate



IR Test Results

■ Mixes with RAP

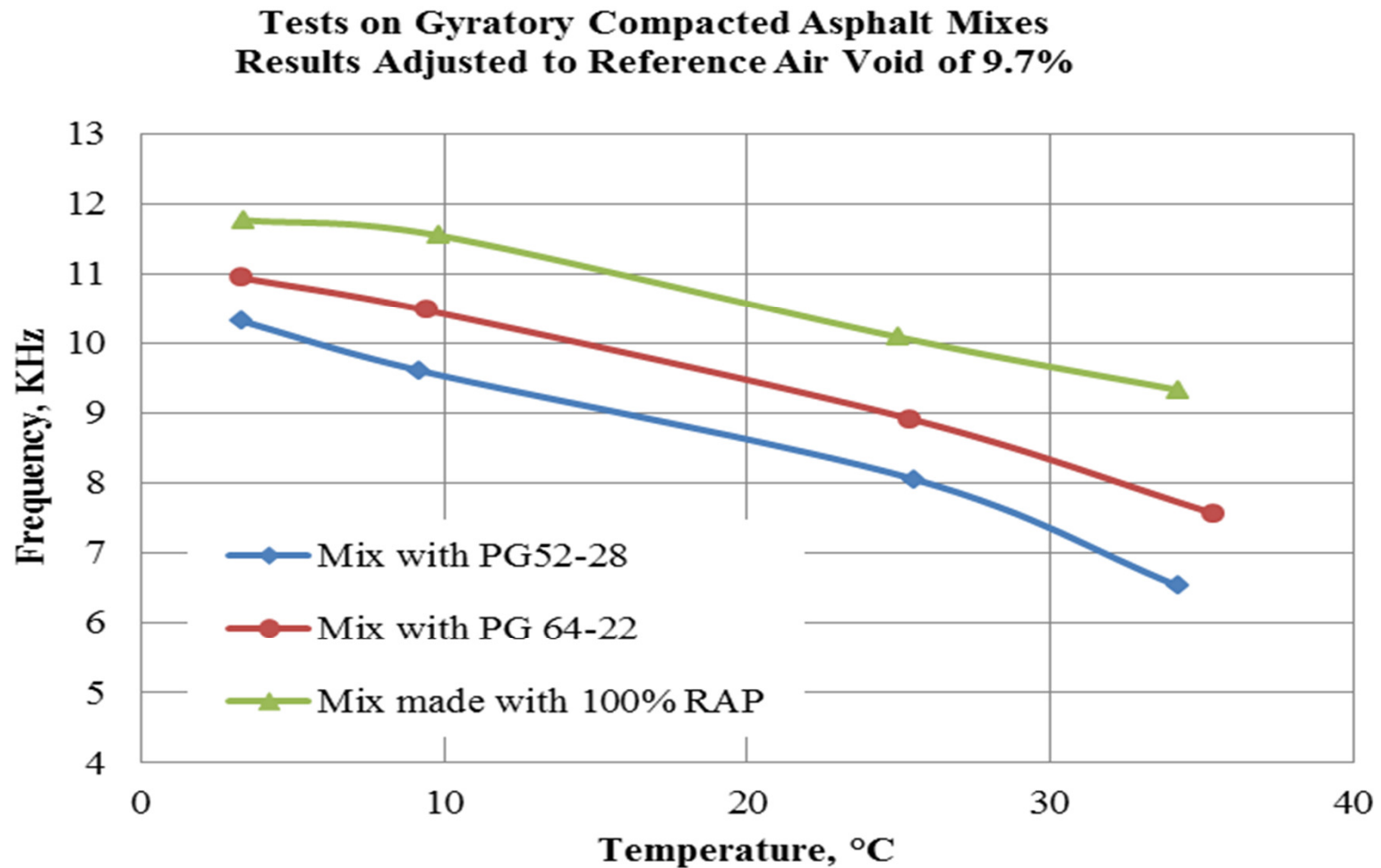
Tests on Gyratory Compacted Asphalt Mixes



Mix with	Compacted Specimen			Avg. Void, %
	1	2	3	
PG52-28	11.9	11.1	-	11.5
PG64-22	12.5	12.7	-	12.6
100%RAP	9.8	9.4	9.9	9.7

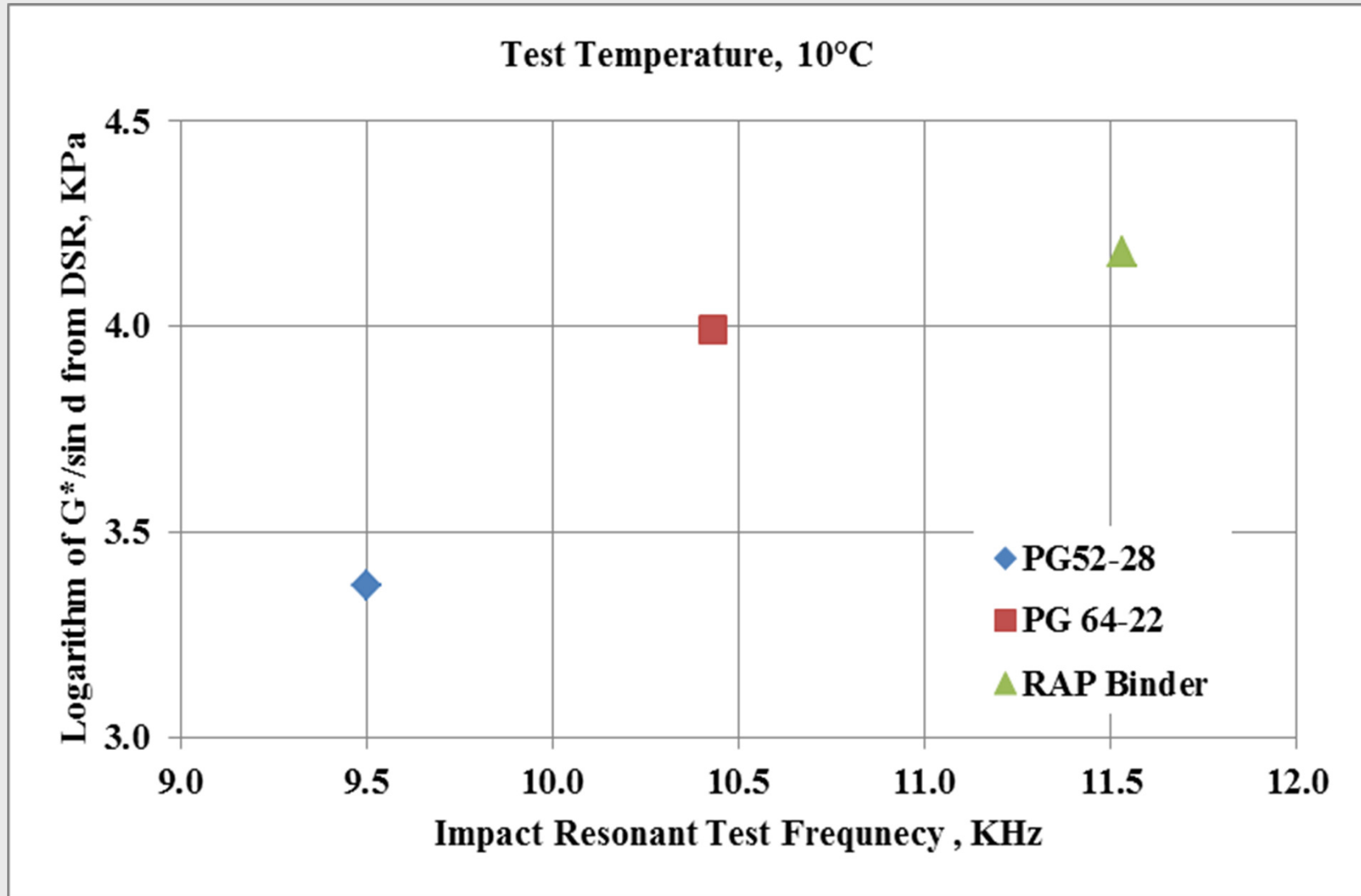
IR Test Results

■ Mixes with RAP



IR Test Results

■ Mixes with RAP

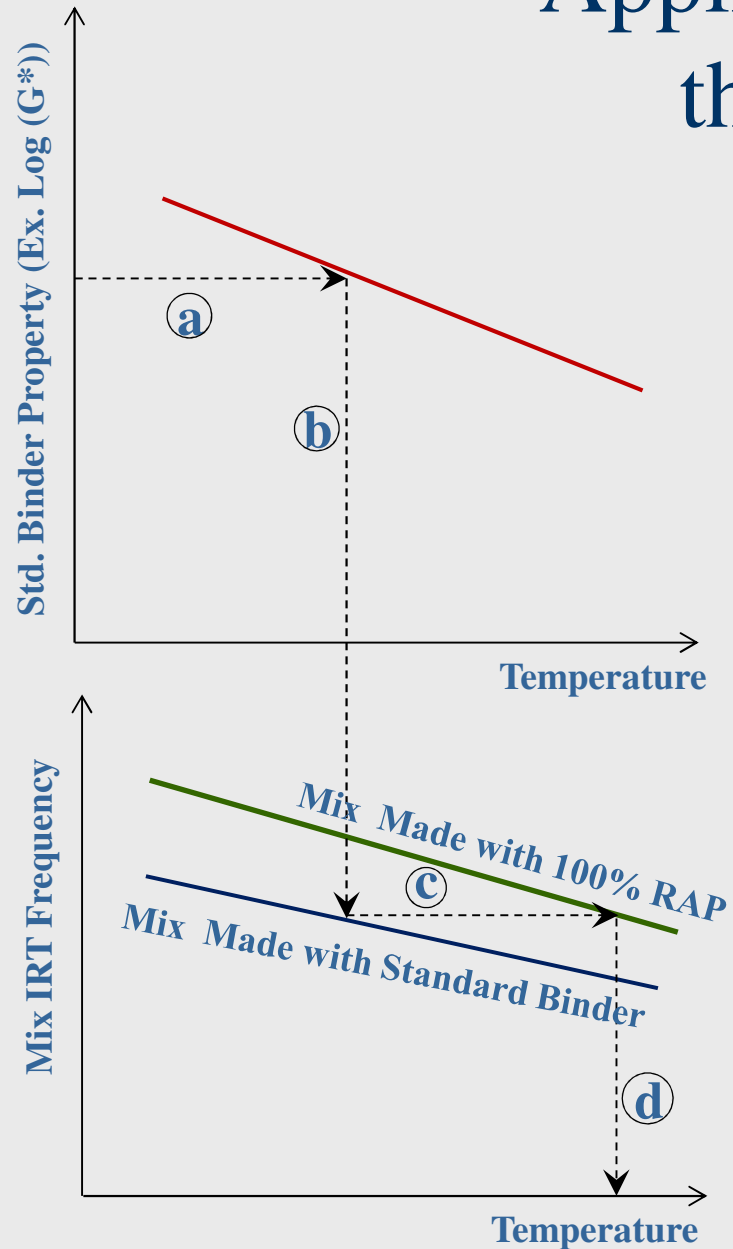


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Application To Determine the RAP Binder Grade



Thank You!

