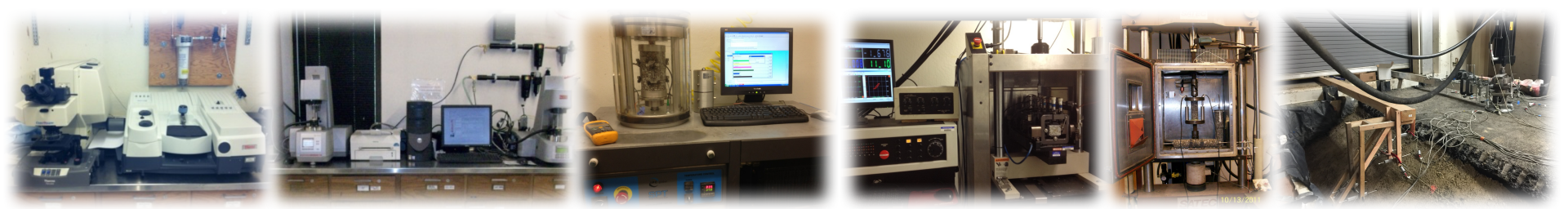


# Performance Evaluation of a 100% Recycled Asphalt Pavement Mixture using a Polymer Binder: A Pilot Study


## Elie Y. Hajj, Murugaiyah Piratheepan, & Peter E. Sebaaly

**Pavement Engineering & Science Program**
**University of Nevada, Reno**



10th International Conference on the Bearing Capacity of Roads, Railways & Airfields
Athens, Greece – June 28-30, 2017

# Introduction – Recycled Asphalt Pavement (RAP)


- Obtained from
  - Reconstruction / utility cuts
  - Millings for resurfacing
  - Plant reject
- Used in
  - HMA & WMA productions (up to ~50%)
    - US (2014), > 70 million tons of RAP used in new pavements
  - Hot or cold in-place recycling (100%)
    - Emulsion
    - Typically requires a surface treatment or an AC overlay

# Introduction

- **Polymeric binder**
  - G5® TechniSoil Ind. http://www.technisoilind.com/technisoil-g5.html
  - A polymer chemistry enabling 100% CIR of AC surface layer.
  - Liquid at room temperature

- **G5-Stabilized RAP mixture**
  - Mixed & compacted at room temperature
  - Cures faster than emulsion
  - Paved surface is 30 - 40°F cooler than the asphalt surface

# G5 Recycling Process Flow

**Milling**

- Cold milling of pavement surface
- Additives injected at milling head
- Grindings ejected to crusher

**Crushing + Screening**

- Horizontal impact crusher
- Oversize material is screened
- Control to achieve desired gradation based on mix design

**Mixing**

- G5 binder is injected into continuous pugmill mixer
- Mixer ejects combined RAP + G5 into a windrow

**Paving + Compaction**

- Pickup machine delivers mixed RAP + G5 into paver
- Paver distributes mixture on the road surface
- Rollers compact material

Milling

Crushing, Screening, Mixing

Paving

Rolling

# Pavement Recycling System

# Objective

- Evaluation of G5 for use with 100% RAP
- Conduct a laboratory evaluation
  - Measure engineering and performance properties
    - Dynamic modulus, rutting resistance, fatigue cracking resistance, thermal cracking resistance.
- Conduct a simple ME analysis
  - Estimate fatigue life of a typical pavement structure

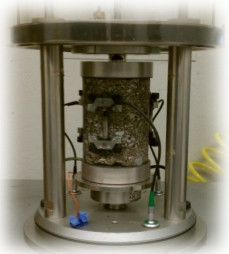
# Sample Preparation

100% passing 9.5 mm sieve crushed RAP (4.1%TWM RAP binder) Mixed with 9.5% (by dry weight of RAP) of G5®

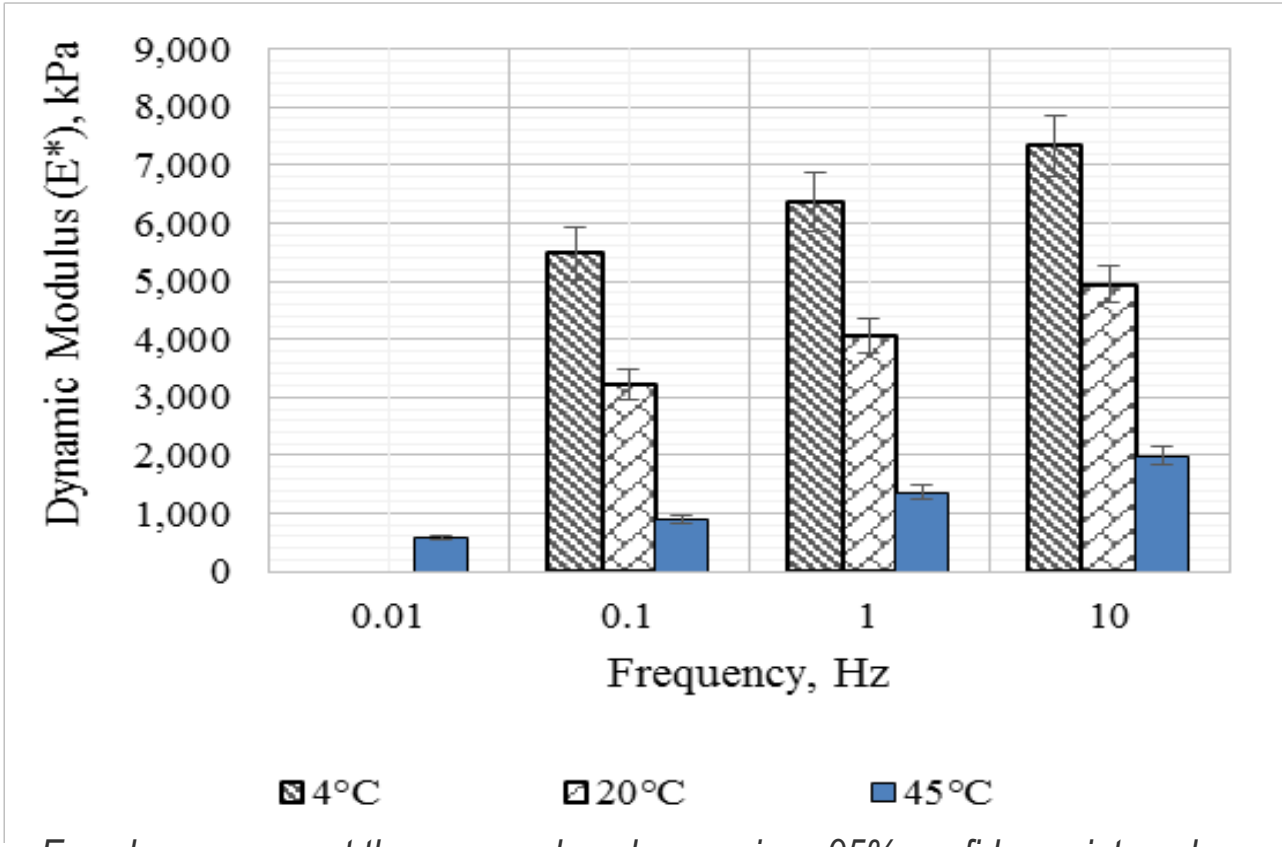

Placed & compacted using a small roller compactor in a large slab

After curing, Cores & slabs taken to prepare test specimens

# G5®-Stabilized RAP Mixture
# Dynamic Modulus, E* (AASHTO TP79)



- 100mm diameter by 150mm height cored samples (12±1%)

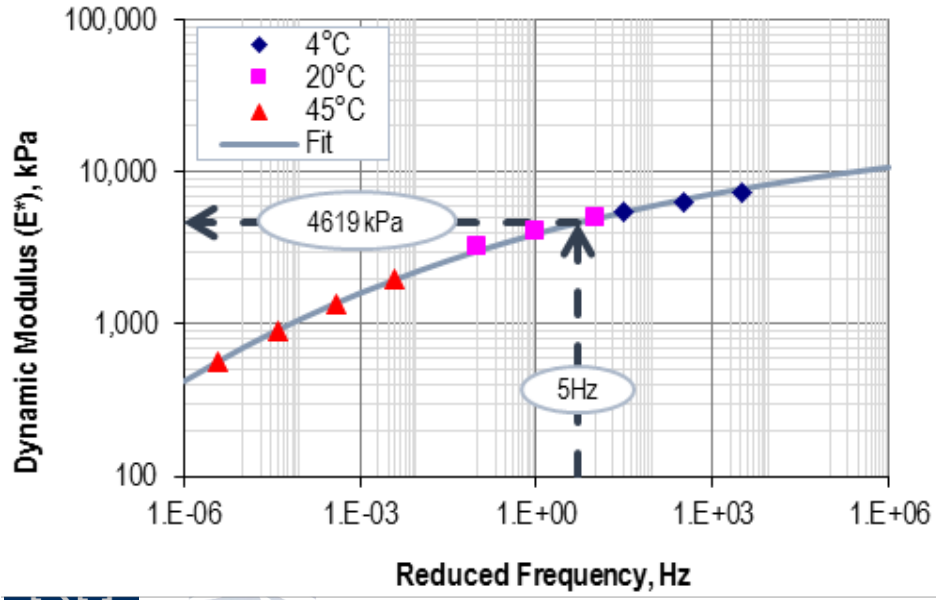


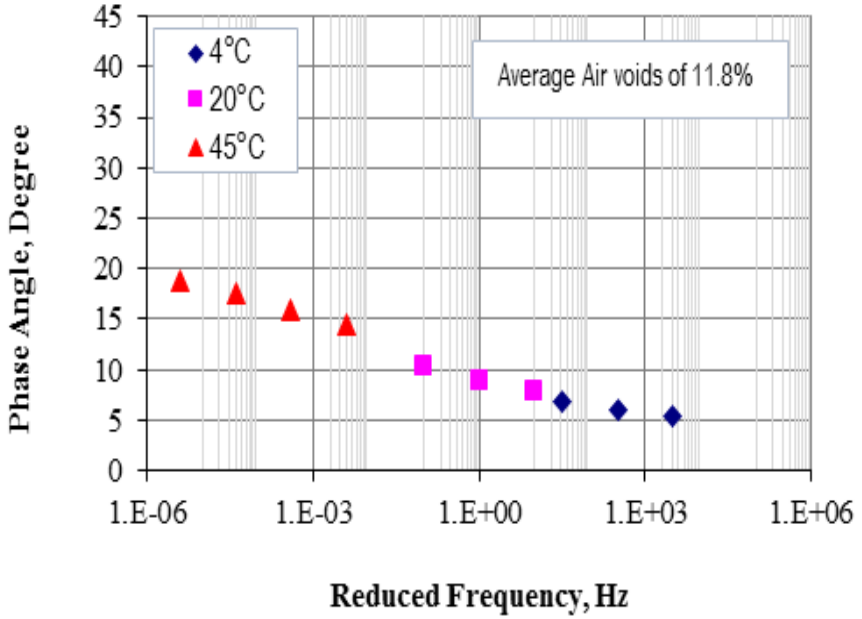

*Error bars represent the mean value plus or minus 95% confidence interval*

## G5®-Stabilized RAP Mixture

# E* Master Curve (AASHTO PP61) at 20°C

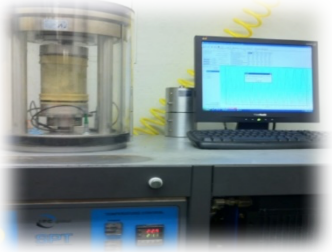
- G5®-stabilized RAP mixture (100% RAP)
  - Viscoelastic behavior.
  - Stable (stiffness similar to that of a typical DG asphalt mixtures).
  - Phase angle values (5 to 20 degrees) indicate high flexibility at low & high temperatures.



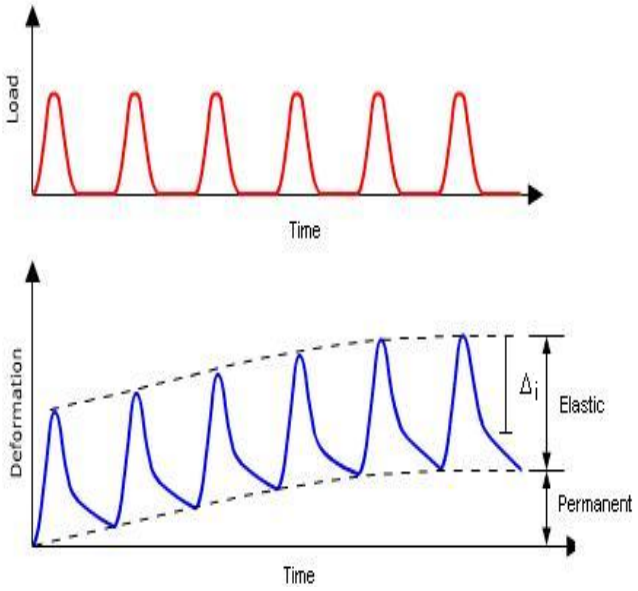



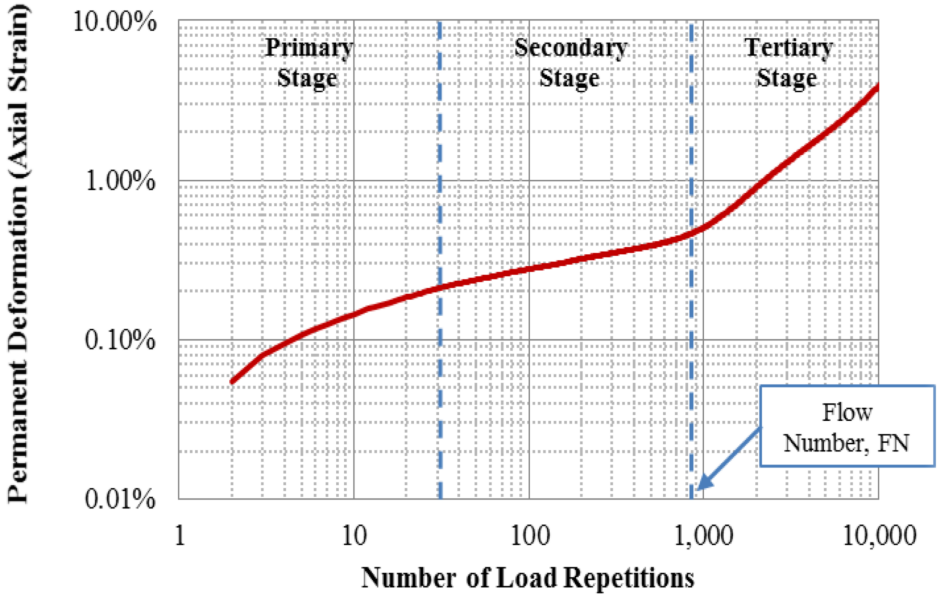
## G5®-Stabilized RAP Mixture

# Resistance to Rutting (AASHTO TP79)



- 100mm diameter x 150mm height cored samples (12±1%)
- Repeated pulse load of 0.1sec & rest period of 0.9sec
- Deviator stress = 600 kPa; Confinement = 0 kPa
- Test temperature = 60°C



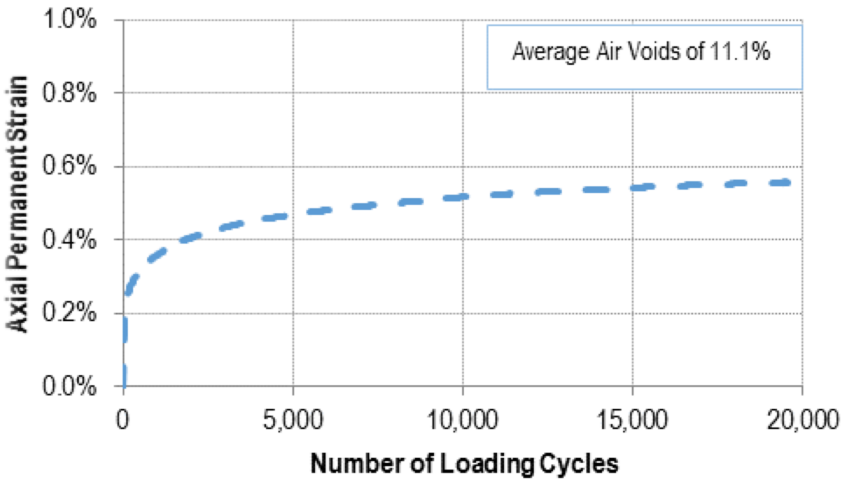



## G5®-Stabilized RAP Mixture

# Resistance to Rutting (AASHTO TP79)

- G5®-stabilized RAP mixture (100% RAP) exhibited a superior & excellent resistance to rutting.
- Can successfully withstand the high & heavy traffic even in hot climates.

**Permanent strain @ 60°C < 1%**

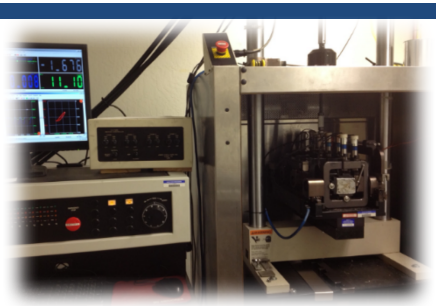


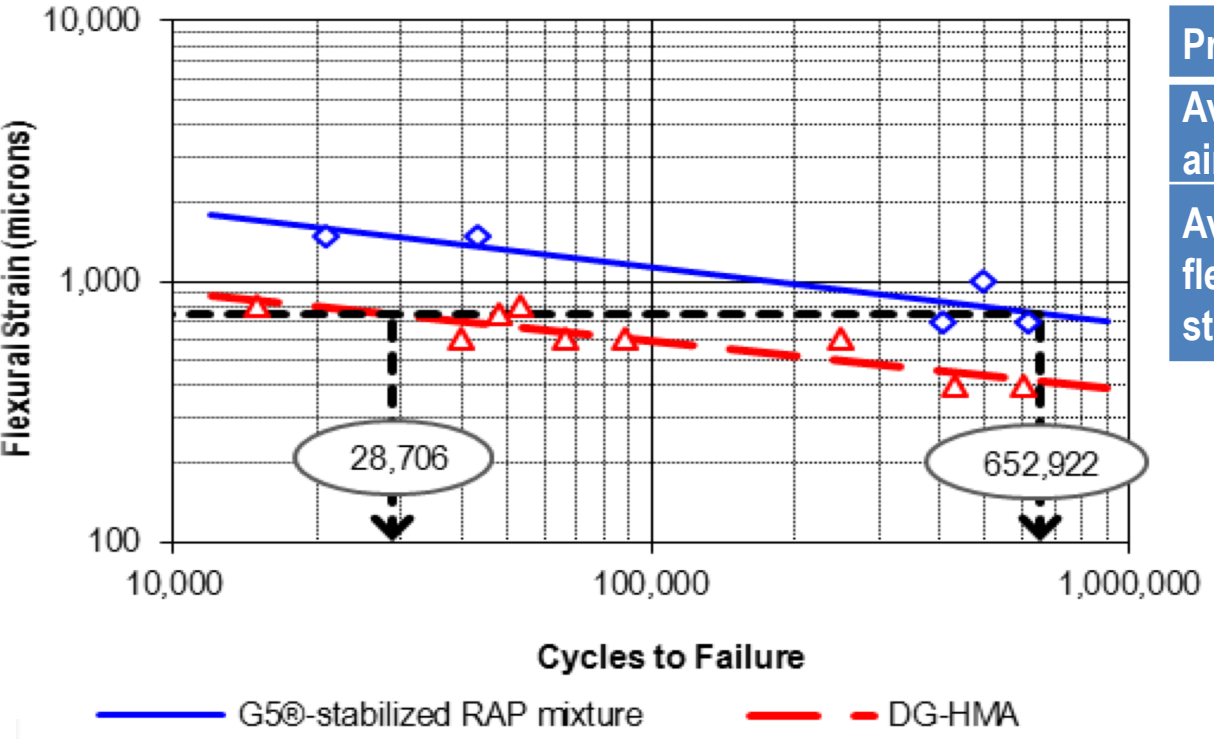

| AASHTO TP 79 – FN Requirements for Hot-Mix Asphalt (HMA) | | | | | Results |
|---|---|---|---|---|---|
| Traffic Level (Million ESALs) | < 3 | 3 to < 10 | 10 to < 30 | ≥ 30 | 100% RAP + G5 |
| Minimum Flow Number (Cycles)[1] | Testing Not Needed | 53 | 190 | 740 | *No Flow after 20,000 Cycles* |

## G5®-Stabilized RAP Mixture

# Resistance to Fatigue Cracking (AASHTO T321)

- Uncut beams long-term aged (5 days at 85°C)
- Constant strain mode of testing; 10 Hz
- Test temperature = 21.1°C





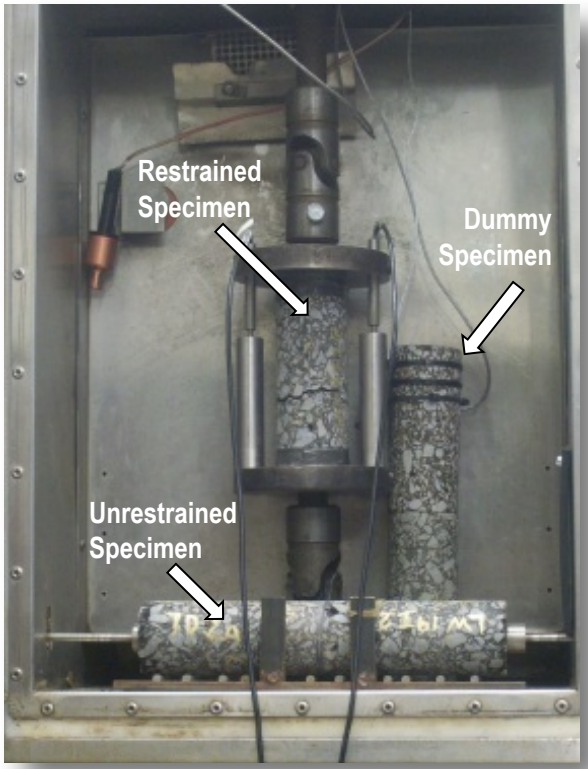

| Property | G5®-stabilized RAP | DG-HMA |
|---|---|---|
| Average air voids | 11.2% | 6.7% |
| Average flexural stiffness | 5,812 MPa | 1,186 MPa |

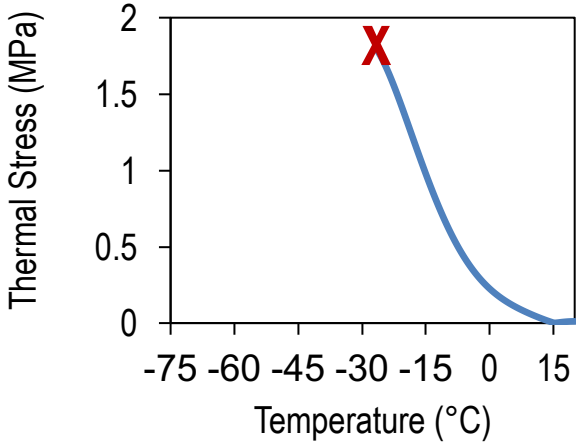
***High Resistance***
*to Fatigue Cracking*

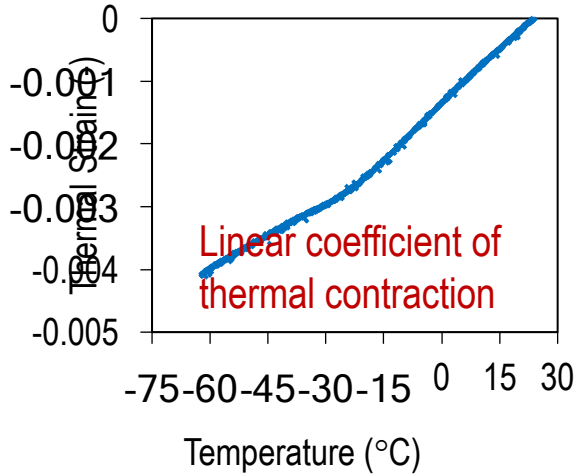
## G5®-Stabilized RAP Mixture

# Resistance to Thermal Cracking (Draft Standard)

- 57 x 140 mm cylindrical specimens (after 5 days at 85°C)
- Cooling rate of 10°C/hour from 20 to (-45)°C



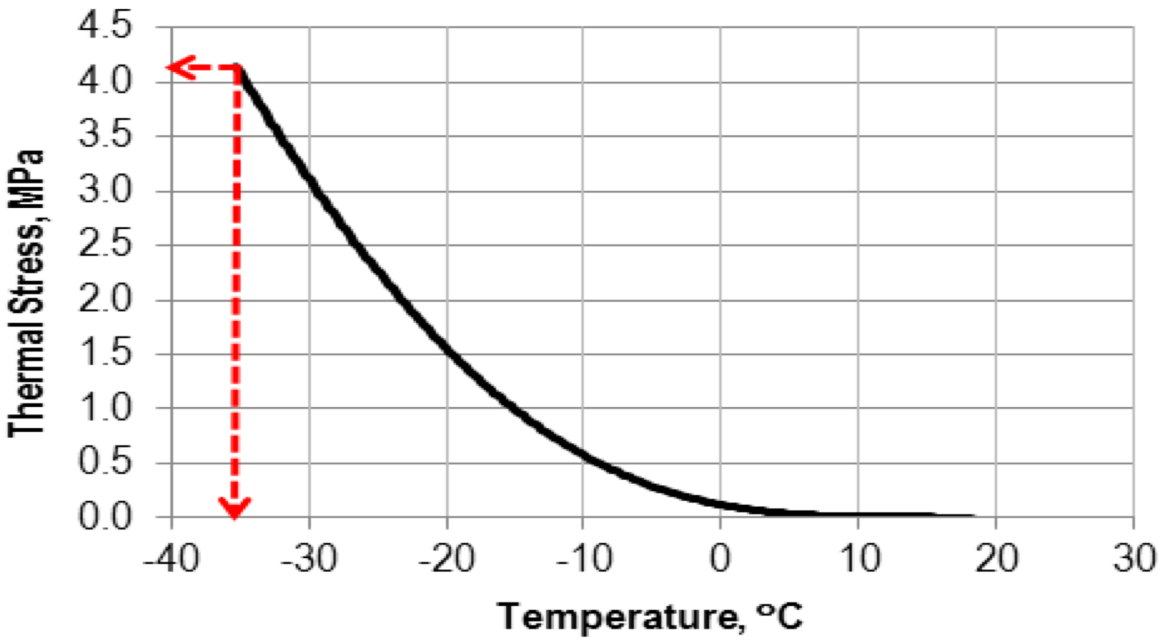



## G5®-Stabilized RAP Mixture

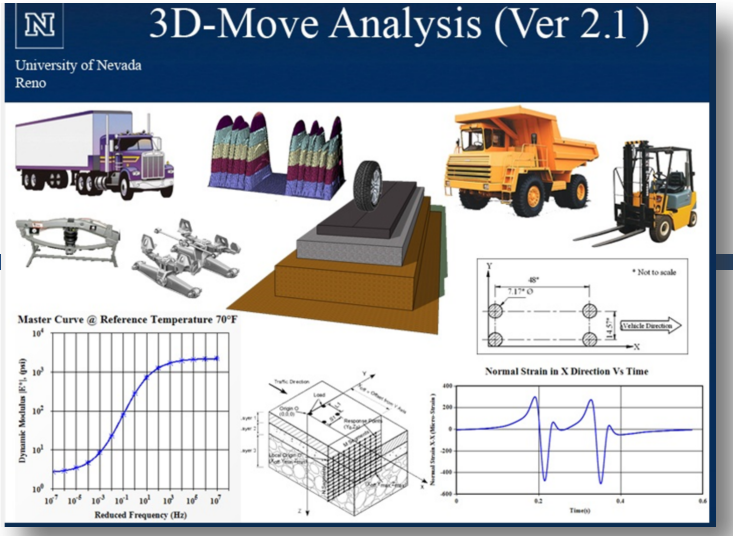
# Resistance to Thermal Cracking (Draft Standard)

| Property | Value |
|---|---|
| Fracture Temperature | -34.1°C |
| Fracture Stress | 4,227 kPa (613 psi) |



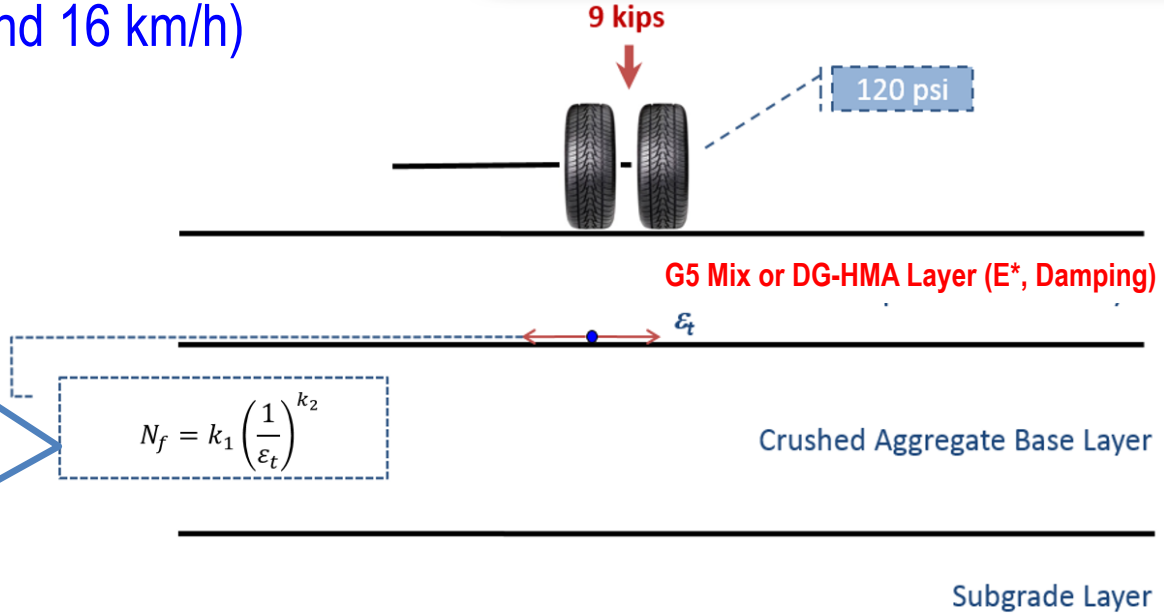

G5®-stabilized RAP mixture exhibited a *low fracture temperature* while maintaining a *high fracture stress* indicating a **good resistance** to thermal cracking in cold climates.

# Simple Mechanical-Empirical (M-E) Analysis



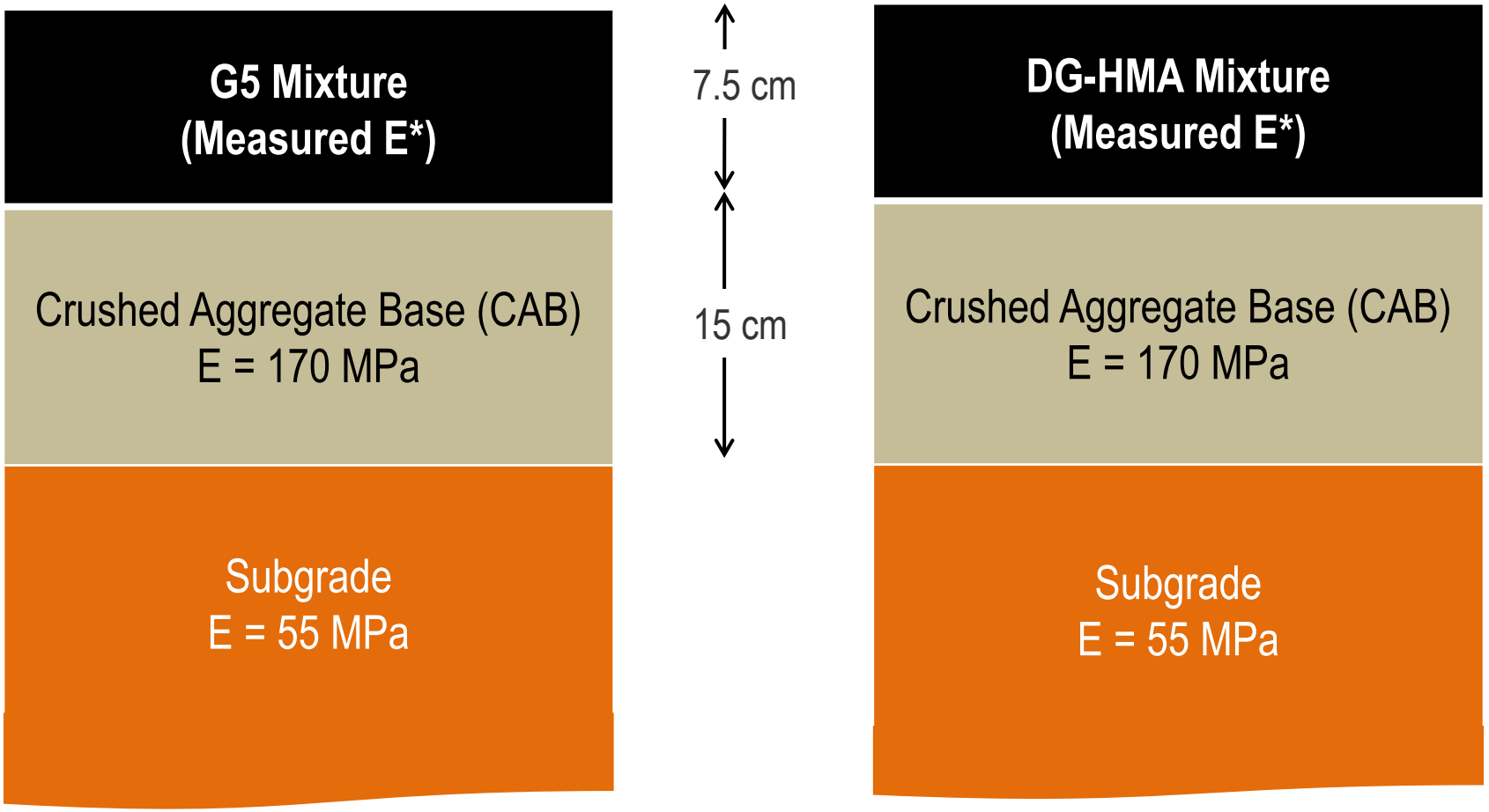

- Bottom-up fatigue cracking Analysis Using 3D-Move analysis
  - Viscoelastic properties
  - 2 vehicle speeds (72 and 16 km/h)

| Property | G5 Mix | DG-HMA |
|---|---|---|
| Average air voids | 11.2% | 6.7% |
| $K_1$ | 4.524E-09 | 8.293E-13 |
| $K_2$ | 4.531 | 5.293 |




***Download 3D-Move for free @ https://www.unr.edu/wrsc***

# Simple Mechanical-Empirical (M-E) Analysis (Cont'd)



# Simple Mechanical-Empirical (M-E) Analysis (Cont'd)

| Vehicle Speed | Surface Mixture | Fatigue Analysis at 21°C | |
|---|---|---|---|
| | | Number of repetitions to failure, $N_f$ (million) | Fatigue life ratio |
| 72 kph (45 mph) | G5-100%RAP | 23.2 | 8.0 |
| | DG-HMA | 2.9 | |
| 16 kph (10 mph) | G5-100%RAP | 17.6 | 14.7 |
| | DG-HMA | 1.2 | |

- High resistance to fatigue cracking for G5®-stabilized RAP mixture when used as a surface layer.

# Demonstration Project

- Reconstruction project: Al Wakar water station, Doha, Qatar.
  - ~60 m long by x 3 m wide stretch.
- Traffic: more than 1,000 water trucks per day, 7 days per week, each loaded with 4,000-5,000 gallons of water.
- Average high air temperature of over 38°C
  - Daily high air temperature often exceeds 43°C during summer.
- Annual rainfall ~75 mm.

# Demonstration Project (Cont'd)

- ~75 mm of G5®-stabilized 100%RAP mix on top of subbase.
  - 5% G5®
  - 2 lifts compacted with 5-ton roller (3 vibratory passes)
- Average in place air voids: 10% (top lift) & 14.5% (bottom lift).

# Conclusion

- The laboratory test results show that the G5®-stabilized mixture (100% RAP)
  - Is stable with a high stiffness.
  - Has high resistance to rutting at 60°C; hence, offering significantly more resistance to rutting at higher pavement temperatures.
  - has a high resistance to fatigue cracking at 21°C while maintaining a high flexural stiffness.
  - Has a cold fracture temperature of -34°C indicating that the mixture will perform well in designated cold environment.
- The ME analysis shows that G5®-stabilized mixture (100% RAP) significantly improved fatigue life of thin pavements.
- The demonstration project had no construction-related issues & a recent visual distress survey shows no distresses in the pavement after 6 months.

# THANK YOU!