Performance Evaluation of Jet Fuel Resistant Polymer-Modified Asphalt for HMA Pavements

AFK 10 Committee Meeting
Philadelphia, PA
April 24, 2006

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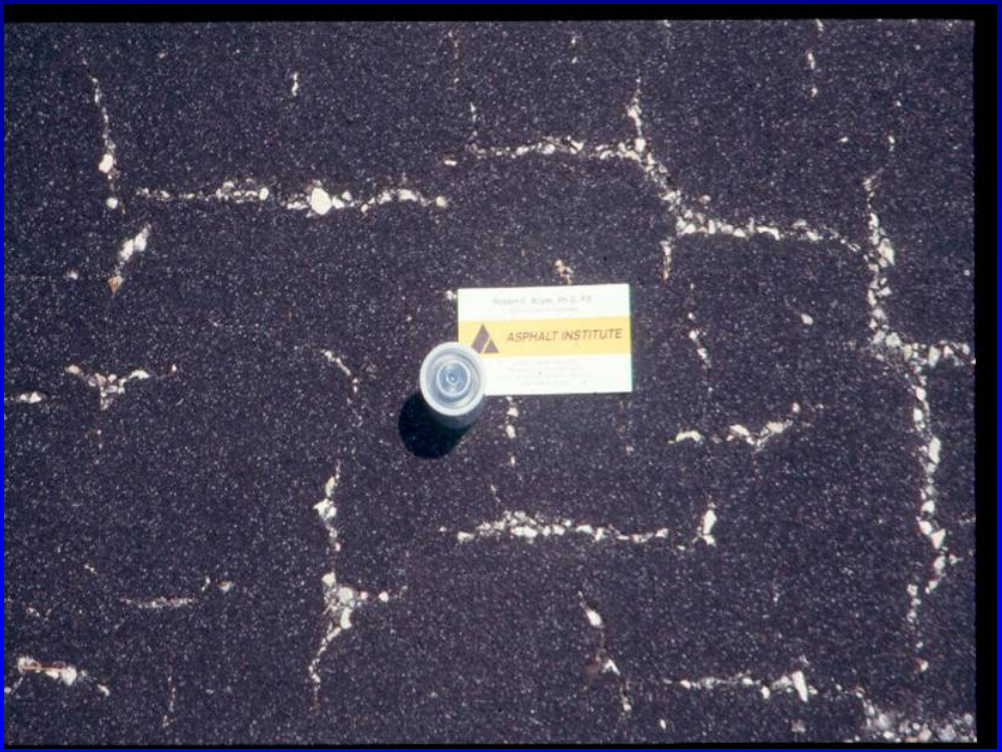
CITGO Asphalt Refining Company

Background

- Airports experience jet fuel spills on aprons and taxiways
  - Fueling operations
  - Aircraft sitting in queues
  - Softens (weakens) asphalt
  - Causes permanent deformations and failures
- Truck stops, vehicle fueling areas and parking lots also suffer fuel spills

Fuel Resistant Pavement Sealers



- Coal tar sealers are most commonly used to protect Hot Mix Asphalt pavements from fuel damage
- Different coefficient of expansion for coal tar causes substantial alligator cracking within 2-3 years
- Cracking allows fuel penetration - short service life

Fuel Resistant Pavement Sealers

- Coal tar sealers are carcinogenic
  - <u>MSDS – "Unusual Chronic Toxicity:</u> May cause cancer of the skin, lungs, kidney and bladder."
  - Adding carcinogenic material to pavement that may be recycled – future exposure
- Austin, TX and United States Geological Survey Report
  - 90% of PAHs in waterways may come from runoff from coal tar sealed pavements
  - Austin may outlaw use
- Coal Tar sealers are outlawed in California

Development of Fuel-Resistant PMA

- Kuala Lumpur Airport specified jet fuel resistant asphalt pavements for new construction in 1995
- Ooms Avenhorn Holding, Netherlands, developed Fuel-Resistant PMA for airport usage
- Objective – add fuel resistance to SBS technology without sacrificing performance
- Contains no Coal Tar

Development of Fuel-Resistant PMA

- **Specifications required compacted mix samples to be immersed in jet fuel for 24 hours.**
- **Average weight loss of 4 Marshall or Superpave specimens must be less than 1.0%**

Development of Fuel-Resistant PMA

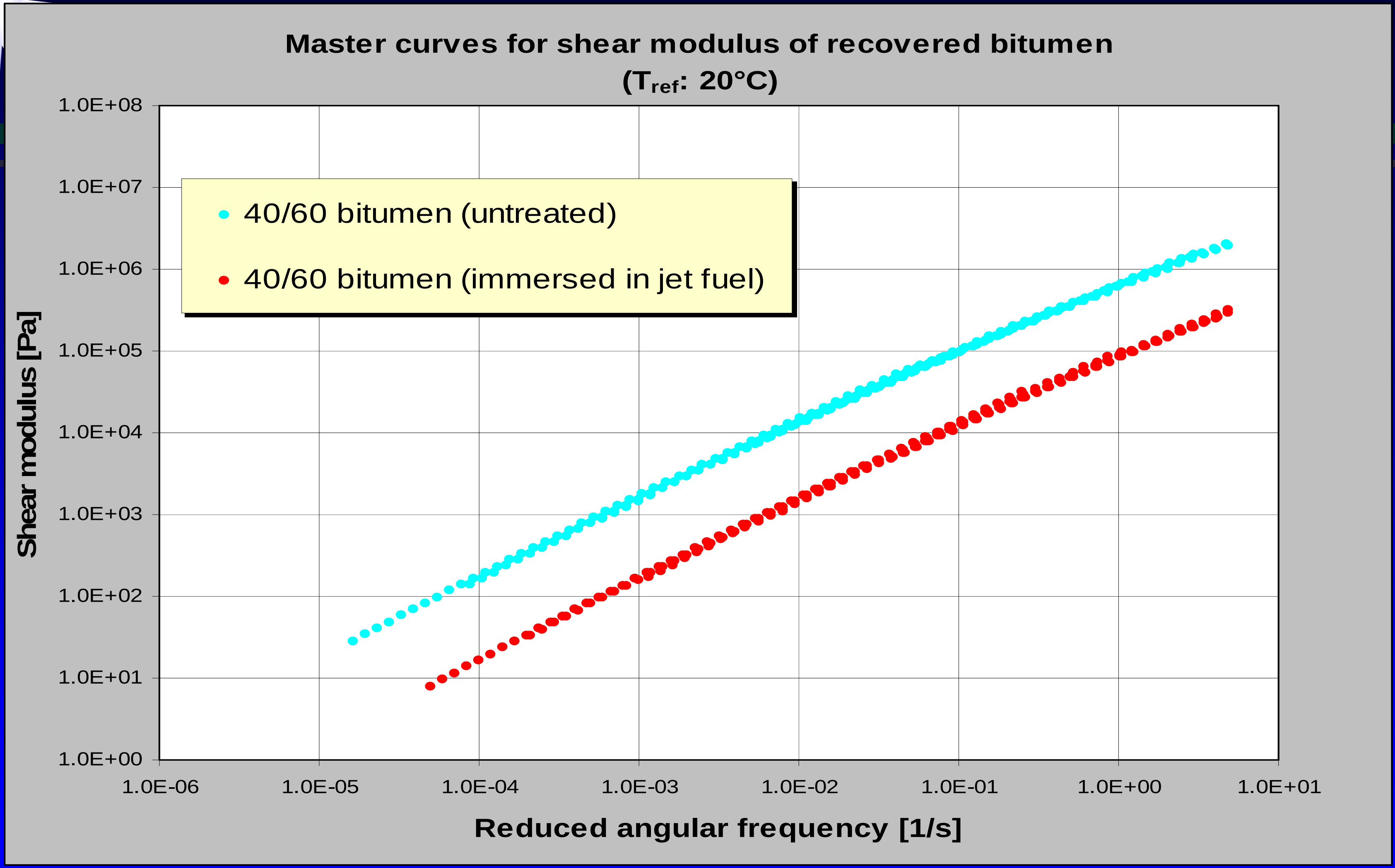
- Standard Hot Mix Asphalt mixture loses 10% weight from 24 hour soak in jet fuel
- Standard Polymer Modified Asphalt (PG 76-22) loses 4.5% weight after 24 soak in jet fuel
- Fuel Resistant PMA – less than 0.5% weight loss

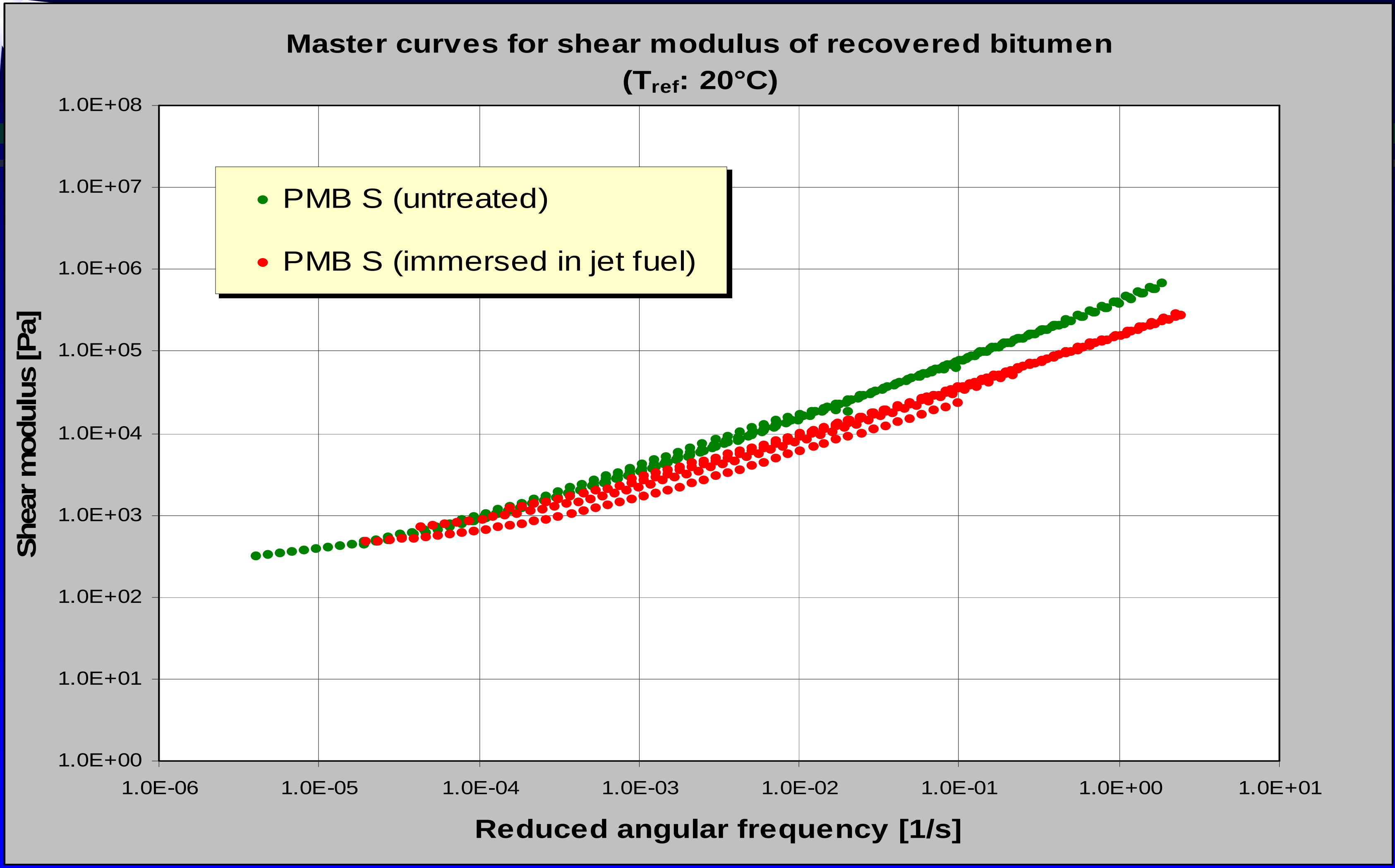
Asphalt Binder Testing

- Compared original asphalt with asphalt submersed in jet fuel
  - Recovered asphalt soaked in jet fuel for 3 hours and dried for 5 days
- Compared unmodified 40/60 pen asphalt (PG 70-22) with PMA PG 76-22 and fuel resistant PMA

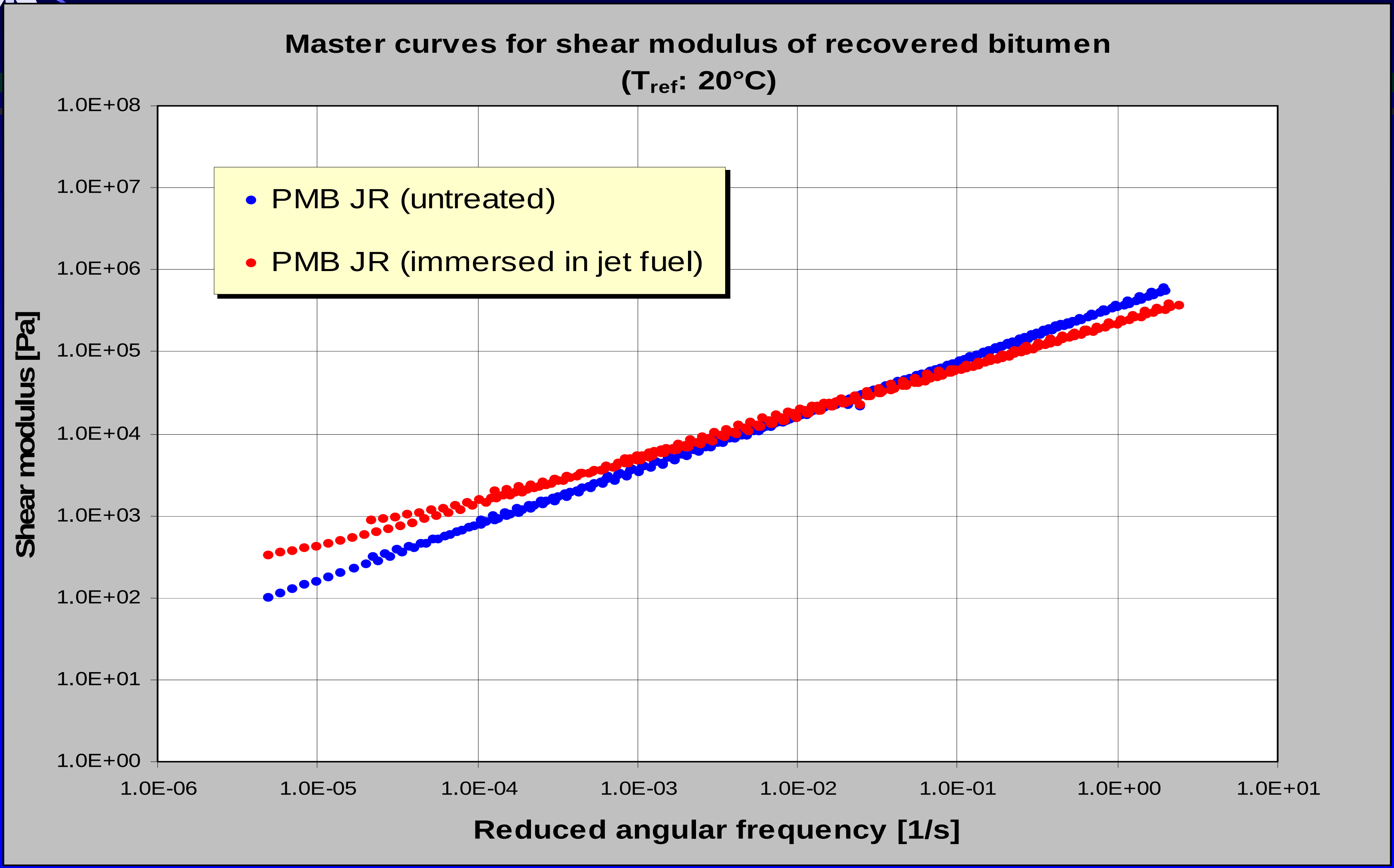
Asphalt Binder Testing

- **Complex Shear Modulus (G*)**

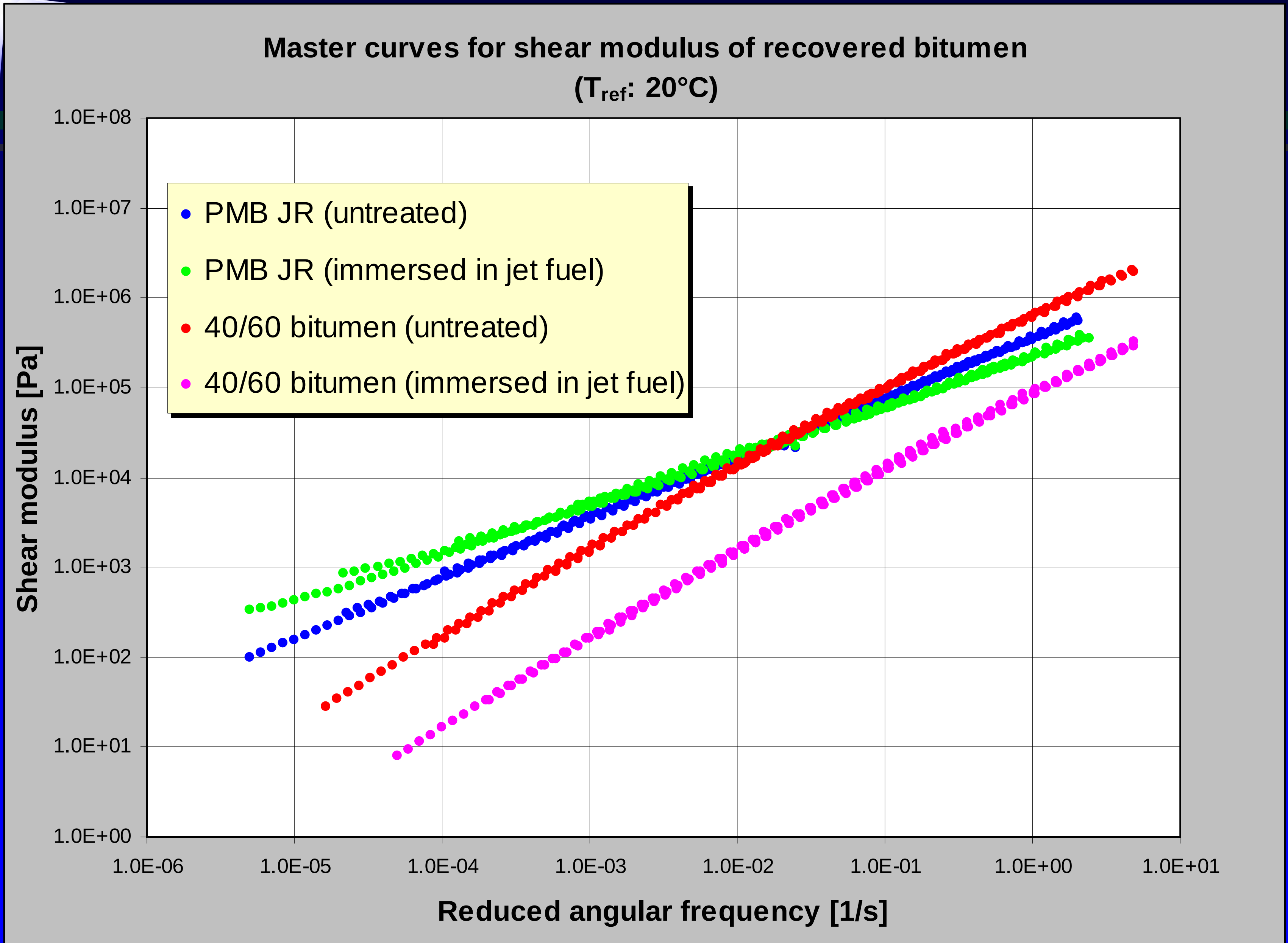

Master curves for shear modulus of recovered bitumen
(T_{ref}: 20°C)
40/60 bitumen (untreated)
40/60 bitumen (immersed in jet fuel)
Shear modulus [Pa]
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-06
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E+00
1.0E+01
Reduced angular frequency [1/s]



Master curves for shear modulus of recovered bitumen
(T_{ref}: 20°C)
PMB S (untreated)
PMB S (immersed in jet fuel)
Shear modulus [Pa]
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-06
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E+00
1.0E+01
Reduced angular frequency [1/s]



Master curves for shear modulus of recovered bitumen
(T_ref: 20°C)
PMB JR (untreated)
PMB JR (immersed in jet fuel)
Shear modulus [Pa]
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-06
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E+00
1.0E+01
Reduced angular frequency [1/s]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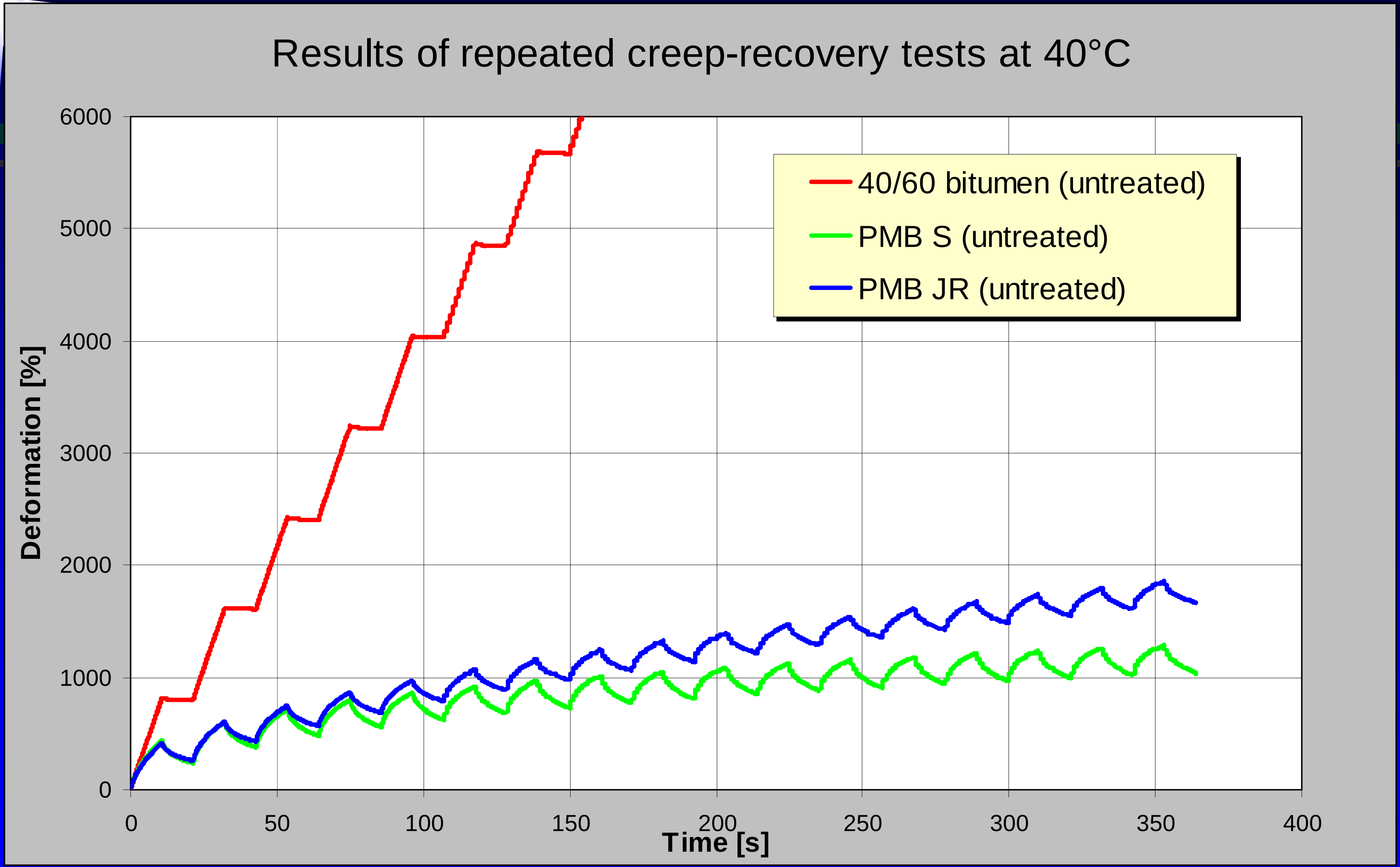
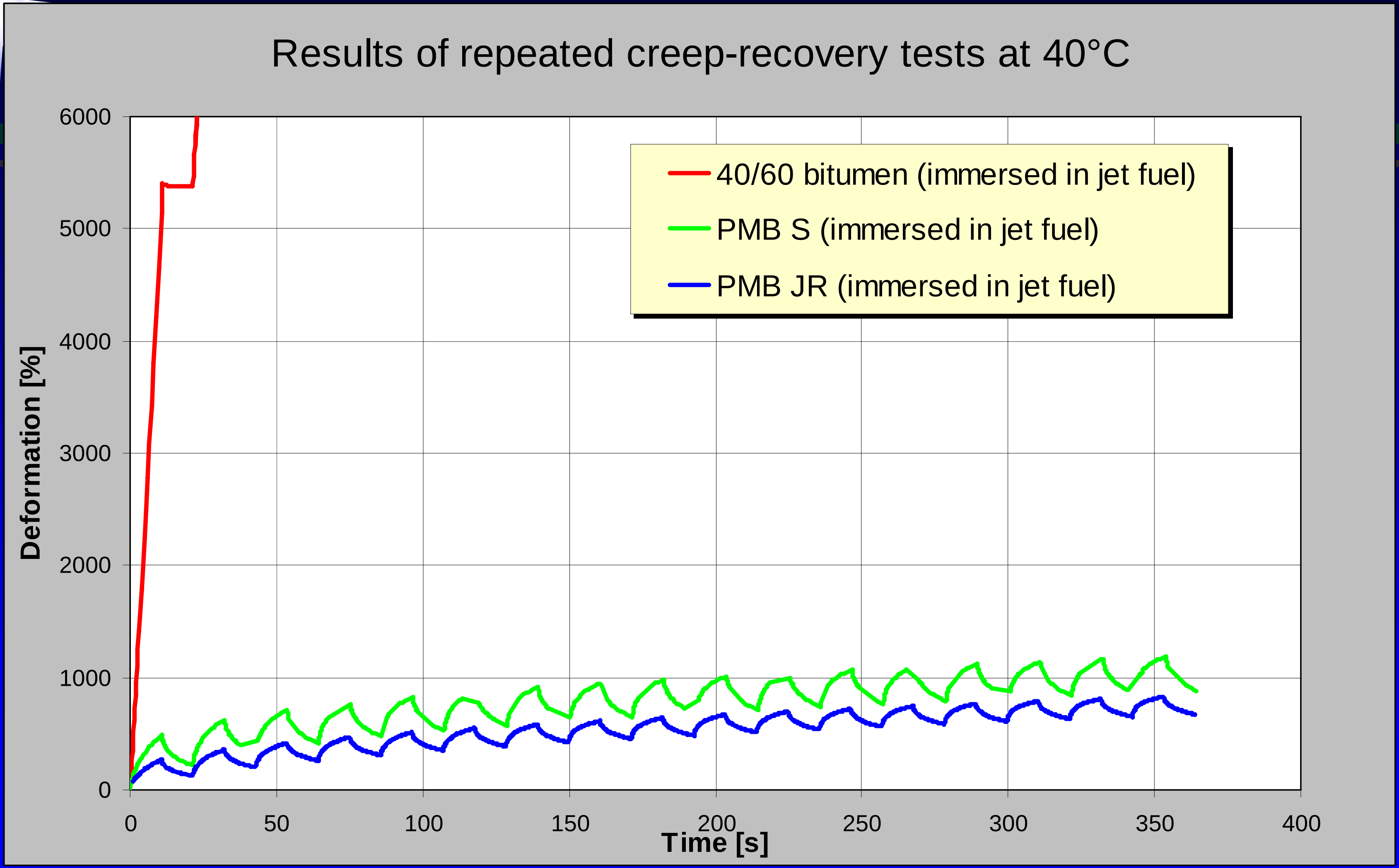
(T$_{ref}$: 20°C)
PMB JR (untreated)
PMB JR (immersed in jet fuel)
40/60 bitumen (untreated)
40/60 bitumen (immersed in jet fuel)
Shear modulus [Pa]
1.0E+08
1.0E+07
1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-06
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E+00
1.0E+01
Reduced angular frequency [1/s]

Asphalt Binder Testing

- Repeated Creep-Recovery Test
  - Apply 10 kPa load for 11 seconds, followed by 11 second recovery period
  - 17 Creep-Recovery cycles were applied at 40˚C
  - Deformation was continuously recorded



Results of repeated creep-recovery tests at 40°C
Deformation [%]
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
400
Time [s]
40/60 bitumen (untreated)
PMB S (untreated)
PMB JR (untreated)



Results of repeated creep-recovery tests at 40°C
40/60 bitumen (immersed in jet fuel)
PMB S (immersed in jet fuel)
PMB JR (immersed in jet fuel)
Deformation [%]
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
400
Time [s]

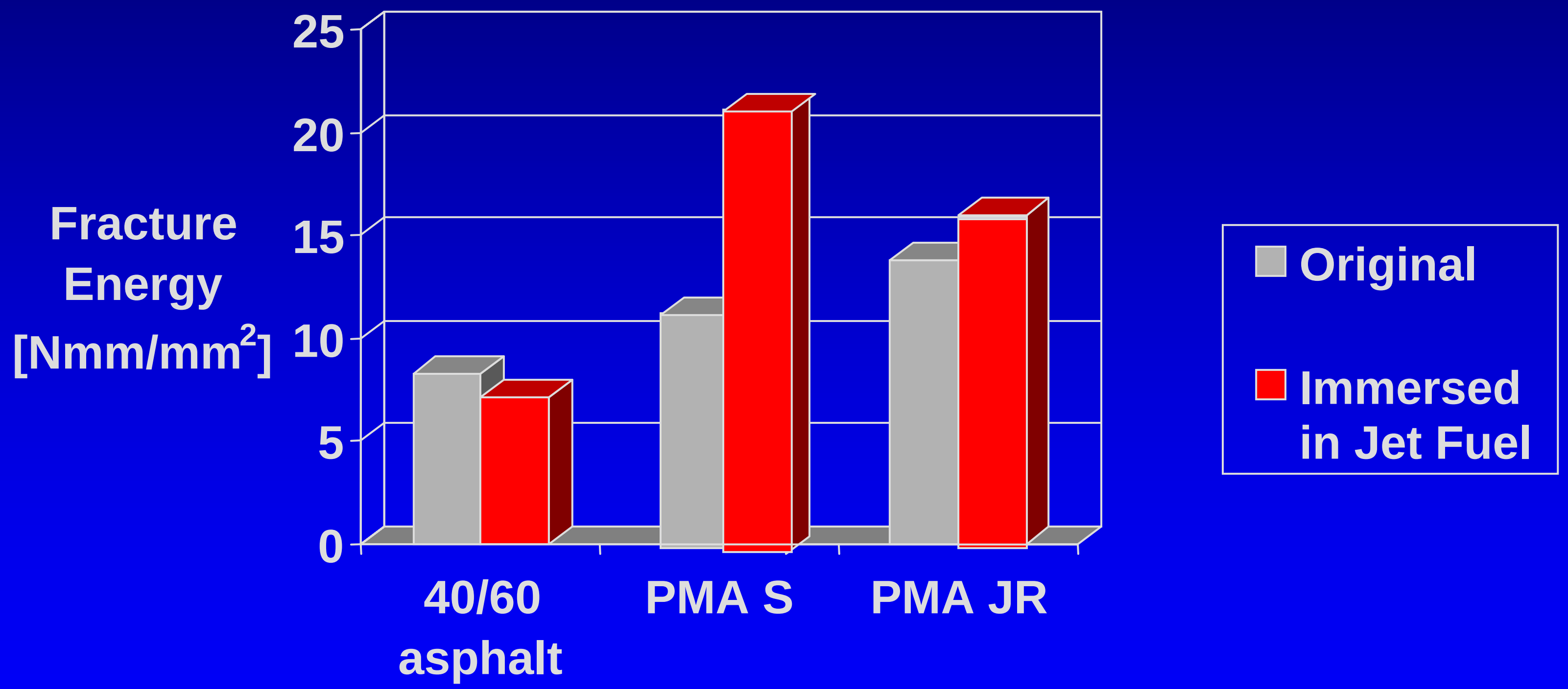
Laboratory Testing - Mixture

- Compared original hot mix asphalt (HMA) with mix submersed in jet fuel
- Compared unmodified PG 70-22 with PMA PG 76-22 and fuel resistant PMA
- Tested resistance to rutting and cracking

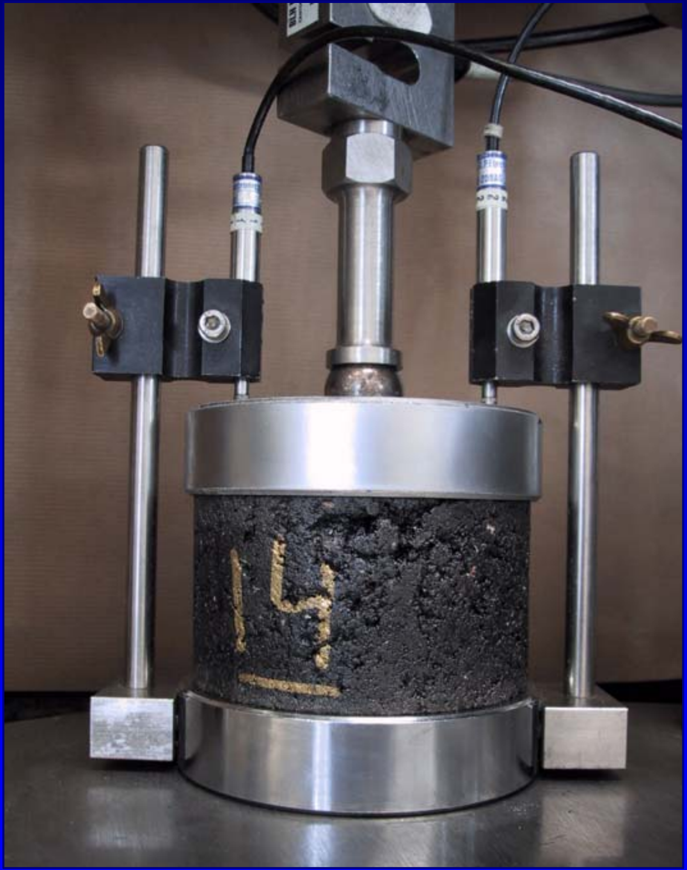
Laboratory Testing - Mixture

- Tested resistance of mixture to cracking with indirect tensile strength test
- Test temperature 0°C
- Deformation rate of 0.85 mm/sec
- Measured fracture energy

Indirect Tensile Strength Test

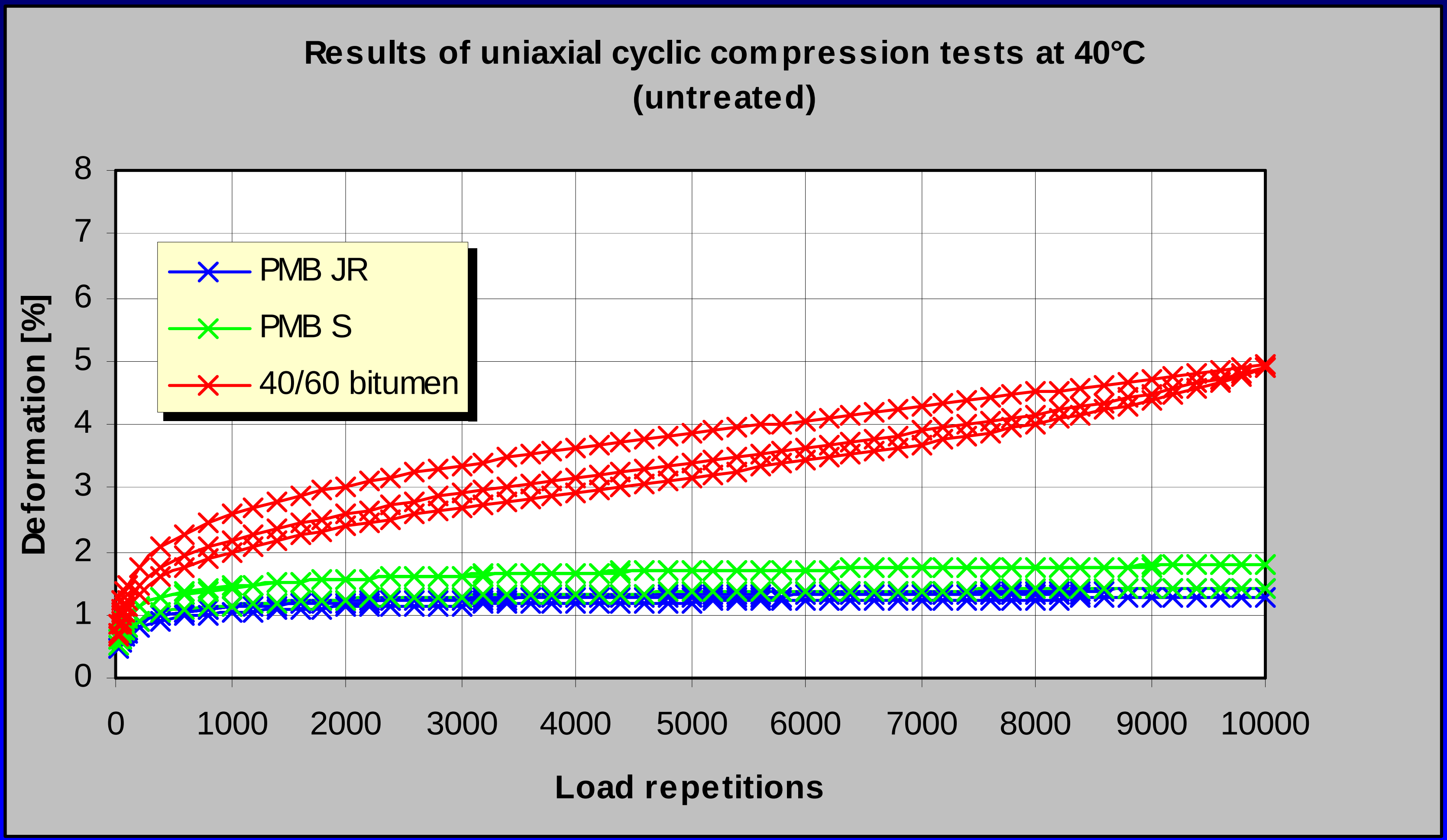


Laboratory Testing - Mixture

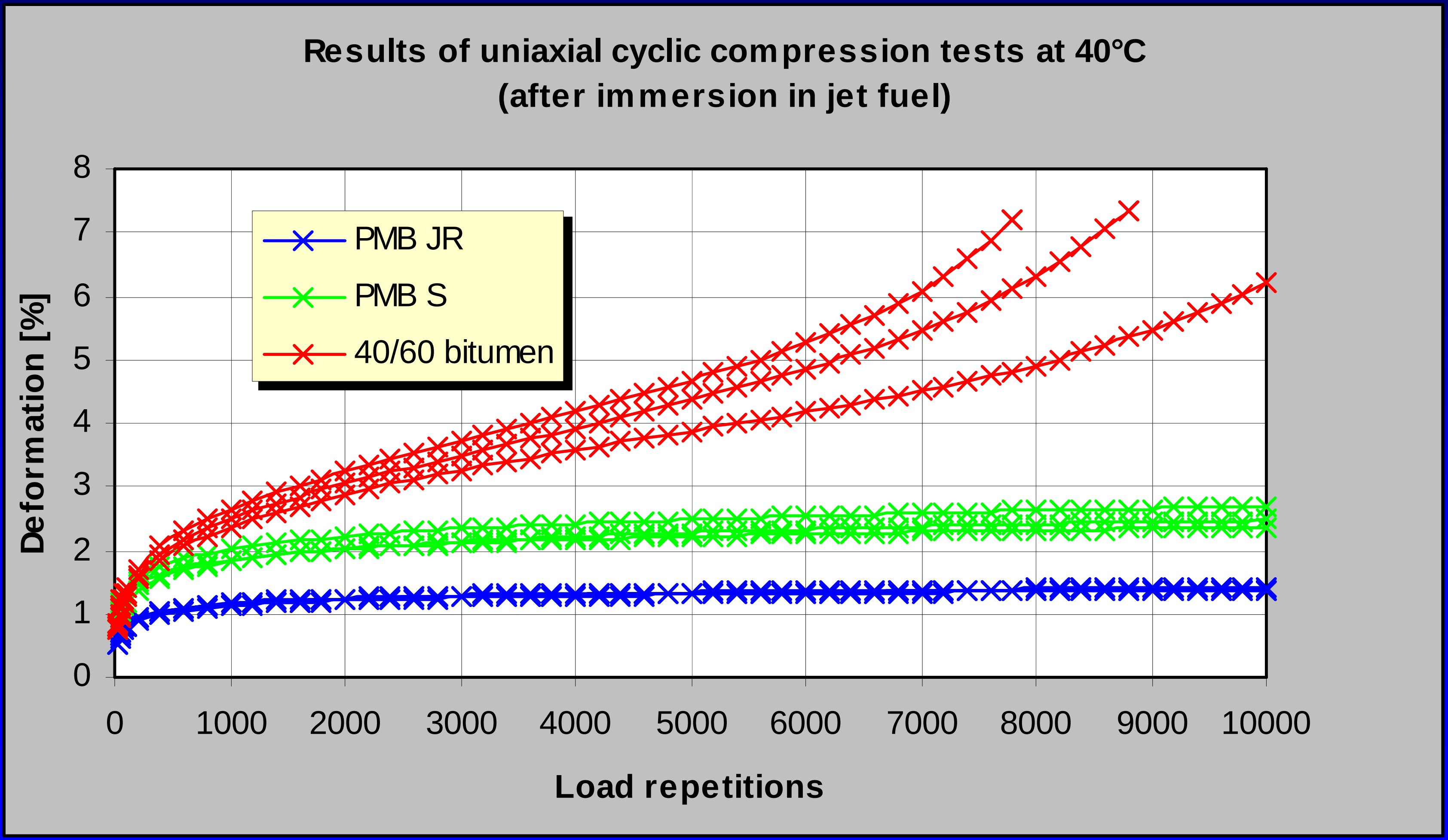


- **Tested resistance of mixture to permanent deformation with uniaxial cyclic compression test**
  - Test temperature 40˚C (60˚C for St Maarten)
  - 0.4 MPa load applied for 0.3 seconds
  - Rest period 0.7 seconds
  - Test stopped at 10,000 cycles or 7% permanent deformation

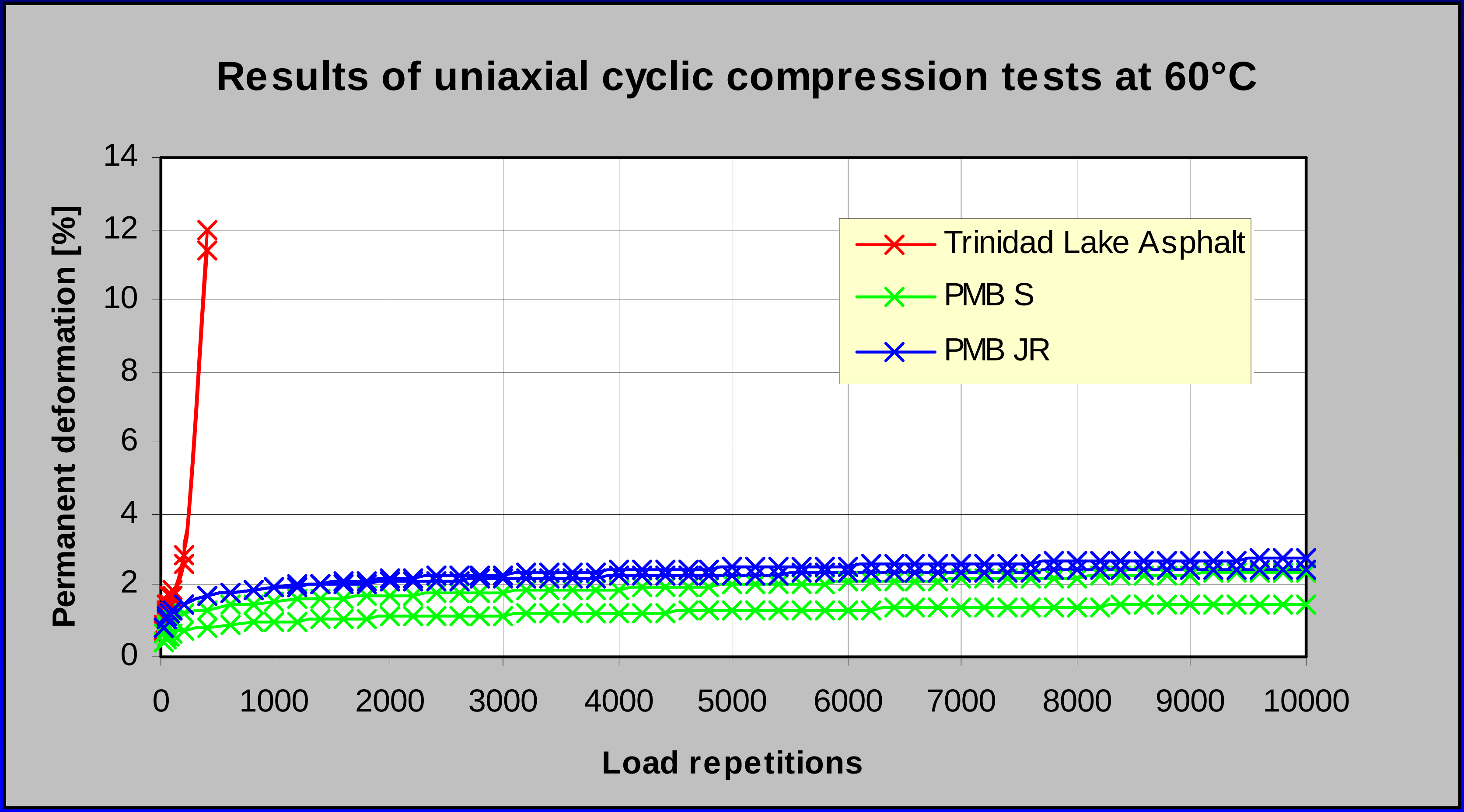
Uniaxial Cyclic Compression Test



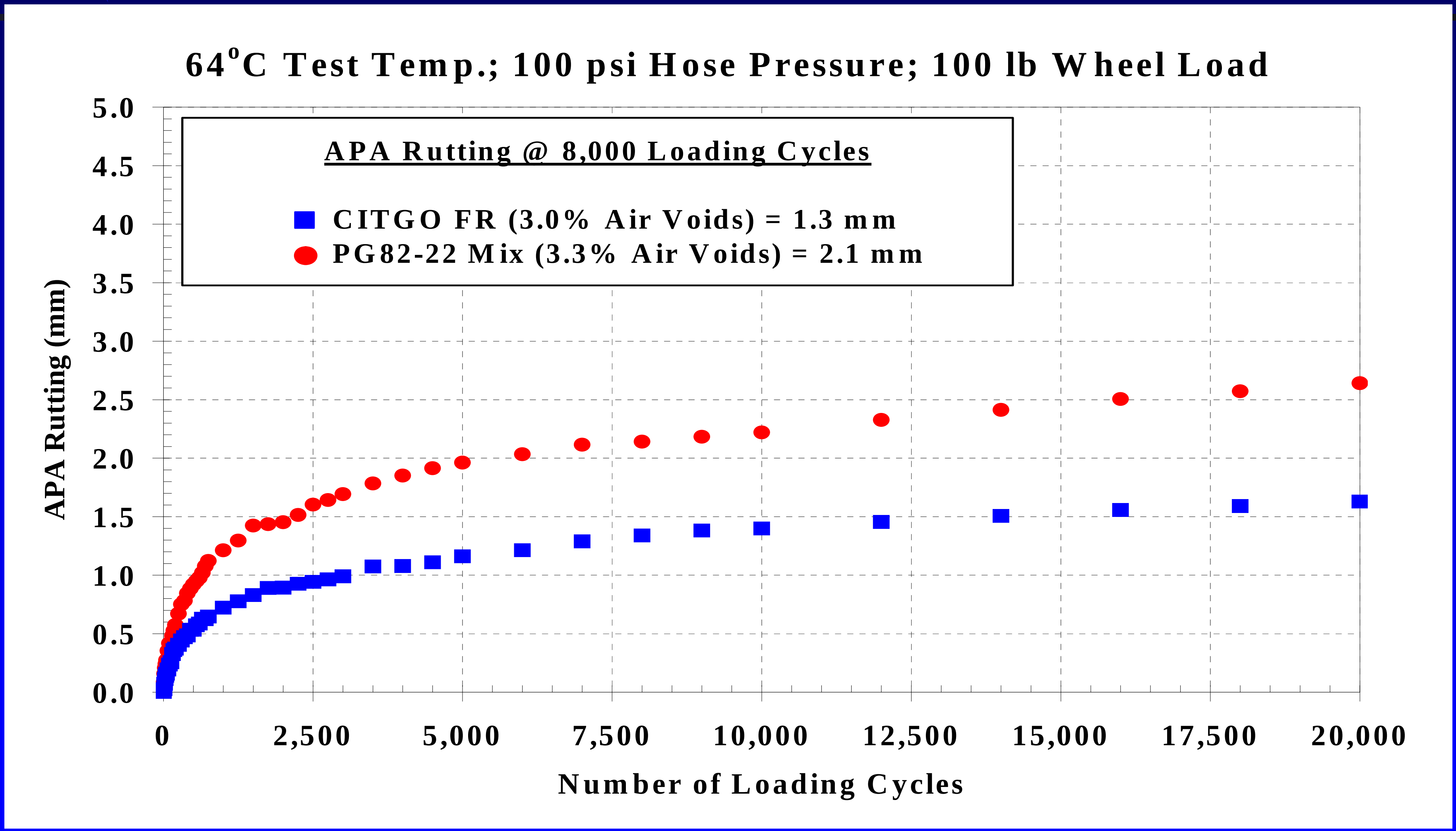
Uniaxial Cyclic Compression Test



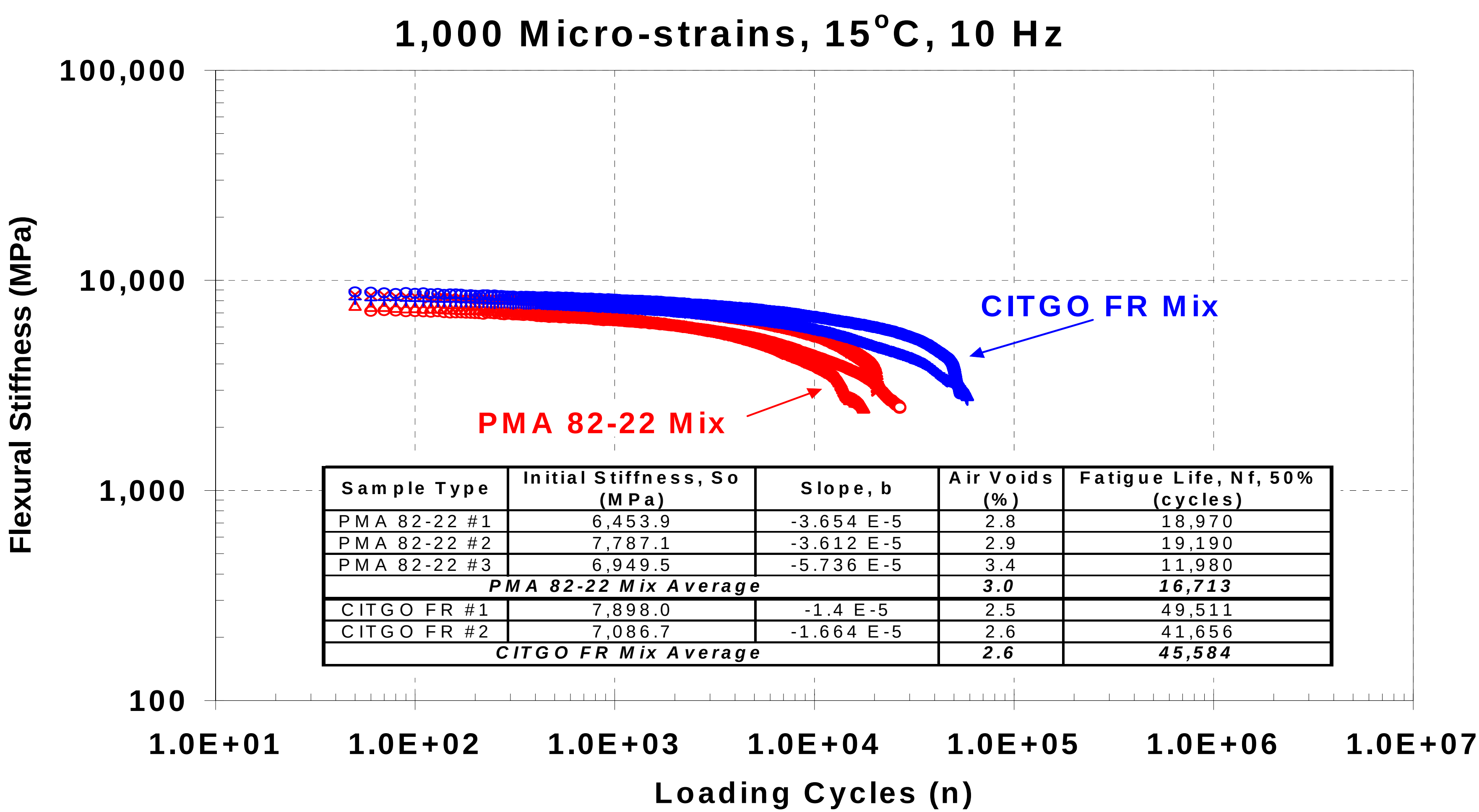
Uniaxial Cyclic Compression Test – St Maarten Airport



Asphalt Pavement Analyzer (APA) Testing



Flexural Beam Testing



Sample Type	Initial Stiffness, So (MPa)	Slope, b	Air Voids (%)	Fatigue Life, Nf, 50% (cycles)
PMA 82-22 #1	6,453.9	-3.654 E-5	2.8	18,970
PMA 82-22 #2	7,787.1	-3.612 E-5	2.9	19,190
PMA 82-22 #3	6,949.5	-5.736 E-5	3.4	11,980
PMA 82-22 Mix Average			***3.0***	***16,713***
CITGO FR #1	7,898.0	-1.4 E-5	2.5	49,511
CITGO FR #2	7,086.7	-1.664 E-5	2.6	41,656
CITGO FR Mix Average			***2.6***	***45,584***

First Fuel-Resistant PMA Usage - Kuala Lumpur International Airport

Kuala Lumpur International Airport

- Constructed between 1996 and 1998
- 450mm cement treated base
- 100mm HMA base – conventional asphalt
- 150mm HMA base and surface containing jet fuel resistant PMA
  - 260,000 tons HMA

Fuel-Resistant PMA Usage

- Fuel Resistant PMA Airport Projects Around the World
  - Cairo, Egypt Airport – Reconstruction of main runway – 1997 (220,000 tons)
  - Aden, Yemen Airport – Reconstruction of main runway – 1999-2000 (40,000 tons)
  - St Maarten Airport – Reconstruction of apron – 2001 (12,000 tons)
- All projects report excellent performance to date

Fuel-Resistant PMA Usage

- **First Construction Project in US – La Guardia Airport**
  - **Test section on taxiway – 450 tons**

Fuel-Resistant PMA Usage – La Guardia

- Placed Fuel Resistant PMA at La Guardia Airport August 2002
- Graded as PG 94-22
- Pumped into plant at 330°F
- Produced mix at 340°F
- Placed in silo for 4 hours

Fuel-Resistant PMA Usage – La Guardia

- **Paved at 330°F**
- **No problems with placement**
- **Handwork and longitudinal joints look good**
- **Density achieved**
- **Paving crew could not see a difference in fuel resistant PMA material from standard PMA**

Fuel-Resistant PMA Usage – La Guardia

- Inspected fuel resistant pavement in October 2003
- Excellent condition
  - No rutting
  - No cracking
  - No surface deterioration

Fuel-Resistant PMA Usage

- At major airports, coarse mixes used to prevent rutting
  - Low AC %
  - Prone to segregate
  - Durability
- Recommend 1 ½” surface containing fuel resistant PMA to provide fuel resistance to entire pavement structure
  - Use ½” P-401 mix
  - Design at 2.5% air voids

Fuel-Resistant PMA Usage

- Developed generic specification for fuel resistant HMA
  - Minimum PG 82-22 polymer modified asphalt
    - Pass fuel resistance test
    - Minimum 85% Elastic Recovery
  - Standard test method for fuel resistance
  - ½” P-401 mix
    - 50 blow Marshall design
    - Design at 2.5% air voids

Fuel-Resistant Usage – Logan Airport

- **Placed 1300 tons of fuel resistant mix on Taxiway N and Runway 4L-22R at Logan Airport in June 2004**

Fuel-Resistant Usage – Logan Airport

- Fuel Resistant Asphalt graded as PG 94-22
- 1/2" P-401 mix designed at 2.5% air voids
- 7% asphalt content design target

Fuel-Resistant Usage – Logan Airport

- Mix produced in drum plant at 340˚F
- Placed at 325˚F without difficulty
- Met density specification
- Excellent surface appearance

Fuel-Resistant Usage – Logan Airport

- Revisited Logan in October 2004 & October 2005
- Previous HMA materials on this taxiway exhibited plastic flow (rutting and shoving) after one summer

Fuel-Resistant Usage – Logan Airport

- October 2005 – after 2 summers
  - No rutting
  - No raveling
  - No cracking
  - “Grooving looks like the day we cut them”

Fuel-Resistant Usage – Logan Airport

- October 2005 – Alleyway Project
  - Mill 8” of existing HMA
  - Base - 6.0” of ¾” P-401 with PG 82-22 PMA
  - Surface – 2” of ½” P-401 with PG 94-22 FR

Fuel-Resistant Usage – Logan Airport

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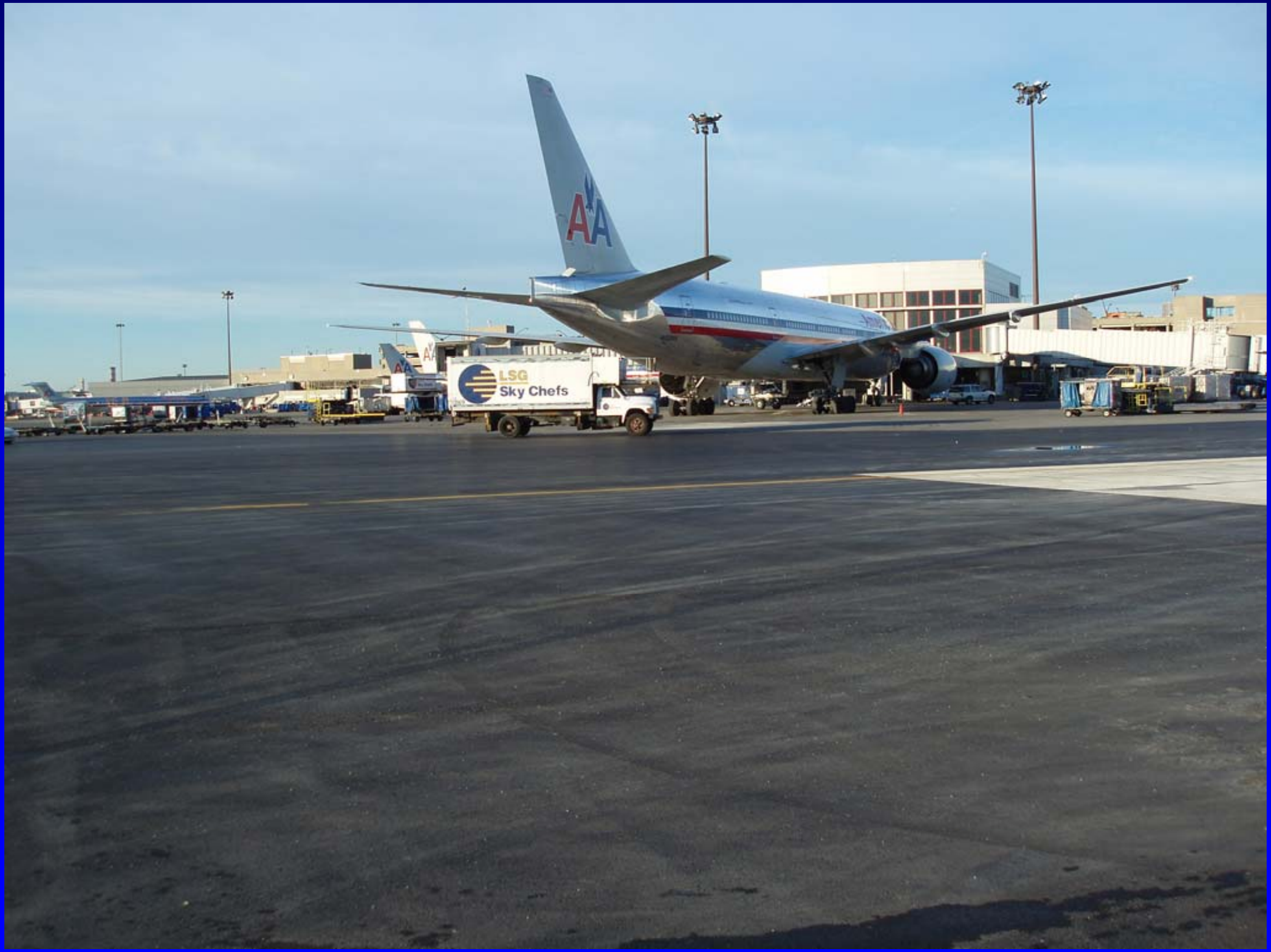
Fuel-Resistant Usage – Logan Airport



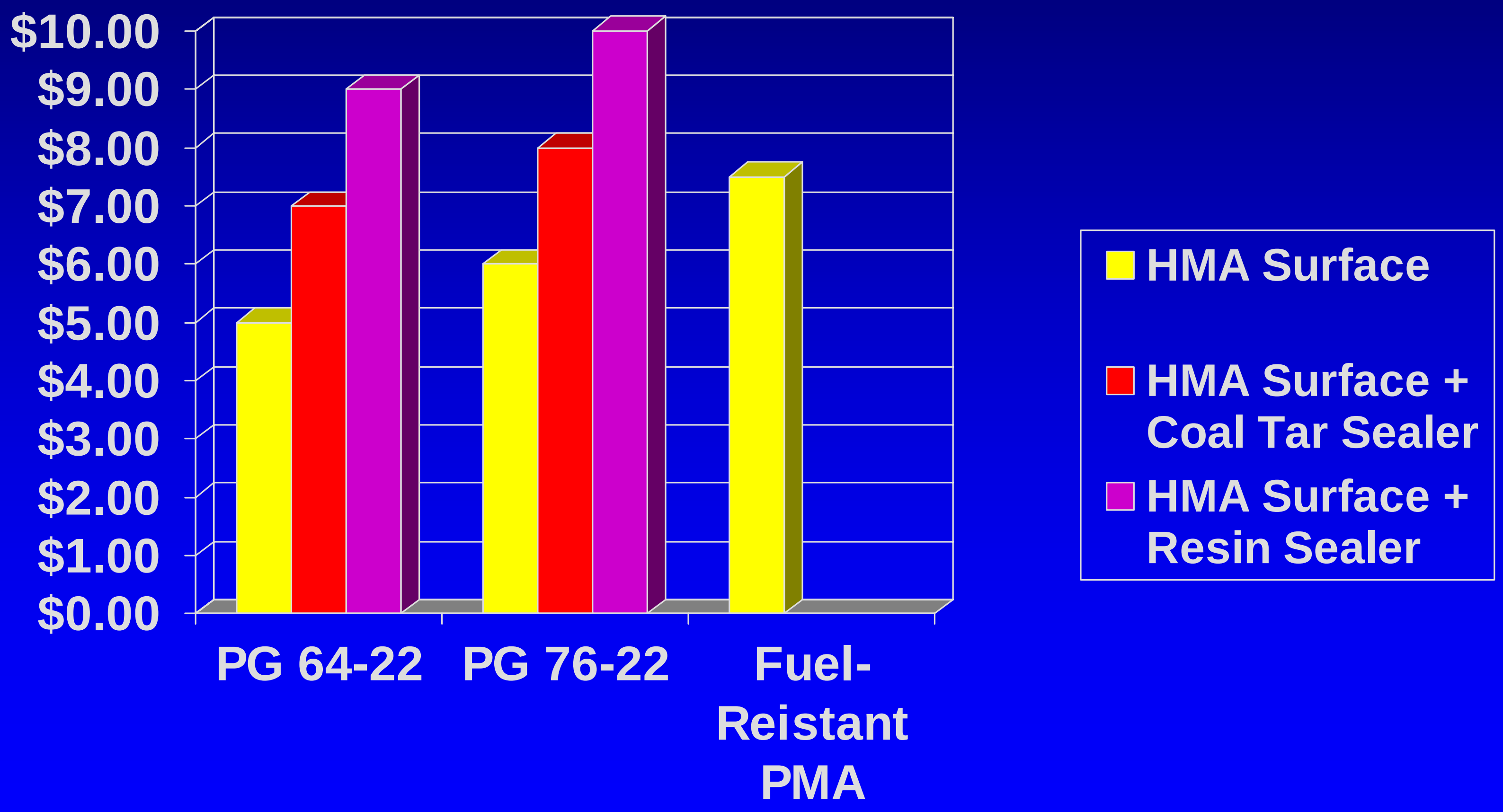
Fuel-Resistant Usage – Logan Airport

- October 2005 – Alleyway Project
  - Project in 8 phases to maintain air traffic
  - Planes pushed back one day after paving on new HMA

Fuel-Resistant Usage – Future Projects

- **Boston, MA - Logan Airport**
  - **Alleyway Project – Summer 2006**
- **Charlotte, NC - Douglas International Airport**
  - **Taxiway Project – Summer 2006**
- **Florida DOT**
  - **I-95 Truck Inspection Station – Summer 2006**

Cost Comparison



Fuel Resistant PMA Summary

- Polymer-Modified Asphalt developed specifically to resist fuel damage
- Eliminate need for coal-tar sealers
- Environmentally sensitive solution for fuel spills on HMA pavements
  - Airports
  - Truck stops
  - Truck inspection facilities
  - Parking lots

Questions?