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

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CITGO

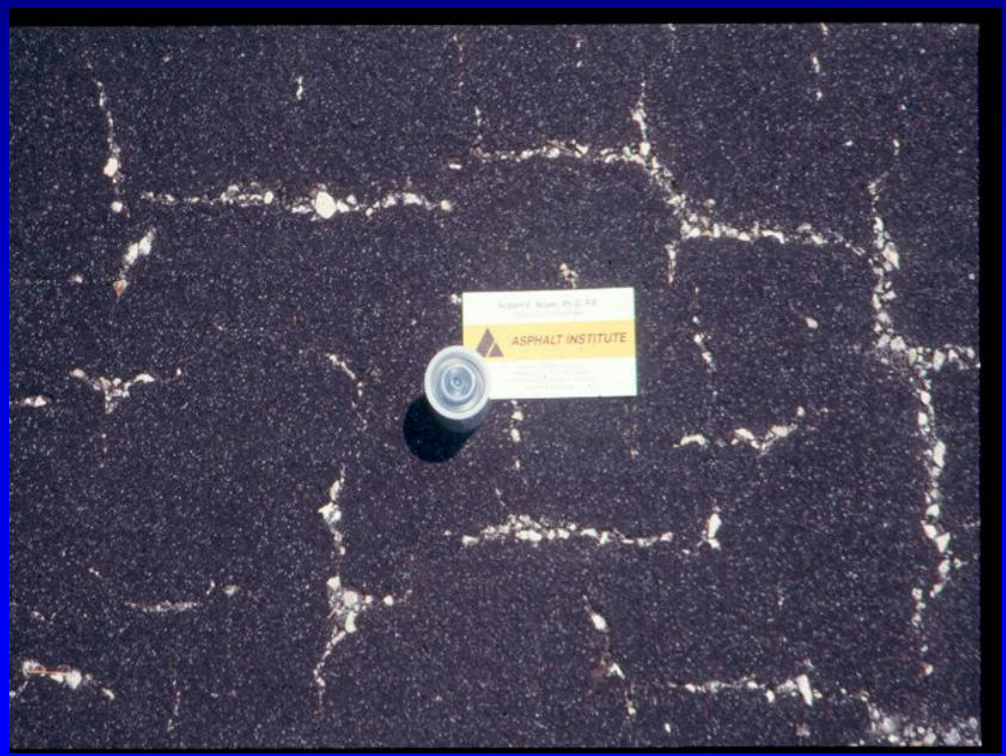
Acknowledgements

- Co-Authors
- Ronald C. van Rooijen
  - R&D Laboratory Manager
- Arian H. De Bondt
  - R&D Manager
- Ooms Avenhorn Holding, The Netherlands
  - Developed fuel resistant polymer-modified asphalt
  - Performed initial laboratory analysis

Background

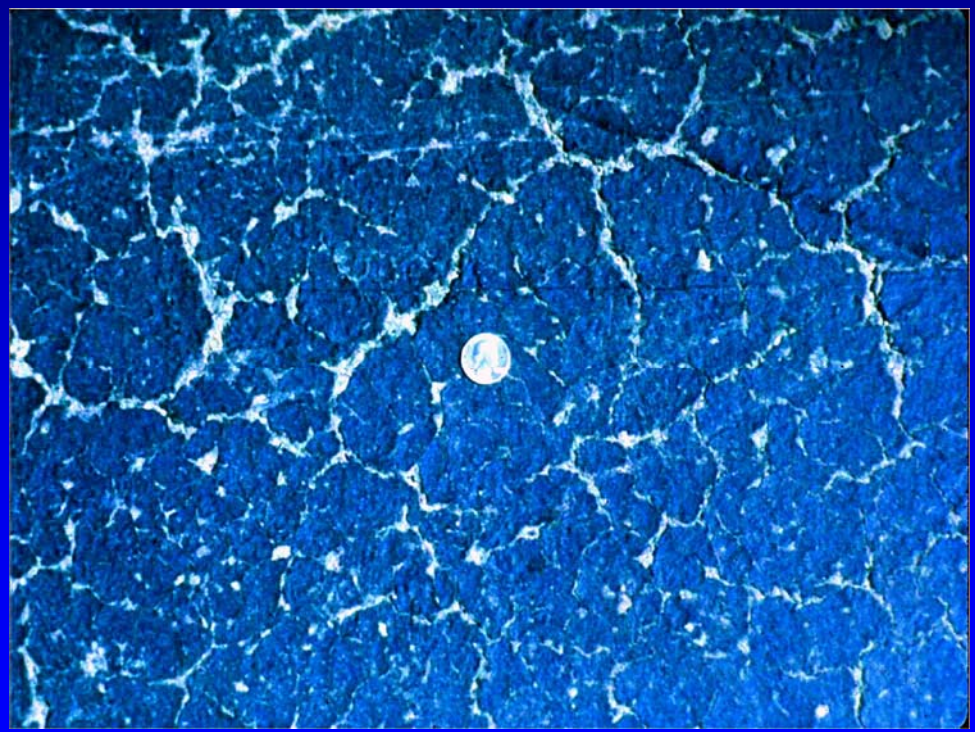
- Airports experience jet fuel spills on aprons and taxiways
  - Fueling operations
  - Aircraft sitting in queues
  - Softens (weakens) asphalt
  - Causes permanent deformations and failures

Fuel Resistant Pavement Sealers



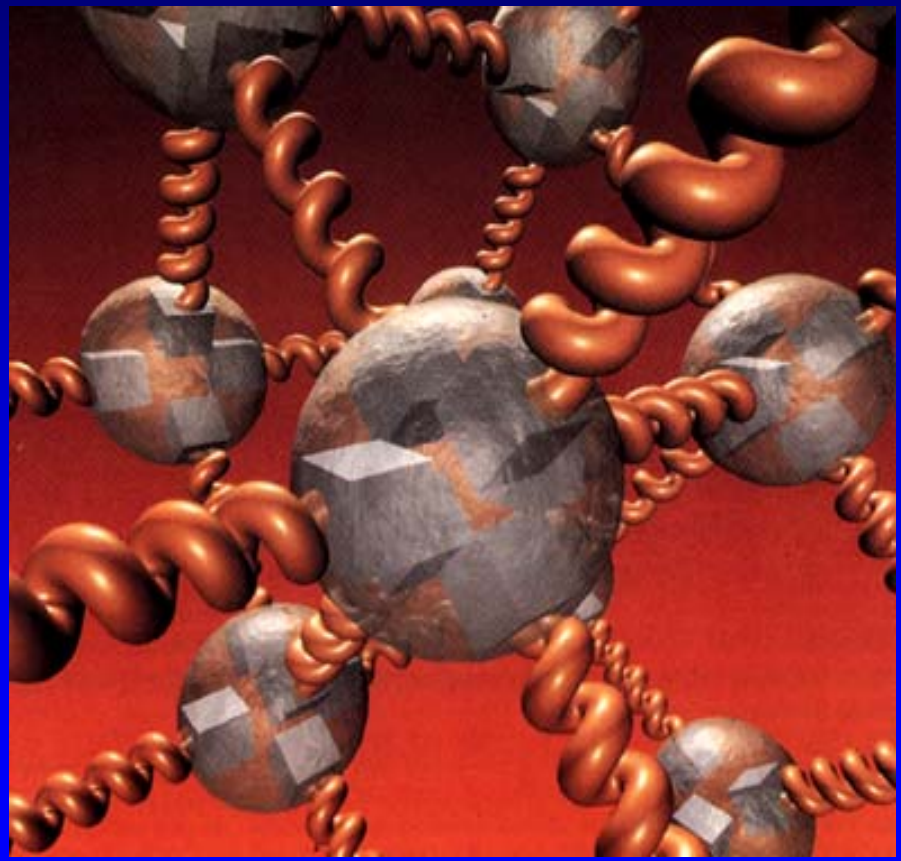
- Coal tar sealers are most commonly used to protect Hot Mix Asphalt pavements from fuel damage
- Different coefficient of expansion for coal tar causes substantial alligator cracking within 2-3 years
- Cracking allows fuel penetration - short service life

Fuel Resistant Pavement Sealers



- **Coal tar sealers are carcinogenic**
  - **MSDS – "Unusual Chronic Toxicity: May cause cancer of the skin, lungs, kidney and bladder."**
  - **Adding carcinogenic material to pavement that may be recycled – future exposure**

Development of Fuel-Resistant PMA



- Ooms Avenhorn Holding (The Netherlands) developed Sealoflex® polymer modified asphalt (PMA) system in late 1970's
  - Cross-linked Styrene–Butadiene-Styrene (SBS) polymer
  - Excellent resistance to both rutting and cracking
- Used around the world for over 20 years in both highway and airport applications

Development of Fuel-Resistant PMA

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

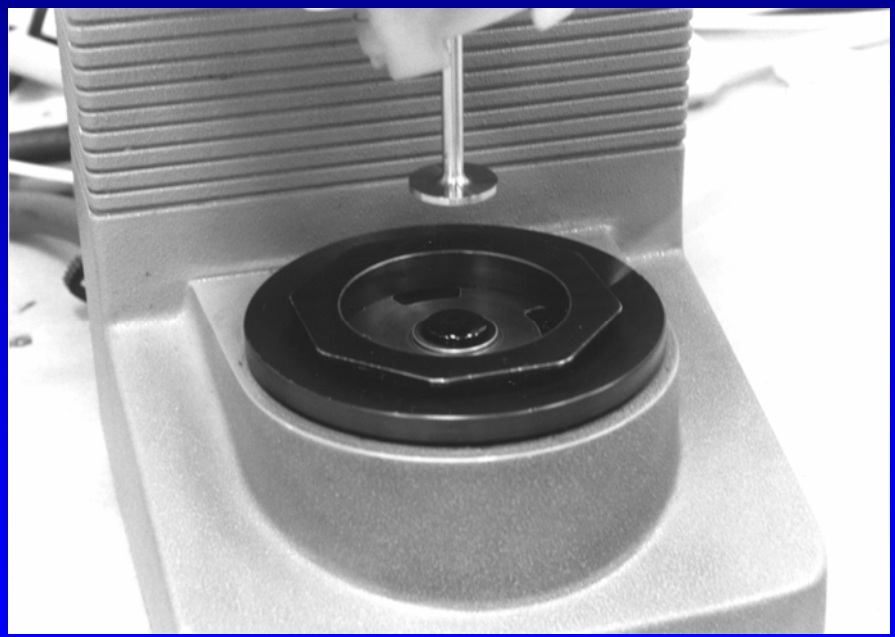
Development of Fuel-Resistant PMA

- 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 Sealoflex JR® – less than 0.5% weight loss

Laboratory Testing – Asphalt Binder



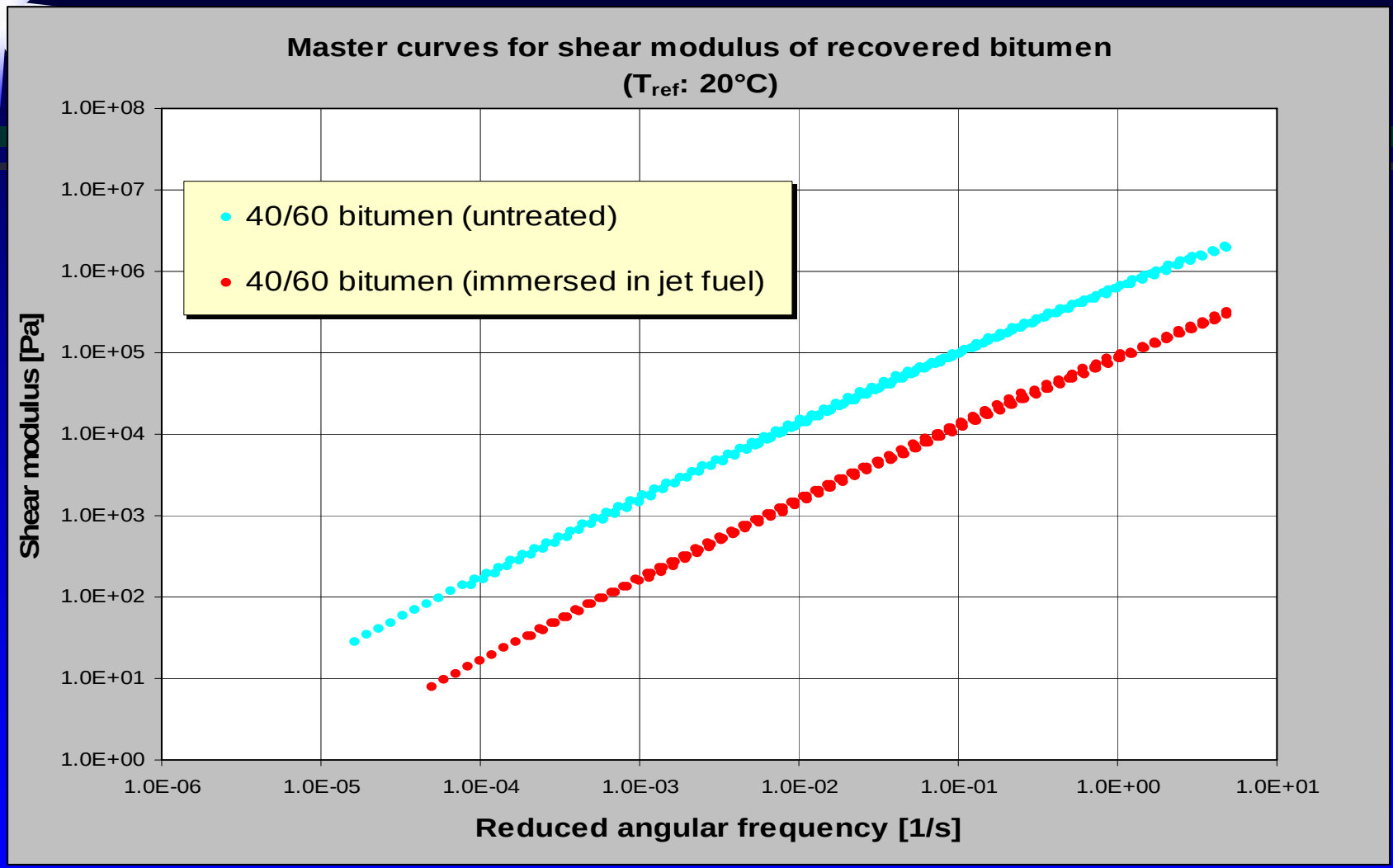
- Tested asphalt binder properties using Dynamic Shear Rheometer (DSR)
- Place asphalt sample between fixed and movable steel plates
- Apply stress to sample by oscillating motion and measure resulting strain

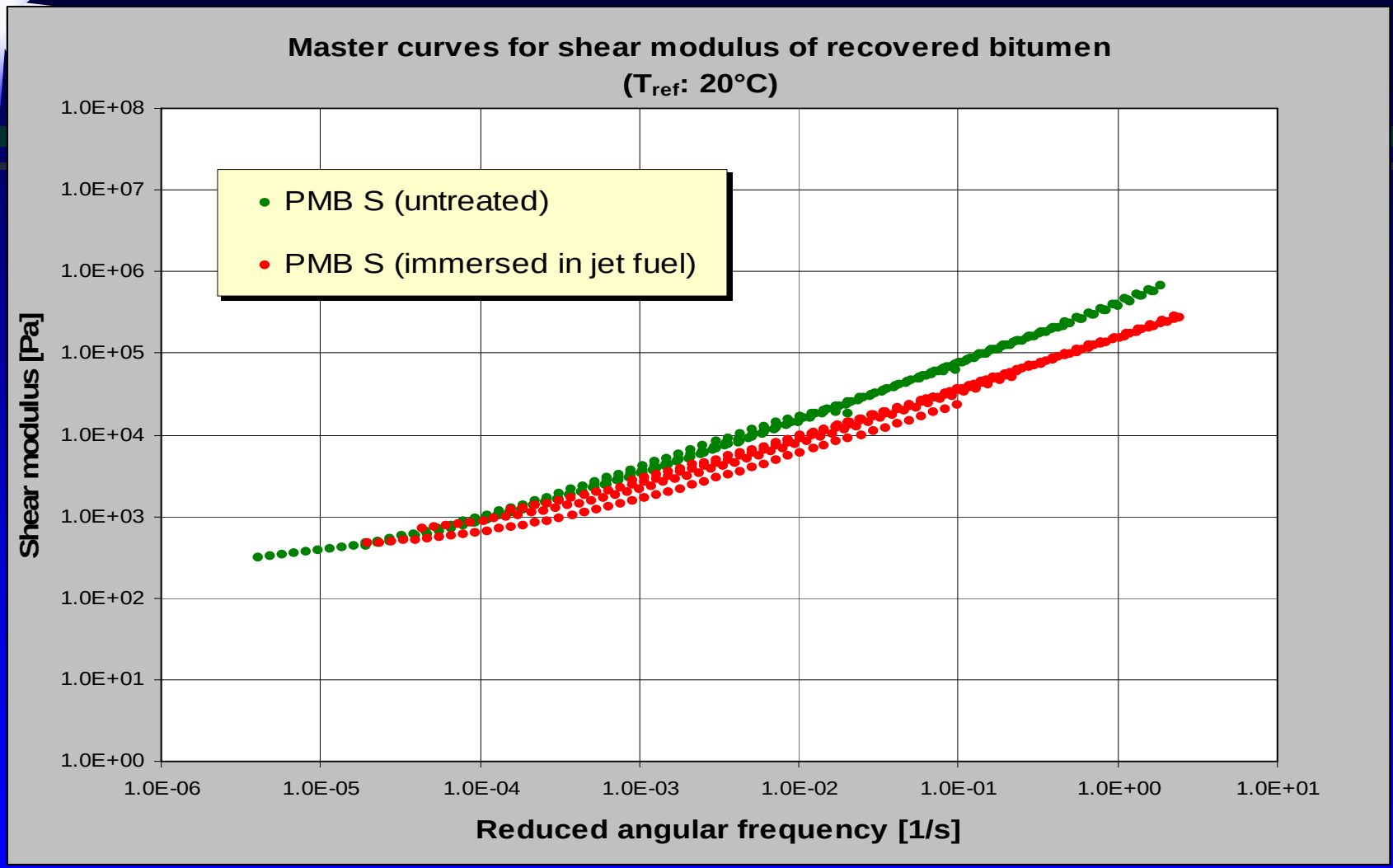
Asphalt Binder Testing

- 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*)**
  - **Measure of asphalt strength**
  - **Mastercurve shows effect of loading frequency**
    - **Low frequency – long loading times**
    - **High frequency – short loading times**


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]
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1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-06
1.0E-05
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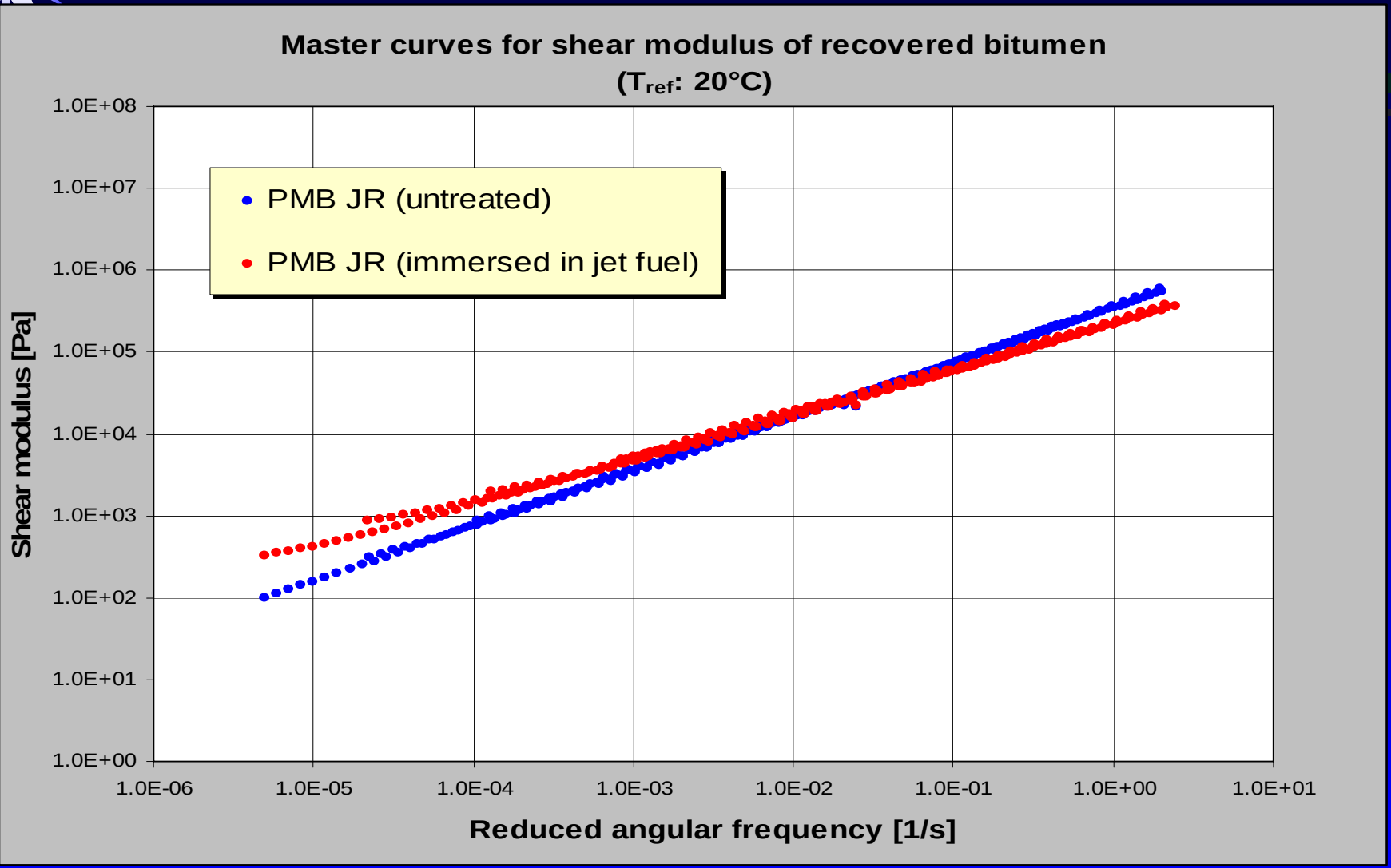
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PMB JR (untreated)
PMB JR (immersed in jet fuel)
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1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
1.0E+01
1.0E+00
1.0E-06
1.0E-05
1.0E-04
1.0E-03
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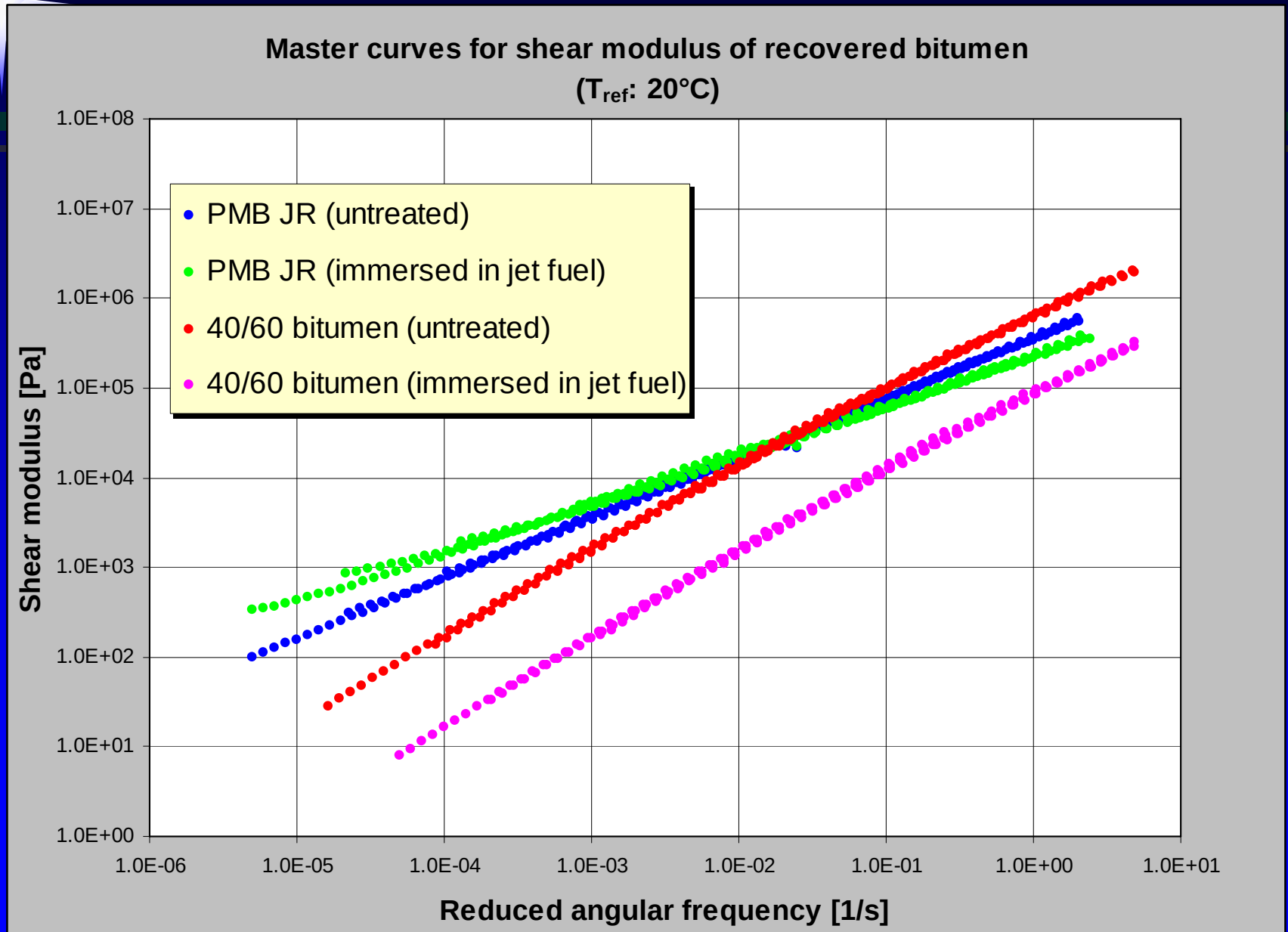
1.0E-01
1.0E+00
1.0E+01
Reduced angular frequency [1/s]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PMB JR (untreated)
PMB JR (immersed in jet fuel)
40/60 bitumen (untreated)
40/60 bitumen (immersed in jet fuel)
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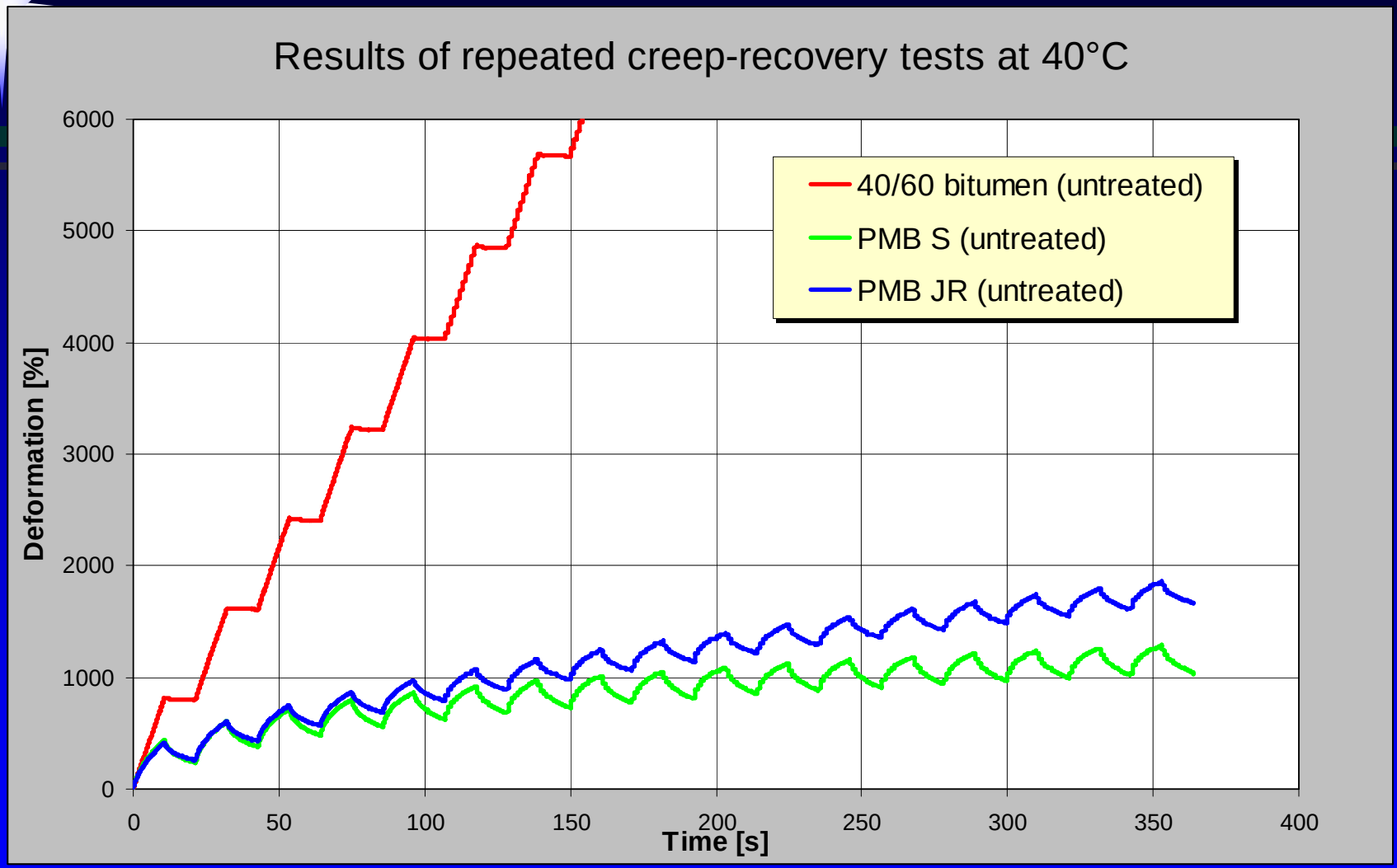
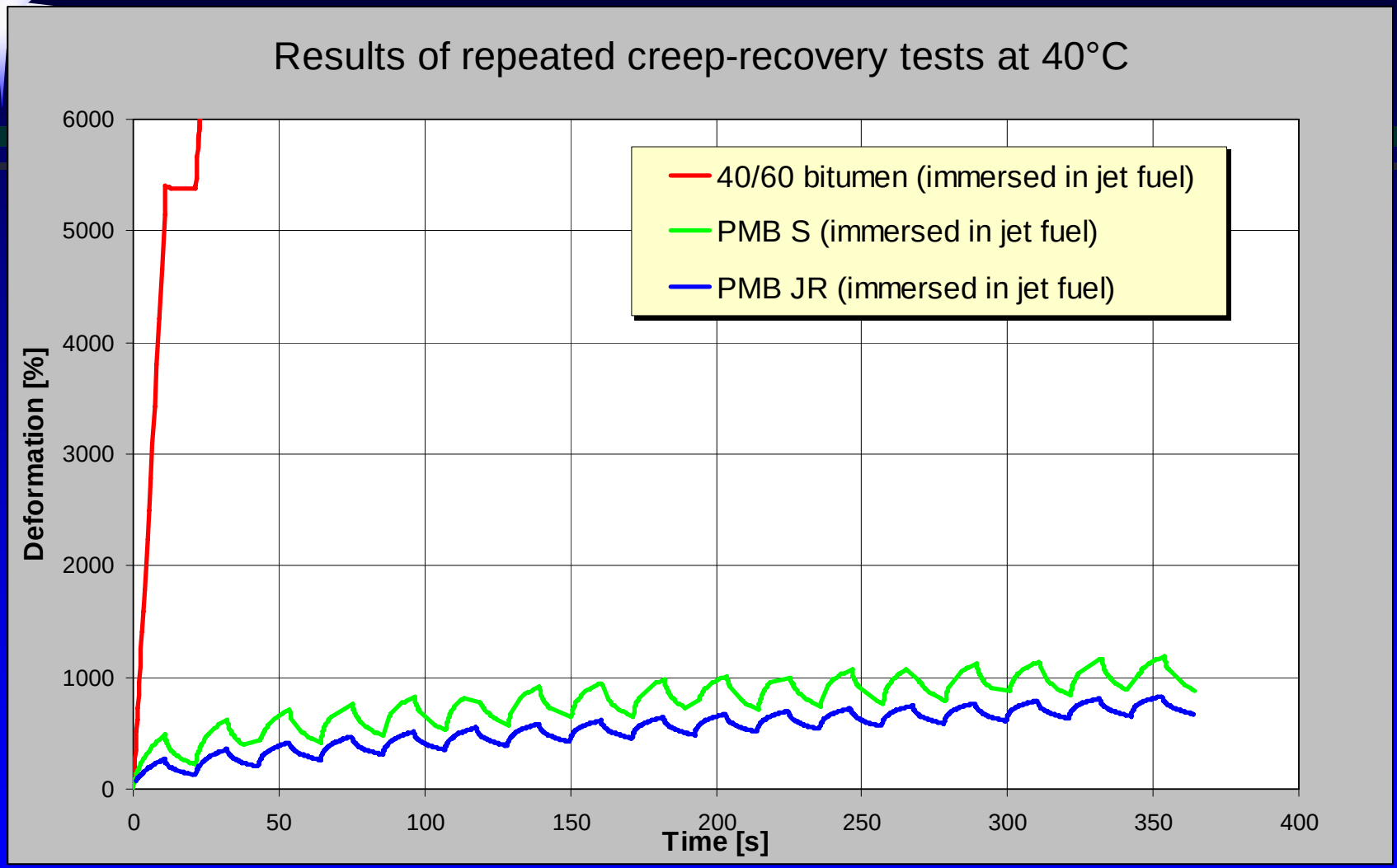
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E+00
1.0E+01
Reduced angular frequency [1/s]

Asphalt Binder Testing

- **Repeated Creep-Recovery Test**
  - **Measures benefits of elastomer**
  - **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]

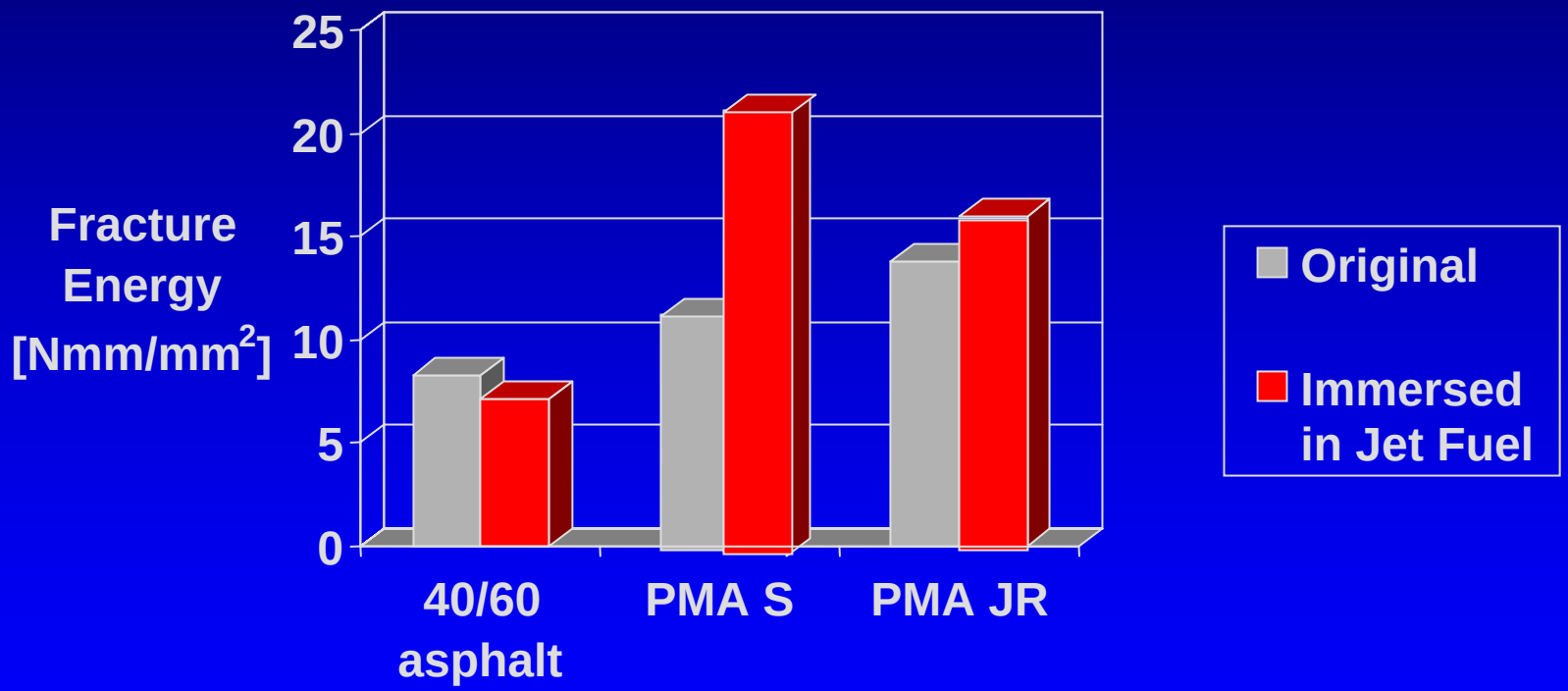
Laboratory Testing - Mixture

- 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
- High fracture energy is desired to prevent cracking

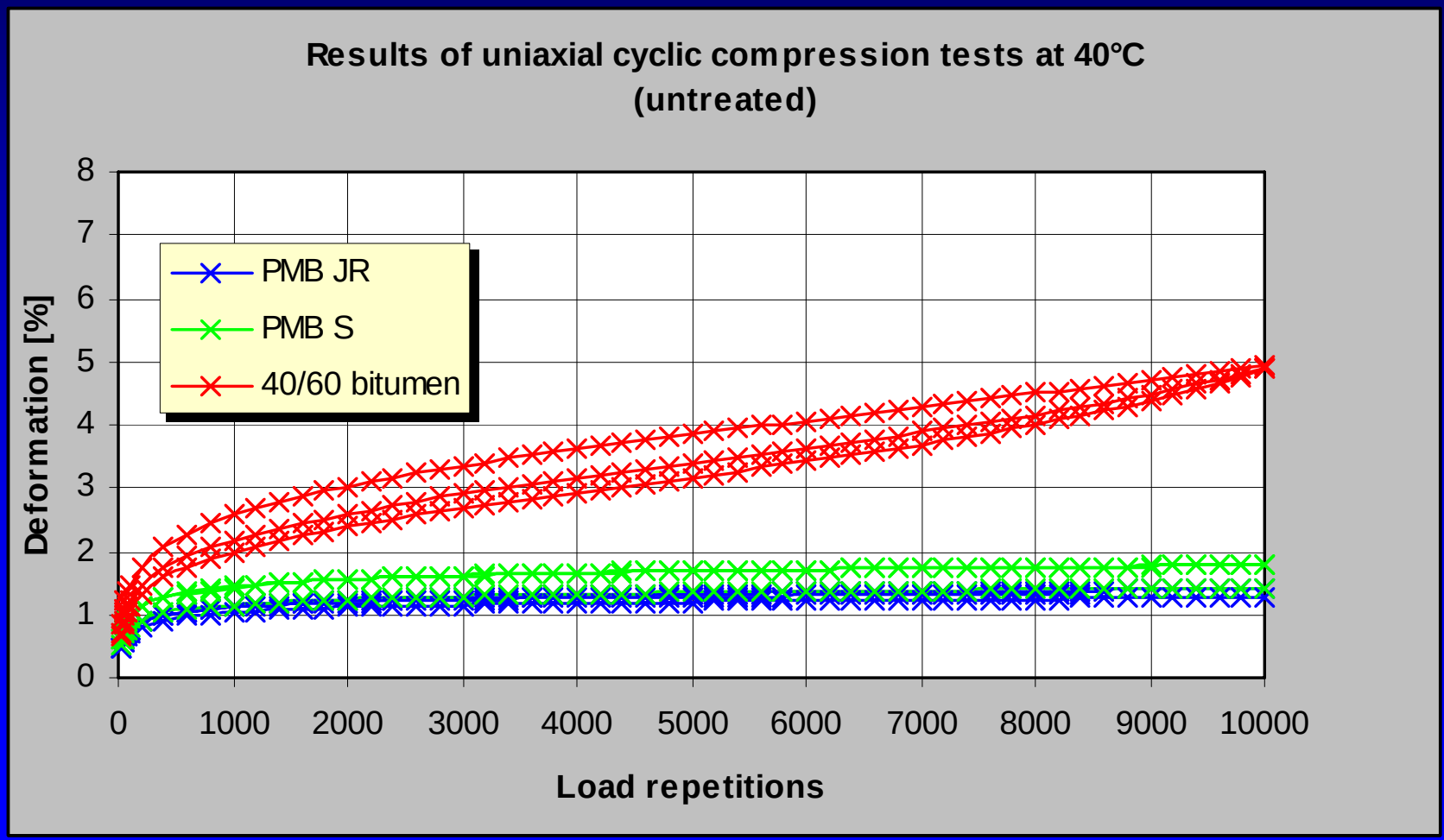
Indirect Tensile Strength Test



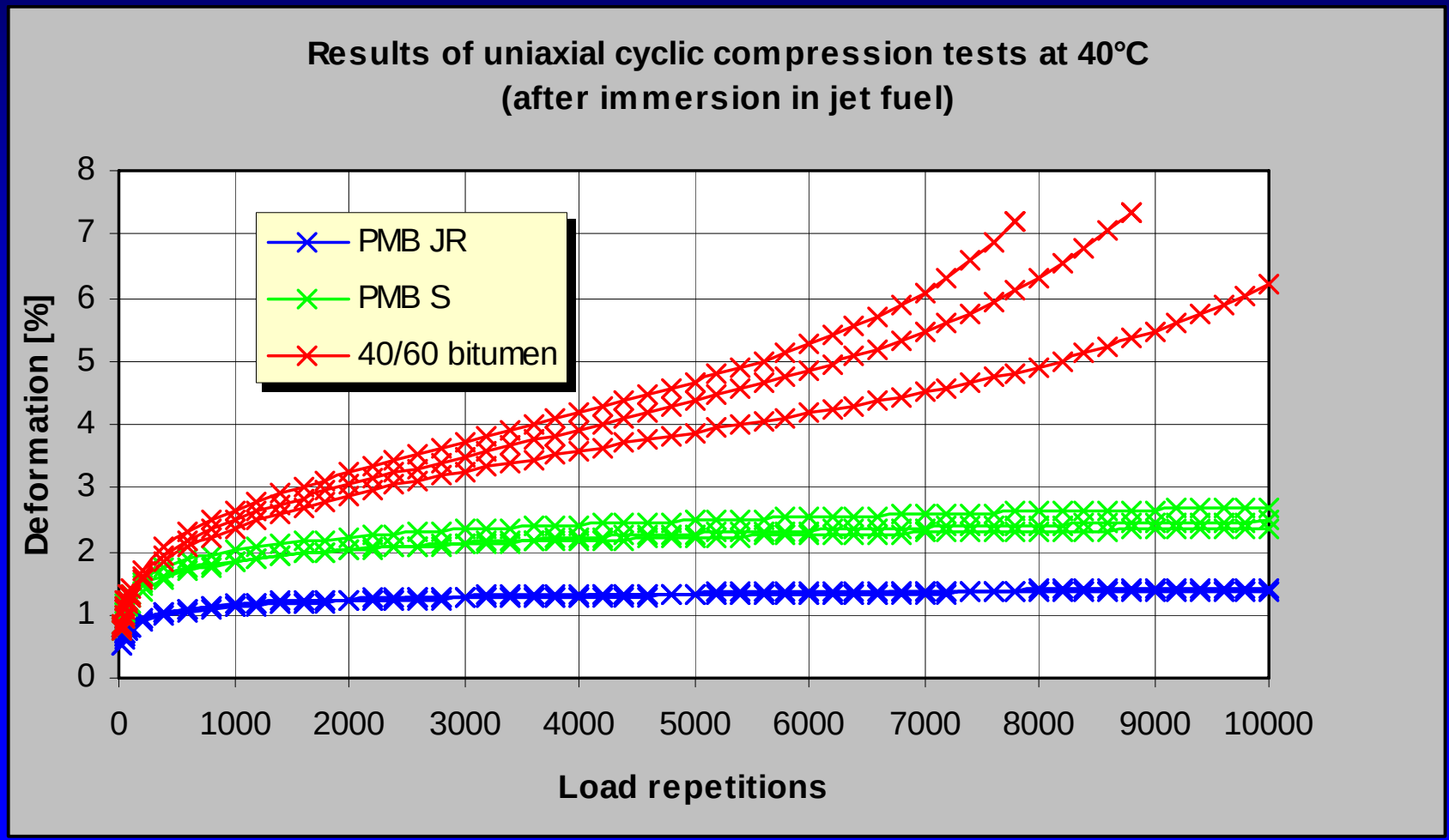
Laboratory Testing - Mixture

- 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

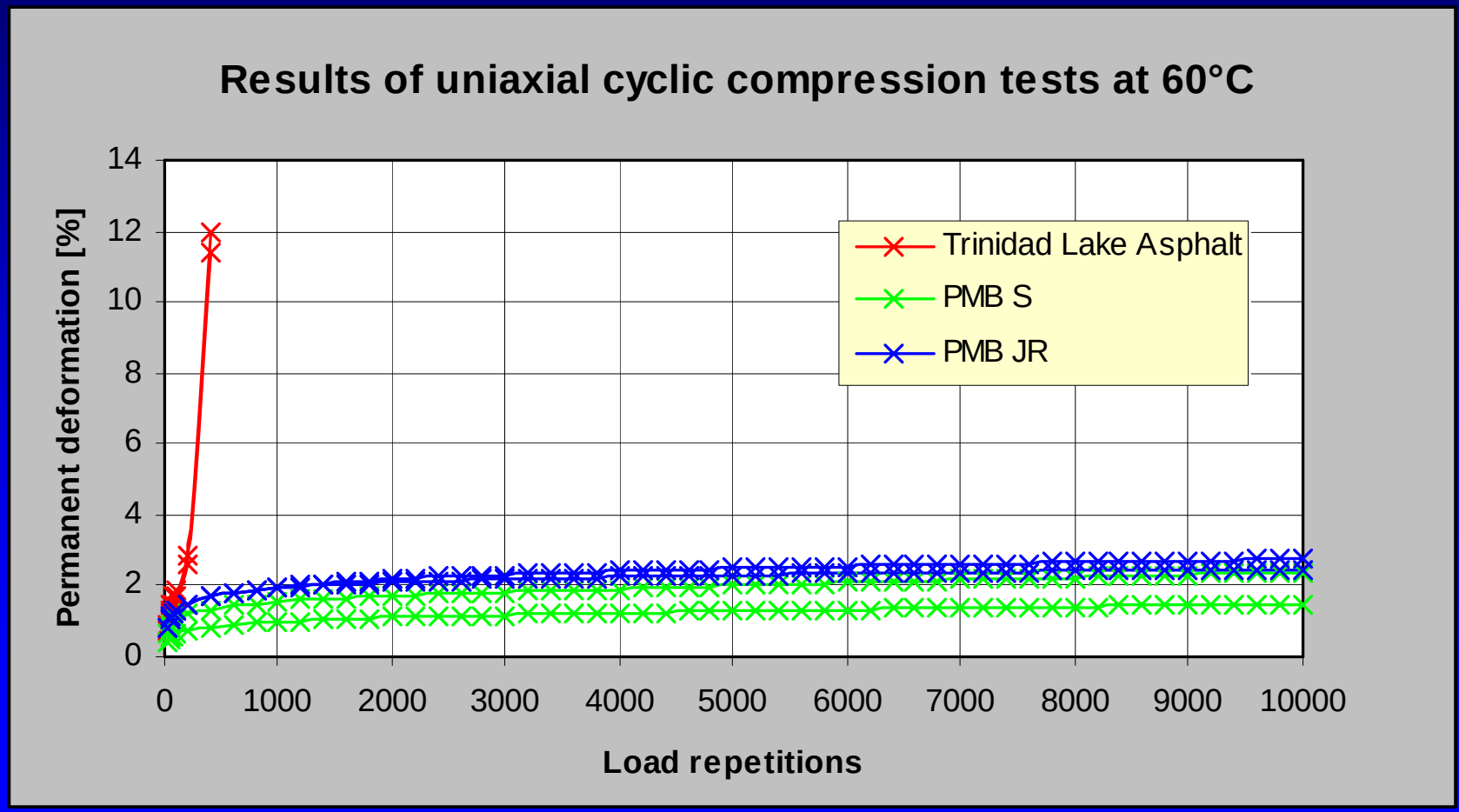
Uniaxial Cyclic Compression Test



Uniaxial Cyclic Compression Test



Uniaxial Cyclic Compression Test – St Maarten Airport



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

- **Sealoflex JR® 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

- Sealoflex JR® Technology Brought to US Market by CITGO Asphalt in 2002 as CITGOFLEX FR®
- First Construction Project in US – La Guardia Airport
  - Test section on taxiway – 450 tons

Fuel-Resistant PMA Usage – La Guardia

- Placed CITGOFLEX FR® 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 CITGOFLEX FR® 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

- 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 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

- FR Asphalt graded as PG 94-22
- 1/2” P-401 mix designed at 2.5% air voids
- 7% asphalt content design target
- APA testing at WPI showed 0.70mm rutting on this mix

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

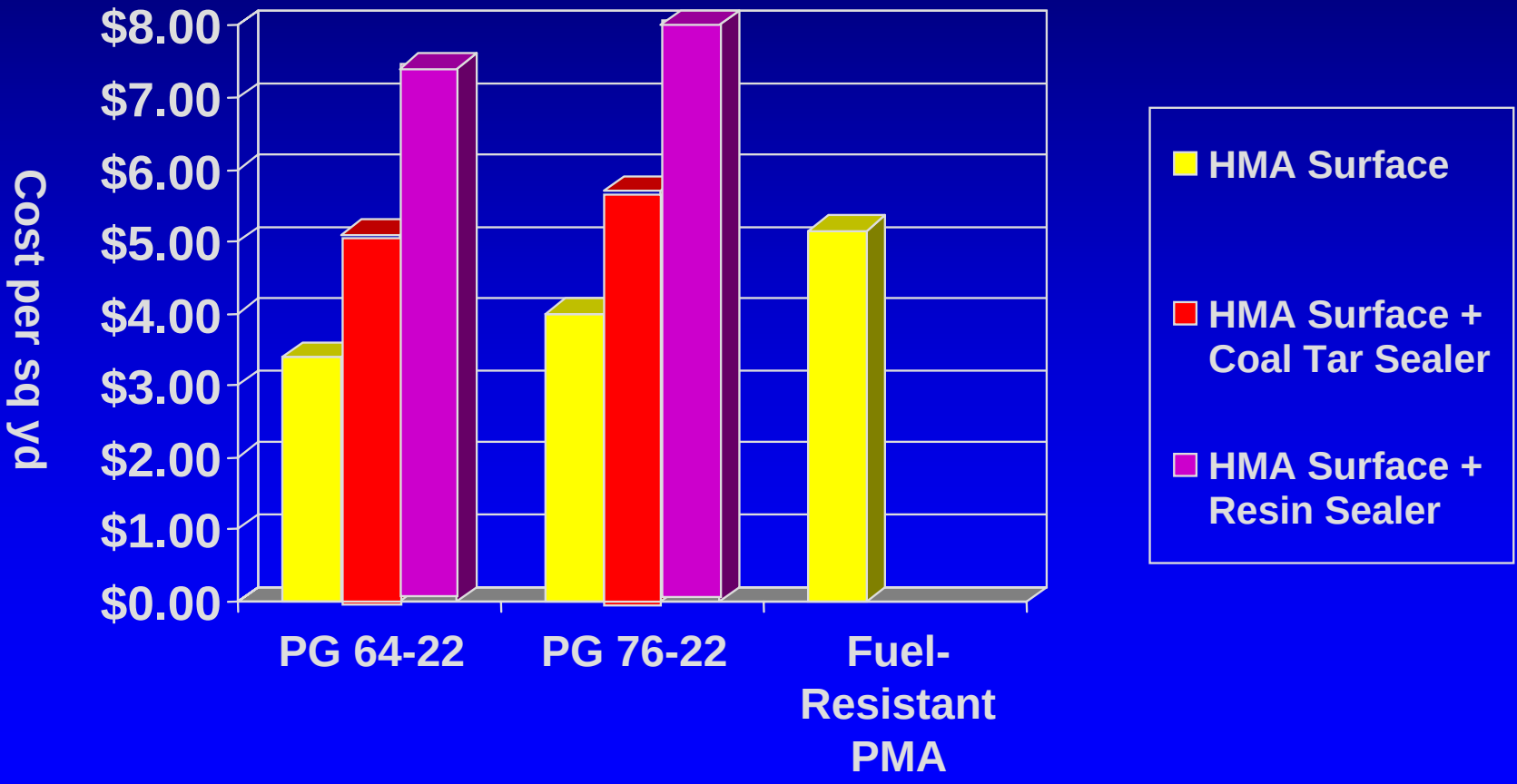
Fuel-Resistant Usage – Logan Airport

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

Fuel-Resistant Usage – Logan Airport

- No evidence of defects
  - No rutting
  - No raveling
  - No cracking

Cost Comparison



Fuel Resistant PMA Summary

- Polymer-Modified Asphalt developed specifically to resist jet fuel damage
- Eliminate need for coal-tar sealers
- Proven product – 7 year history

Fuel Resistant PMA Summary

- Polymer modification provides excellent resistance to permanent deformation and cracking
- Workability allows contractors to use standard construction practices
- Cost effective product

Questions?