Development and Field Evaluation of High Performance and Fuel Resistant Asphalt Mixture

SWIFT Conference & Trade Show
Vancouver, Canada
September 12, 2019

Sina Varamini, Ph.D., P.Eng.
Research and Development Manager
McAsphalt Industries Ltd

Ron Corun, P.E.
Specialty Products Manager
Associated Asphalt Partners LLC

Acknowledgment

Ron Corun, P.E.
Specialty Products Sales and Marketing Manager
Associated Asphalt Partners

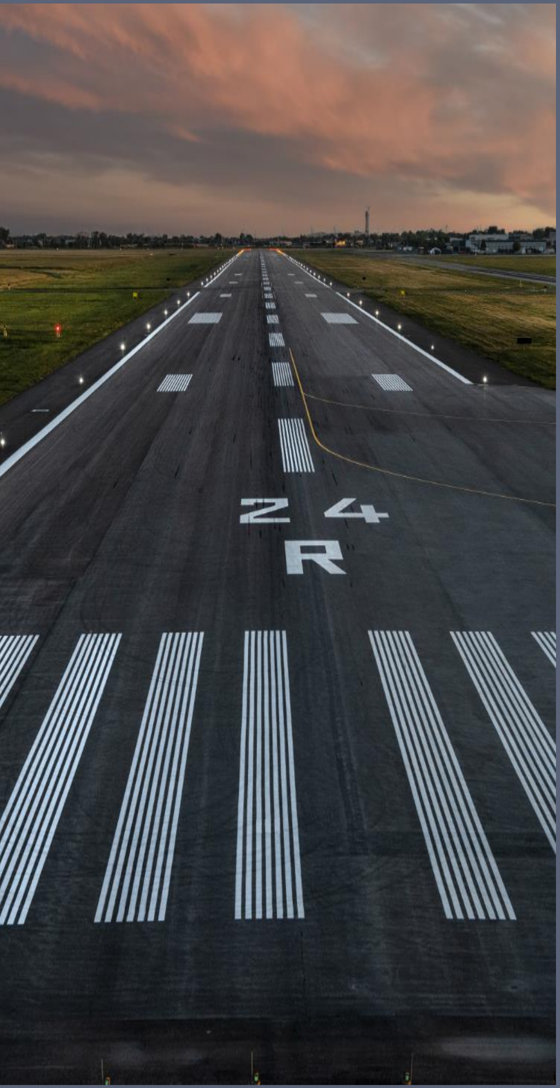
Dr. Thomas Bennert, P.E.
Director and Associate Professor,
Center for Advanced Infrastructure and Transportation (CAIT) Rutgers
The State University of New Jersey

Michael Esenwa, P.Eng.
Manager, Technical Services
McAsphalt Industries Ltd.

Anton S. Kucharek, P.Eng. C.Chem.
Director, Technical Services
McAsphalt Industries Ltd.

Technicians at CAIT, Associated Asphalt Materials Lab & McAsphalt's Central Research Lab

Outline



- Brief background on airfield pavements and asphalt testing
- Need for high performance and fuel resistant asphalt mixtures
- Development of fuel-resistance test
- Initial projects
- Mix performance testing results
- Field performance at various airports
- Updates to specifications
- Summary

Roads Versus Airfield Pavements

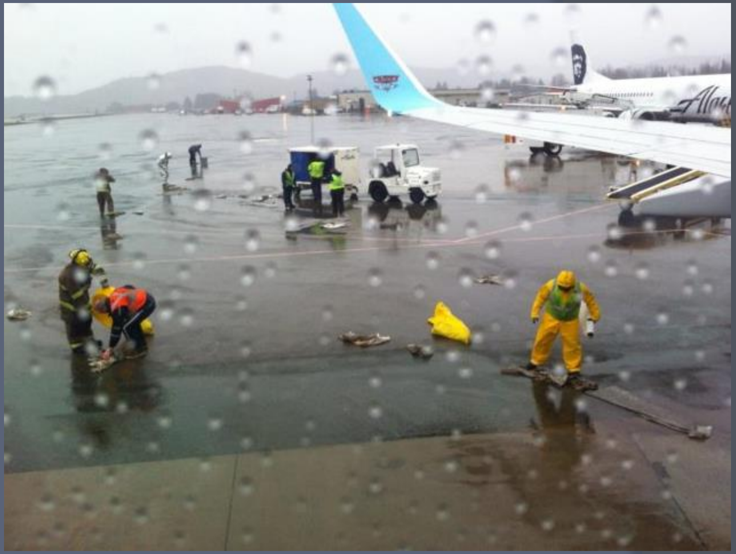
Road Versus Airfield Pavements

- **Airfields provide unique pavement challenges that are different from highways**

Characteristics	Airfield	Road
Load Repetitions	**LOW** (often 100,000 or less)	**HIGH** (more than 1,000,000)
Loading	**HIGH** (up to 25 tonnes/wheel)	**LOW** (often 3 tonnes/wheel)
Traffic Wander	**HIGH** (wide spread aircraft over pavement width)	**LOW** (very channelized traffic in the design lane)
Tire Pressure	**HIGH** (up to 1.7 MPa, and often up to 2.5 MPa for Military aircrafts)	**MODERATE** (generally not more than 0.8 MPa)
Sensitivity to Foreign Object Damage (FOD)	**VERY HIGH**	**LOW**

Exposure to Fuel and De-icing Chemicals

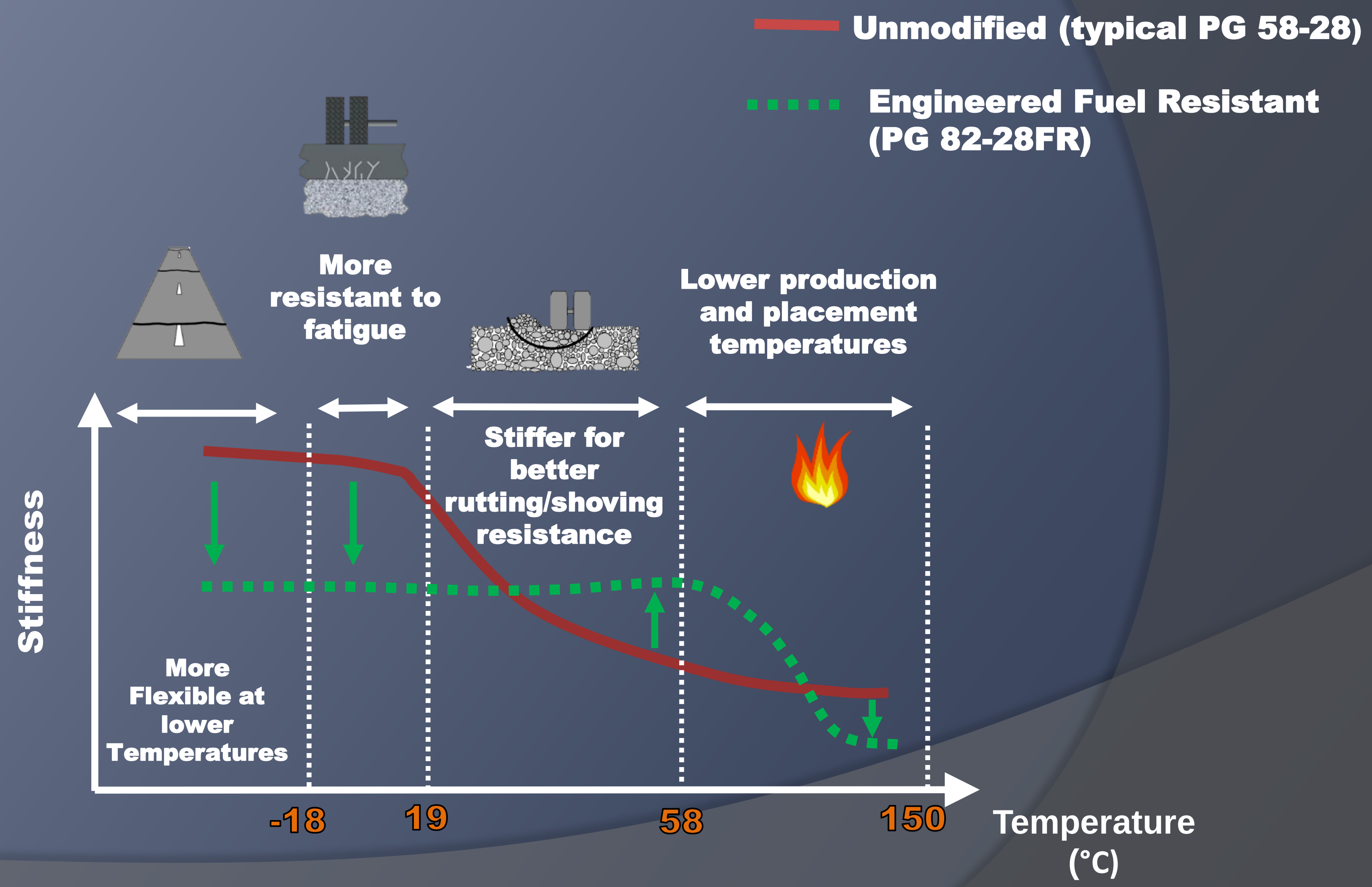
- **Can happen on runways and taxiways while aircraft are parked at the gates or awaiting clearance.**
- **Spillage mainly occurs:**
  - **Thermal expansion of fuel from the overflow port of the storage tank of an aircraft**
  - **Refueling vehicle, or from fuel being spilled during the refueling process (problems with auto shut-off)**
- **De-icing at the gates or designated de-icing areas (run-off to asphalt pavements)**



Fuel Spill - Juneau IAP (2014)

De-Icing at the gate – Porter Toronto AP

DEVELOPMENT OF FUEL-RESISTANT BINDER



DEVELOPMENT OF FUEL AND HIGH SHEAR RESISTANT MIX

1. Engineering aggregate structure – promoting low permeability while maintaining stone-on-stone strength
2. Custom formulation of asphalt cement with specialty polymers/additives – Fuel Resistant
3. Potential for increased workability and ease of compaction by using warm mix technology – cost savings at plant and field

1

AGGREGATE BLEND

Physical properties
Gradation bandwidth

\+

2

PGAC

Engineered Asphalt Binder

\+

3

REDUCED ENERGY

Lowered production and placement temperatures

Development of Fuel-Resistant Binder and Mix

- **Developed test to measure fuel resistance**
- **Weigh 4 Marshall samples after compaction**
- **Immerse in jet fuel for 24 hours**
- **Remove samples from fuel bath, dry and weigh**
- **Average weight loss of 4 Marshall specimens must be less than 1.5%**

Development of Fuel-Resistant Binder and Mix

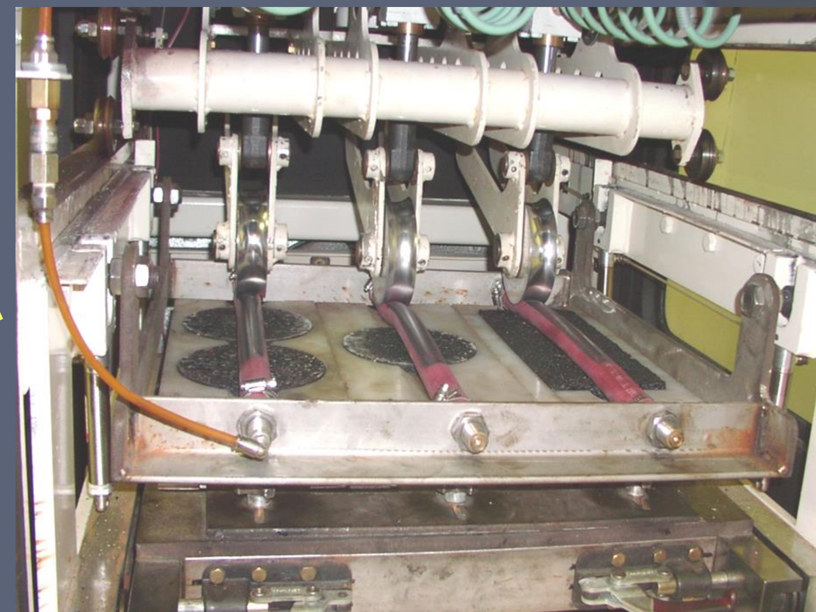
- Standard Hot Mix Asphalt mixture loses 10% weight from 24 hour soak in jet fuel
- Standard Polymer Modified Asphalt (PG 76-22) loses 5-6% weight after 24 soak in jet fuel
- Fuel Resistant PMA – less than 1.0% weight loss

Fuel-Resistant Mix Usage

Indentations in Taxiway GG

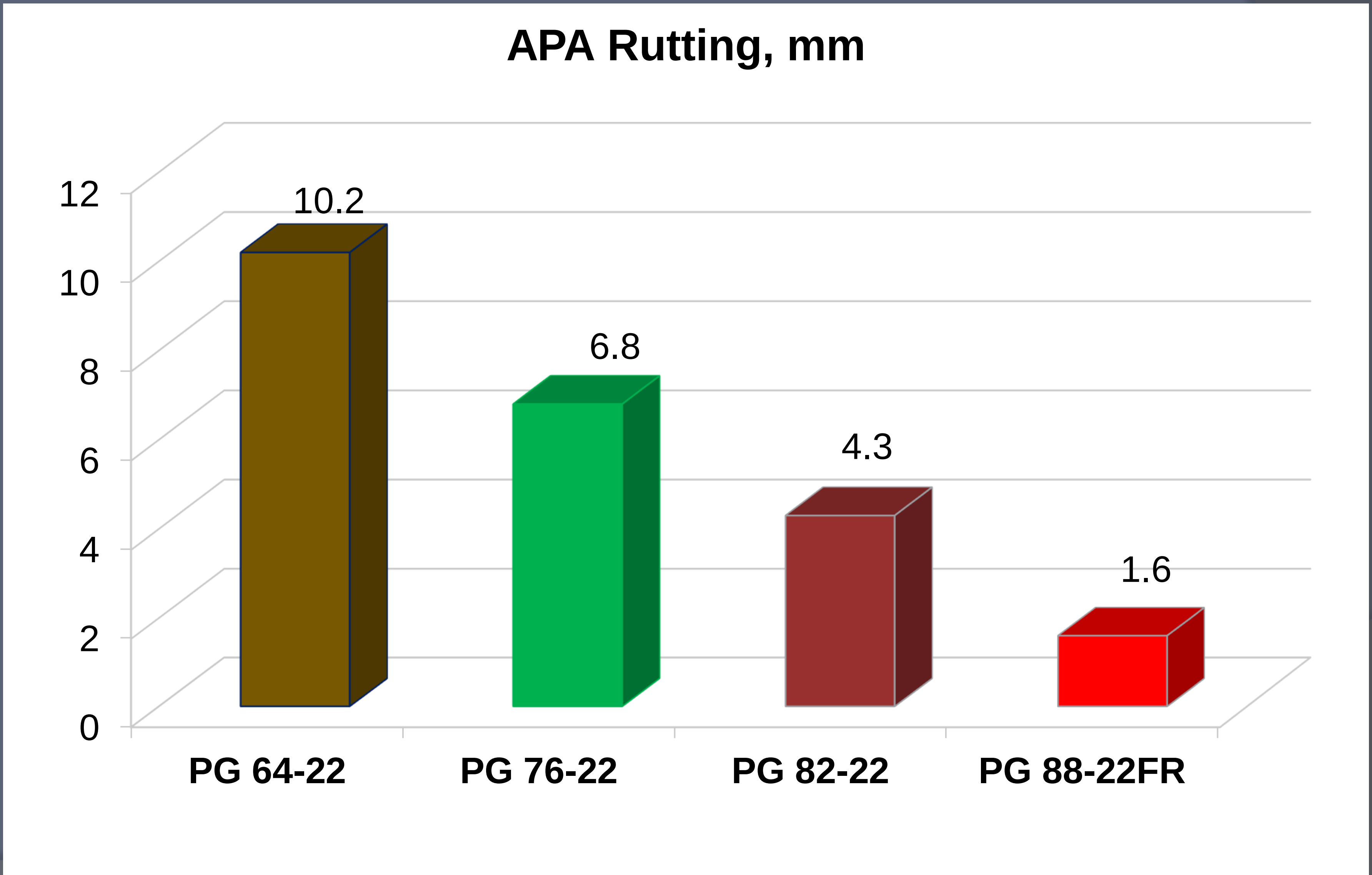
- First Fuel Resistant Mix Construction Project– La Guardia Airport in 2002
  - Severe rutting caused by fuel-softened pavement
  - Test section on Taxiway GG – 450 tons

Asphalt Pavement Analyzer (APA) - Rutting Evaluation of HMA

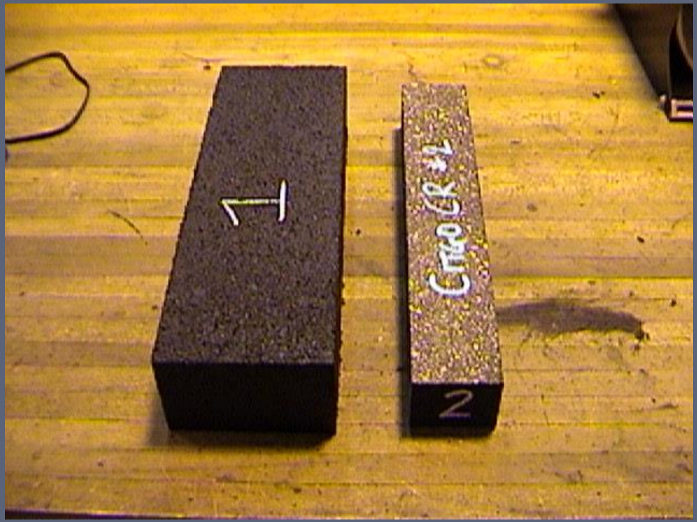


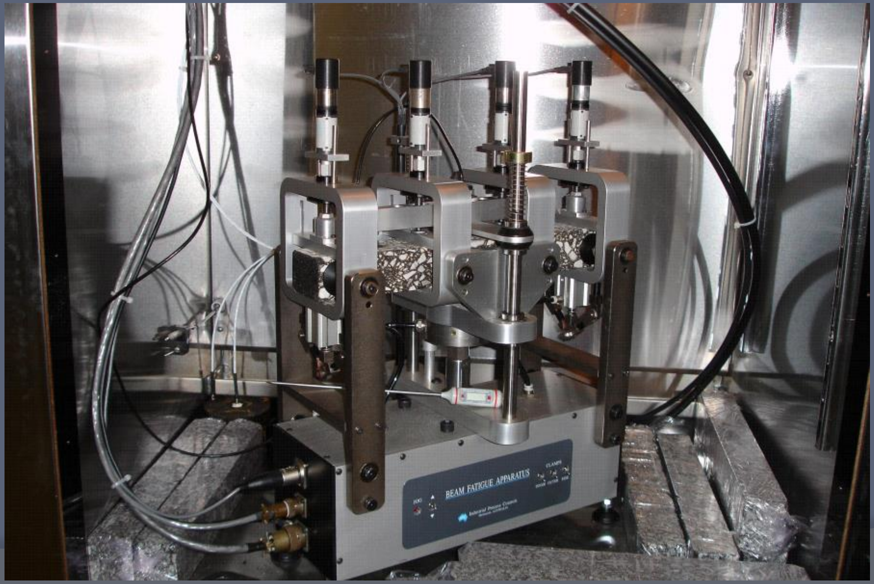
- Moving wheel load (100 lbs) applied to a pressurized hose (100 psi) which lies on top of asphalt samples
- Tested at 64°C for 8,000 loading cycles
- Computer data acquisition system

Fuel Resistant Mix – Rut Resistance



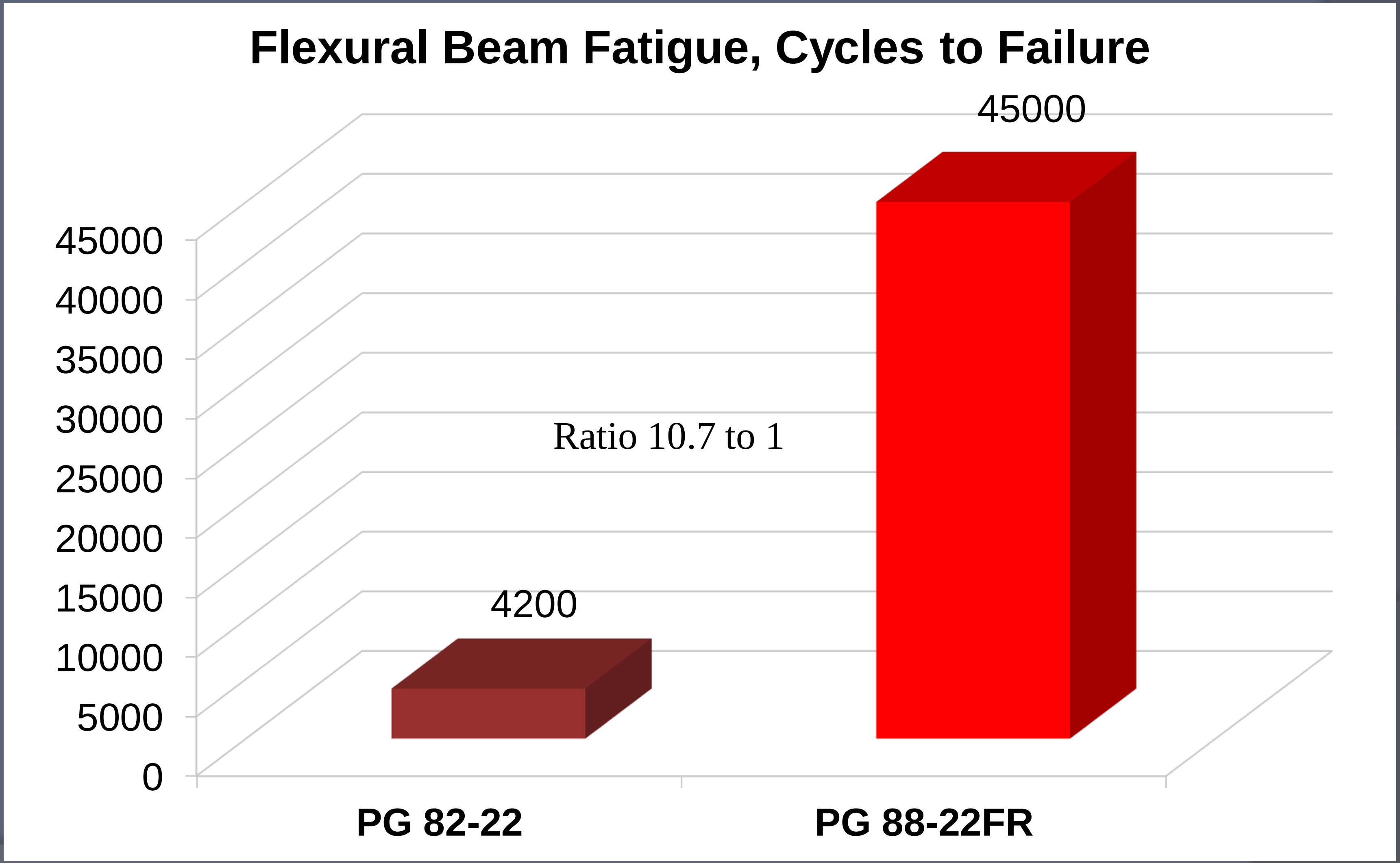
Fuel Resistant Mix – Crack Resistance





- **Flexural Beam Fatigue Device, AASHTO T-321**
  - **Tests mix's ability to withstand repeated bending which causes fatigue failure**
  - **Data = number of loading cycles to failure (loss of stiffness)**
  - **Failure occurs when stiffness of beam < 50% of initial stiffness**
  - **Test parameters – 1000 micro strain, 15°C, 10 HZ**

Fuel Resistant Mix– Crack Resistance



Fuel-Resistant Mix Usage – La Guardia

- **Placed Fuel-Resistant Mix on Taxiway GG at La Guardia Airport August 2002**
- **Graded as PG 94-22**
- **Pumped into plant at 165°C**
- **Produced mix at 170°C**
- **Placed in silo for 4 hours**

Fuel-Resistant Mix Usage – La Guardia

- Milled off 50mm, placed 50 mm thick 19mm (max size) P-401 mix with FR binder
- Paved at 165°C
- 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
- 2019 – still performing well, only pavement at LaGuardia not rutted

Fuel Resistant Mix Specification

- Working with engineers at MassPort (Boston Logan Airport), developed generic specification for fuel resistant HMA
  - PG 88-22FR or PG 82-28FR
    - Pass fuel resistance test
    - Minimum 85% Elastic Recovery
  - Standard test method for fuel resistance
  - 12.5mm P-401 Mix #3 (max size)
    - 50 blow Marshall design
    - Design at 2.5% air voids
- Typical P-401 mix has ≈ 5.5% asphalt content
- These changes to P-401 yield a fuel resistant mix with ≈ 7% asphalt content
- Result – additional asphalt in P-401 mix decreases permeability, increases fuel resistance, increases crack resistance, and durability while maintaining excellent rut resistance

Fuel-Resistant Mix – Logan Airport

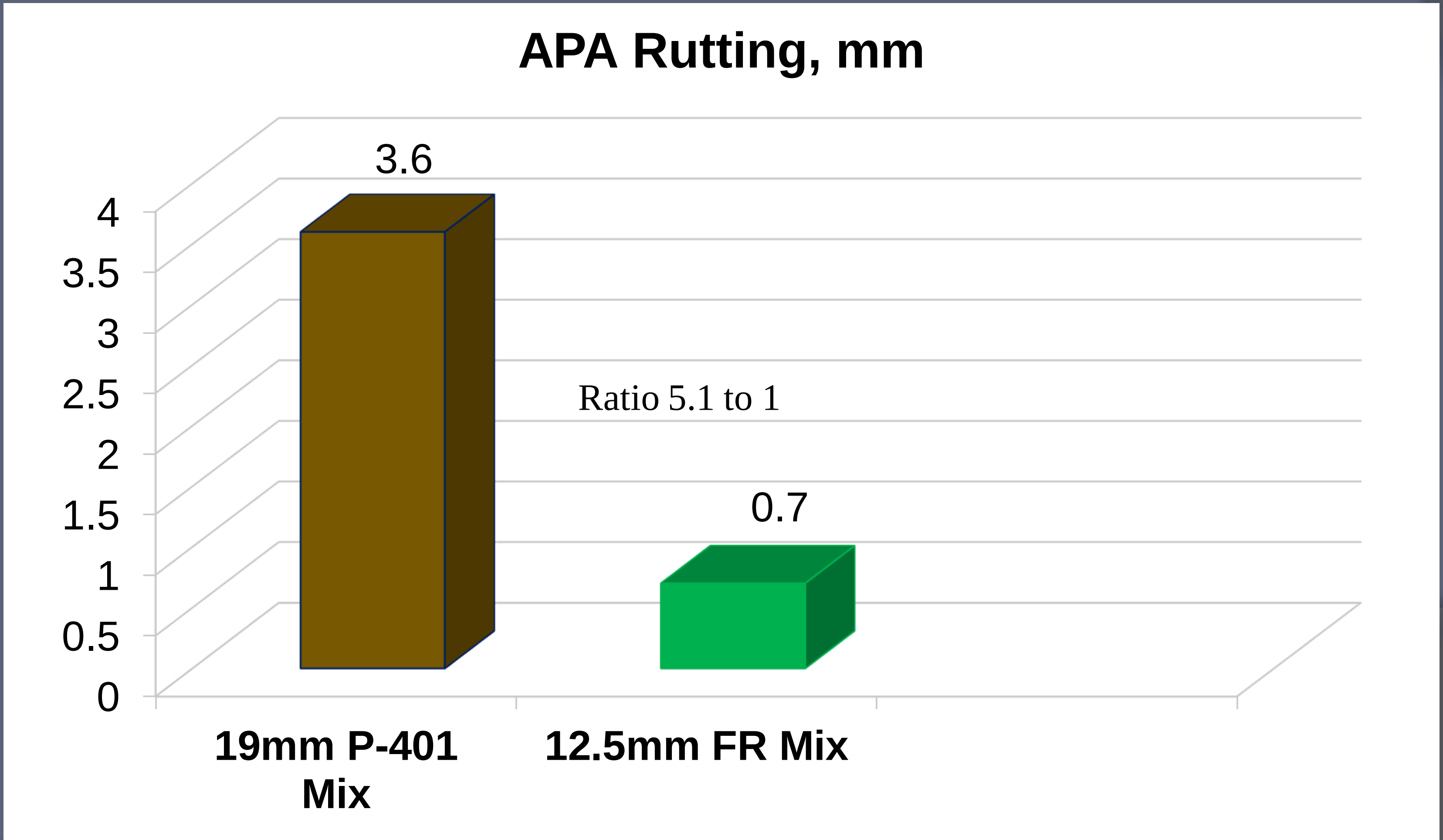
- First use of modified P-401 mix with FR binder at Boston Logan Airport
- Placed 1300 tons of fuel resistant mix 50mm thick on Taxiway N and Runway 4L-22R at Logan Airport in June 2004

Fuel Resistant Mix at Logan Airport

Fuel-Resistant Mix – Logan Airport

- **FR Asphalt graded as PG 94-22**
- **12.5mm P-401 mix designed at 2.5% air voids**
- **7% asphalt content design target**
- **MassPort engineers concerned about rutting**
- **APA testing at Worcester Polytechnic Institute**

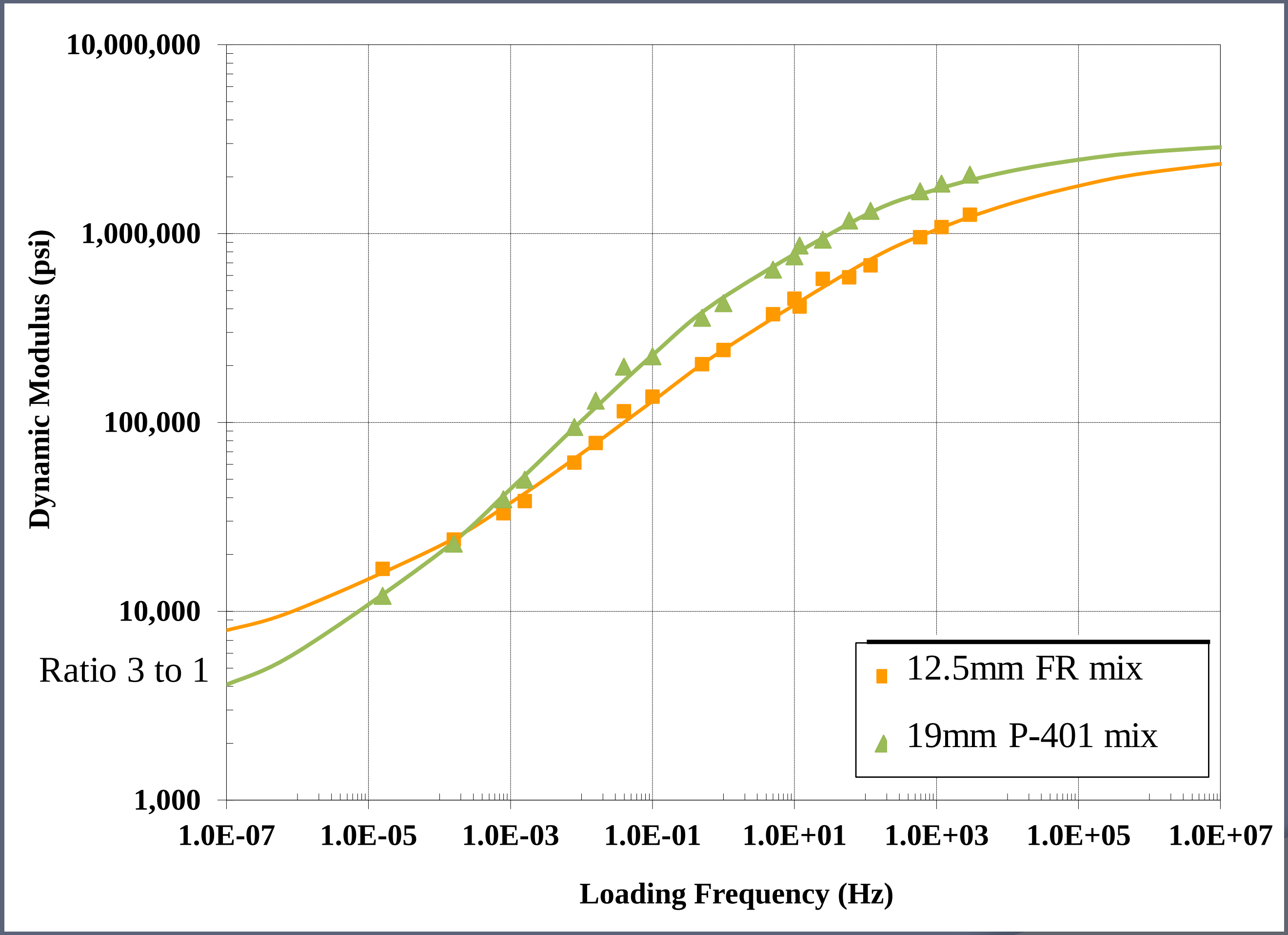
Worcester Polytechnic Institute – APA Rut Testing



Logan P-401 Mix vs FR Mix

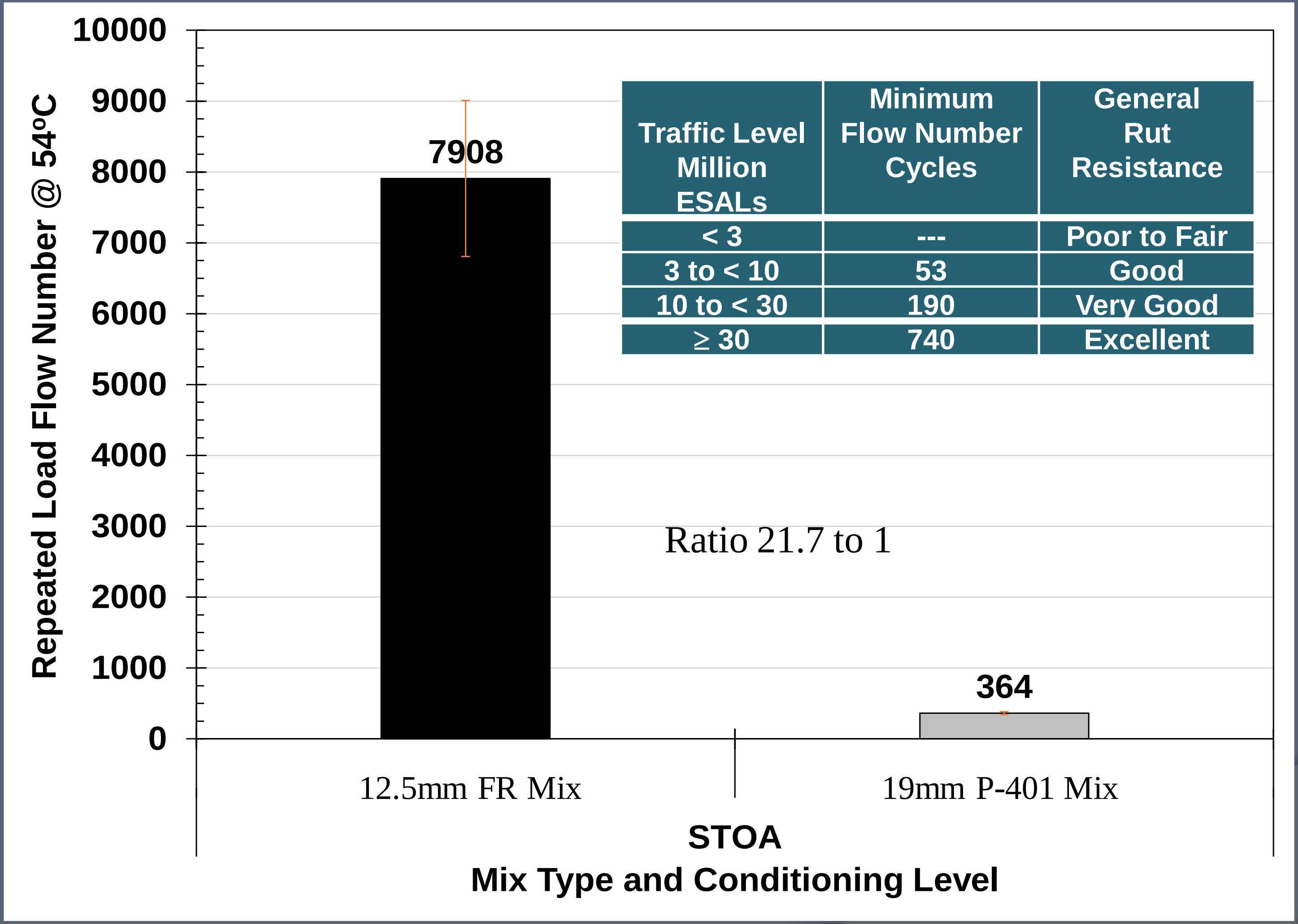
Asphalt Mix Performance Tester (AMPT)

Logan P-401 Mix vs FR Mix



AMPT Dynamic Modulus

Logan P-401 Mix vs FR Mix



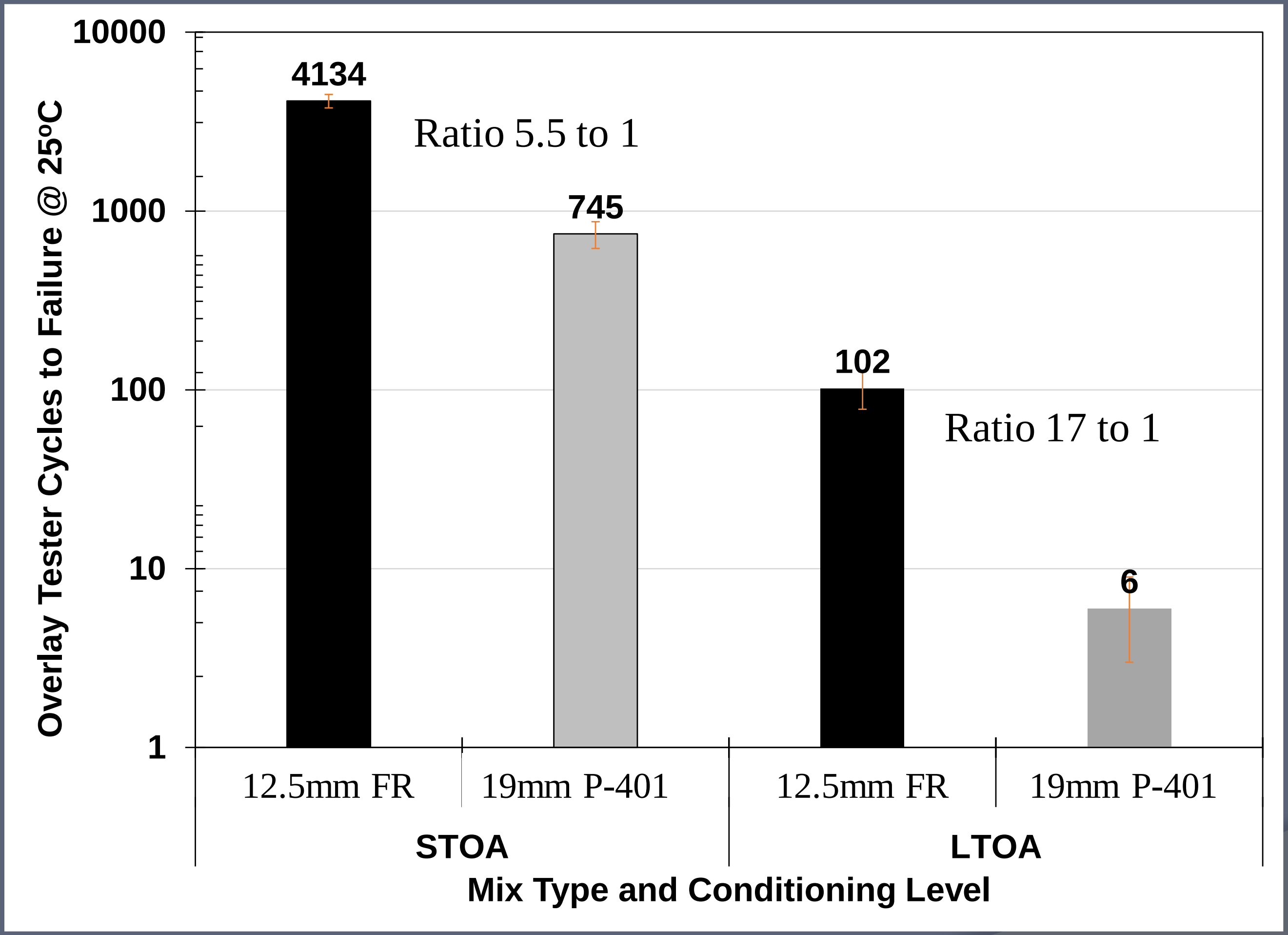
Traffic Level Million ESALs	Minimum Flow Number Cycles	General Rut Resistance
< 3	---	Poor to Fair
3 to < 10	53	Good
10 to < 30	190	Very Good
≥ 30	740	Excellent

AMPT Flow Number

Logan P-401 Mix vs FR Mix

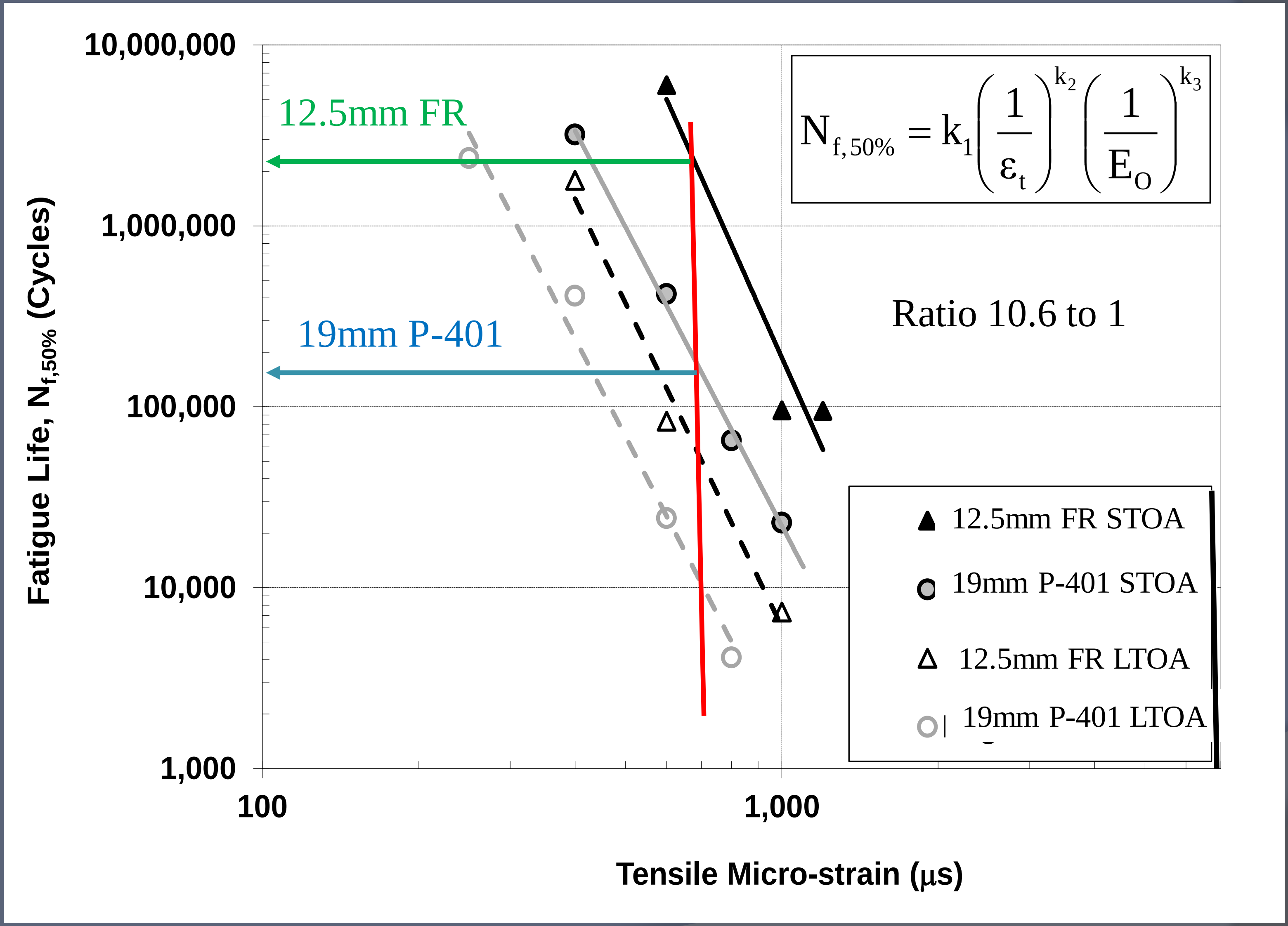
Texas Overlay Tester

Logan P-401 Mix vs FR Mix



Texas Overlay Tester

Logan P-401 Mix vs FR Mix



Flexural Beam Fatigue

Fuel-Resistant Mix – Logan Airport

- Mix produced in drum plant at 170˚C
- Placed at 163˚C without difficulty
- Met density specification
- Excellent surface appearance

Fuel Resistant Mix Projects at Logan Airport

Fuel-Resistant Mix Usage – New Projects

- Boston, MA - Logan Airport
  - Alleyway Projects – 2005, 2006, 2007
- Charlotte, NC - Douglas International Airport
  - Runway Project – Summer 2006
- Florida DOT
  - Truck Inspection Station – Summer 2006
- Portland, ME - Portland Jetport Apron, 2015
- Fryeburg, ME – Eastern Slopes Airport Apron, 2016
- BWI Marshall Airport – Freight Apron, 2016
- Burbank, CA - Bob Hope Airport Apron, 2019
- Numerous GA airports in SE US
- Hurlburt Field – First DOD project. Apron, 2018

Fuel-Resistant Mix Usage – Charlotte Airport

- **Charlotte, NC - Douglas International Airport**
  - **Runway 18L – 36R**
  - **August 2006**
  - **Night work – Runway available from 11:00 pm until 6:00 am**
  - **Mill 50mm**
  - **Pave with 50mm of 12.5mm P-601 Mix**
  - **Lasted eleven years**

Logan Airport - 2014

10 year old P-601 Pavement

Logan Airport - 2014

10 year old P-601 Pavement

Logan Airport – Why did the Joints Open Up?

Logan Airport - 2014

10 year old P-601 Pavement

Logan Airport 2014

10 year old P-601

10 year old P-401

Logan Airport - 2014

- De-icing at Logan Airport is done at the gates
- Alleyway P-601 pavement in picture has been exposed to de-icing chemicals for 13 winters – no visible damage to date

FR at Logan Airport

9 year old P-601 Pavement

BWI Freight Apron - 2016

12.5mm P-601 Mix

Bob Hope Airport Burbank, CA

12.5mm P-601 Mix

P-601 GA Project - Herlong, Florida 2012

Fuel Spill Causes Discoloration, But No Damage to P-601 Pavement

P-601 for Bus Lanes

- Bus lanes have heavy, channelized traffic – rutting may be an issue
- Oil and fuel leaks are also present
- Logan Airport has used P-601 pavement in bus lanes to solve the problem

FAA P-601 Specification

- FAA was looking for alternative to coal tar sealers – projecting it would be outlawed in near future
  - Evaluated performance of Logan Airport Fuel Resistant mixes
  - Adopted Logan Airport FR specification as P-601 “Fuel Resistant Hot Mix Asphalt Pavement” specification in July 2014

FAA P-601 Specification

- FAA has adopted Advisory Circular # 150 / 5370-10G , dated 07/21/2014
- Contains specification item P-601 Fuel Resistant Hot Mix Asphalt (HMA) pavement

FAA P-404 Specification

- **FAA issued Advisory Circular # 150 / 5370-10H on December 21, 2018**
- **Renumbers specification item P-601 Fuel Resistant Asphalt Mix pavement as P-404**

FAA P-404 Specification

- **Asphalt Binder Specification**
  - **ASTM D6373 PG 88-22FR or PG 82-28FR as dictated by climate**
  - **ASTM D6084 Elastic Recovery at 25°C ≥ 85%**
  - **ASTM D7173 Maximum temperature difference of 4°C when using ASTM D36 Ring and Ball apparatus**
- **Mix Specification**
  - **Adds Asphalt Pavement Analyzer (APA) rutting requirement**
    - **<10mm @ 4000 passes, hose pressure 250 psi <u>OR</u>**
    - **Hamburg Wheel Tracking < 10mm @ 20,000 passes**
  - **Allowable lift thickness: 37.5mm – 75mm**
  - **In place density – Maximum <u>4%</u> air voids compared to P-401 7.2% maximum air voids**
  - **Maximum Weight Loss Fuel Soak Test = 1.5%**

19mm P-404 Mix Development

- Despite demonstrated performance over time, many engineers are uncomfortable with a 12.5mm (max size) mix (FAA Mix #3) that is currently in the P-601 specification
- They believe a 19mm (max size) FAA Mix #2 gradation is needed to withstand aircraft loadings on taxiways and runways
- Associated Asphalt sponsored a research project at Rutgers University to see if a 19mm P-401 mix could be designed using P-404 criteria
  - Designed at 2.5% air voids
  - Designed with 50 Marshall blows

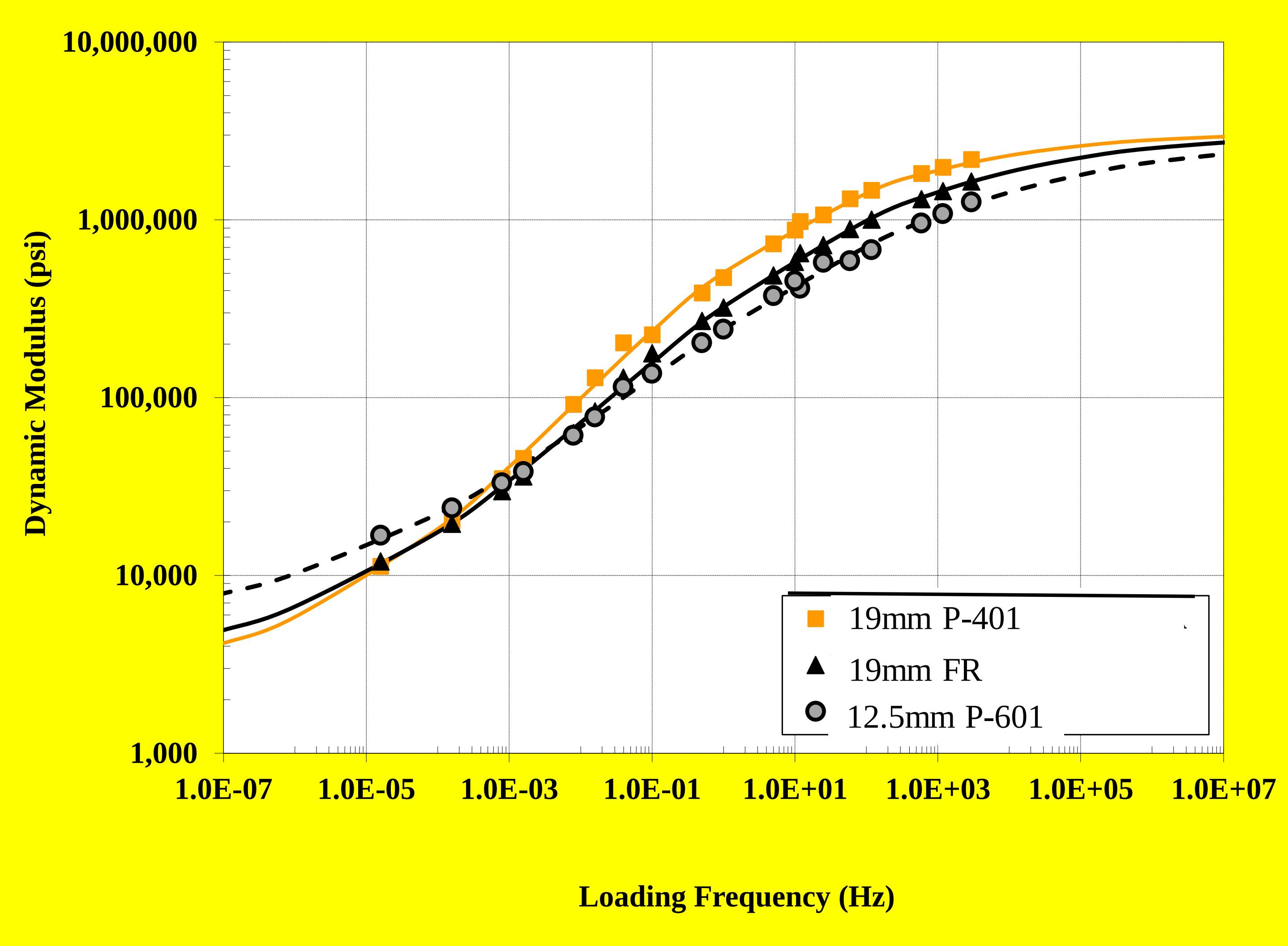
19mm Fuel Resistant Mix

- **Asphalt Binders (true grade)**
  - **PG 82-22: PG 83.1-25.3**
  - **StellarFlex FR: PG 95.1-25.9**

19mm Fuel Resistant Mix

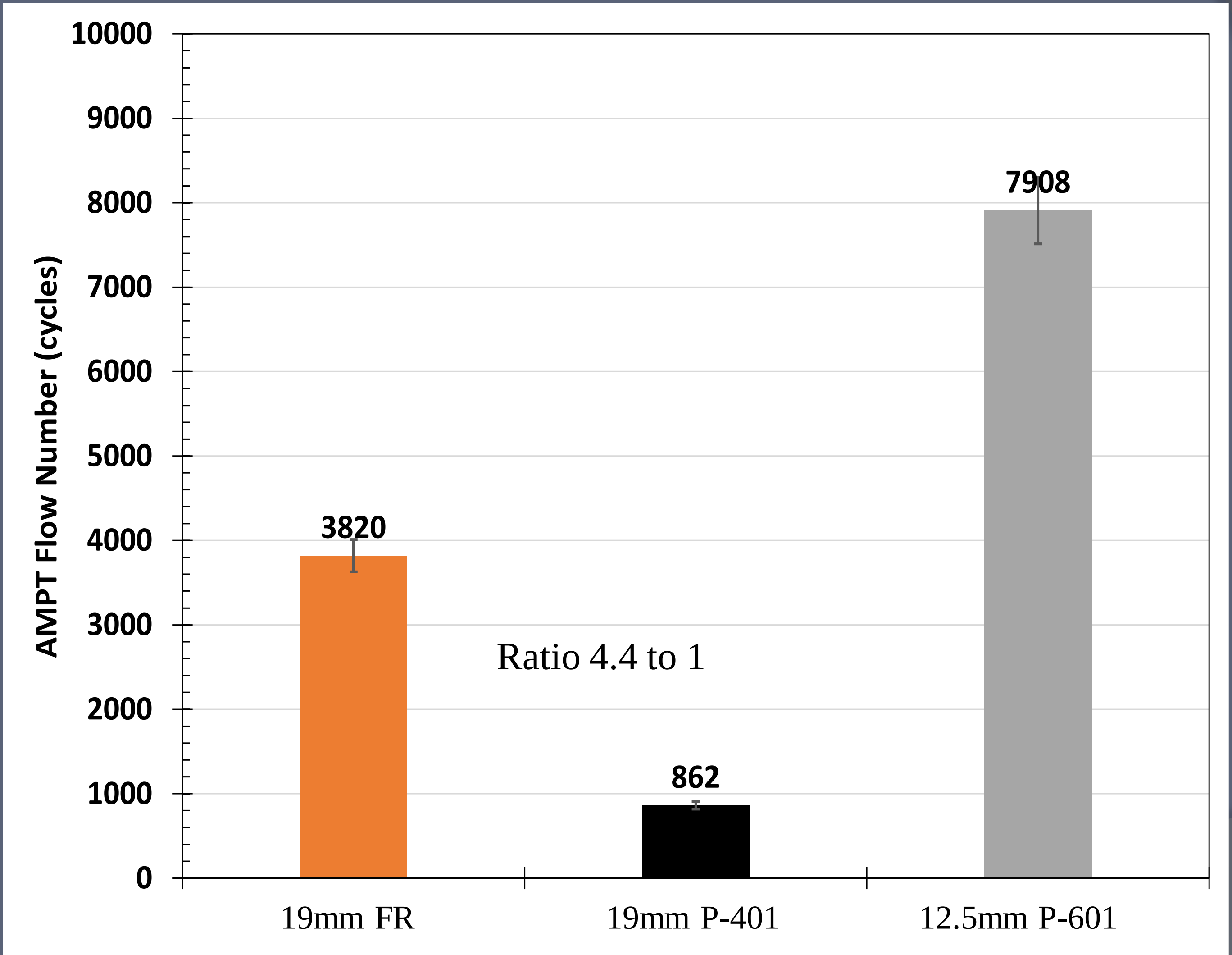
- **Mix Design Results**
  - **Air Voids**
    - **19mm FR = 2.5%**
    - **19mm P401 = 3.5%**
  - **Optimum Asphalt Content**
    - **19mm FR = 6.7%**
    - **19mm P401 = 5.8%**
  - **Voids in Mineral Aggregates (VMA)**
    - **19mm FR = 17.4%**
    - **19mm P401 = 16.3%**
  - **Fuel Resistance Mass Loss**
    - **19mm FR = 0.31%**
    - **19mm P401 = 5.07%**

19mm Fuel Resistant Mix



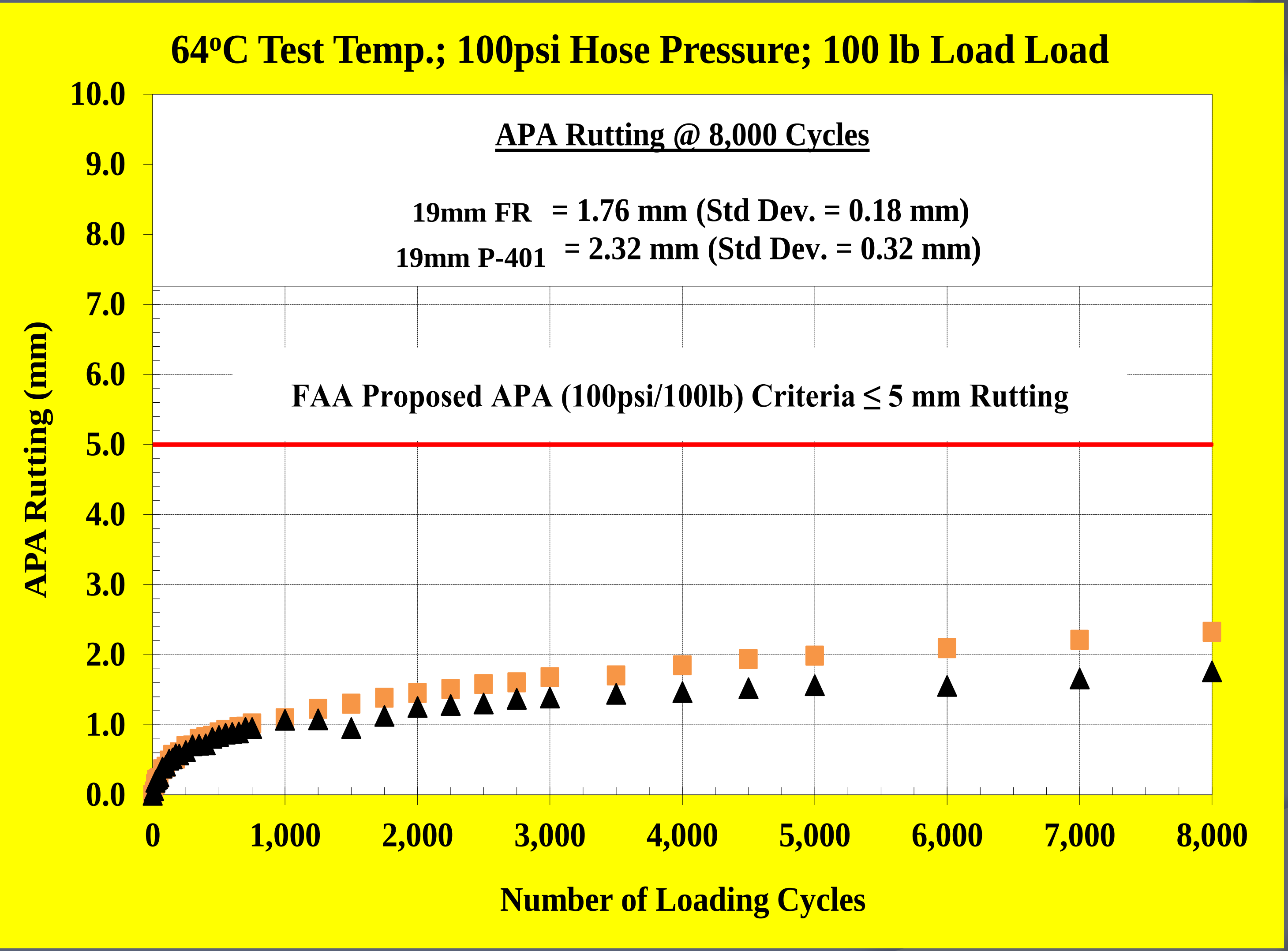
Dynamic Modulus Master Stiffness Curve (STOA)

19mm Fuel Resistant Mix



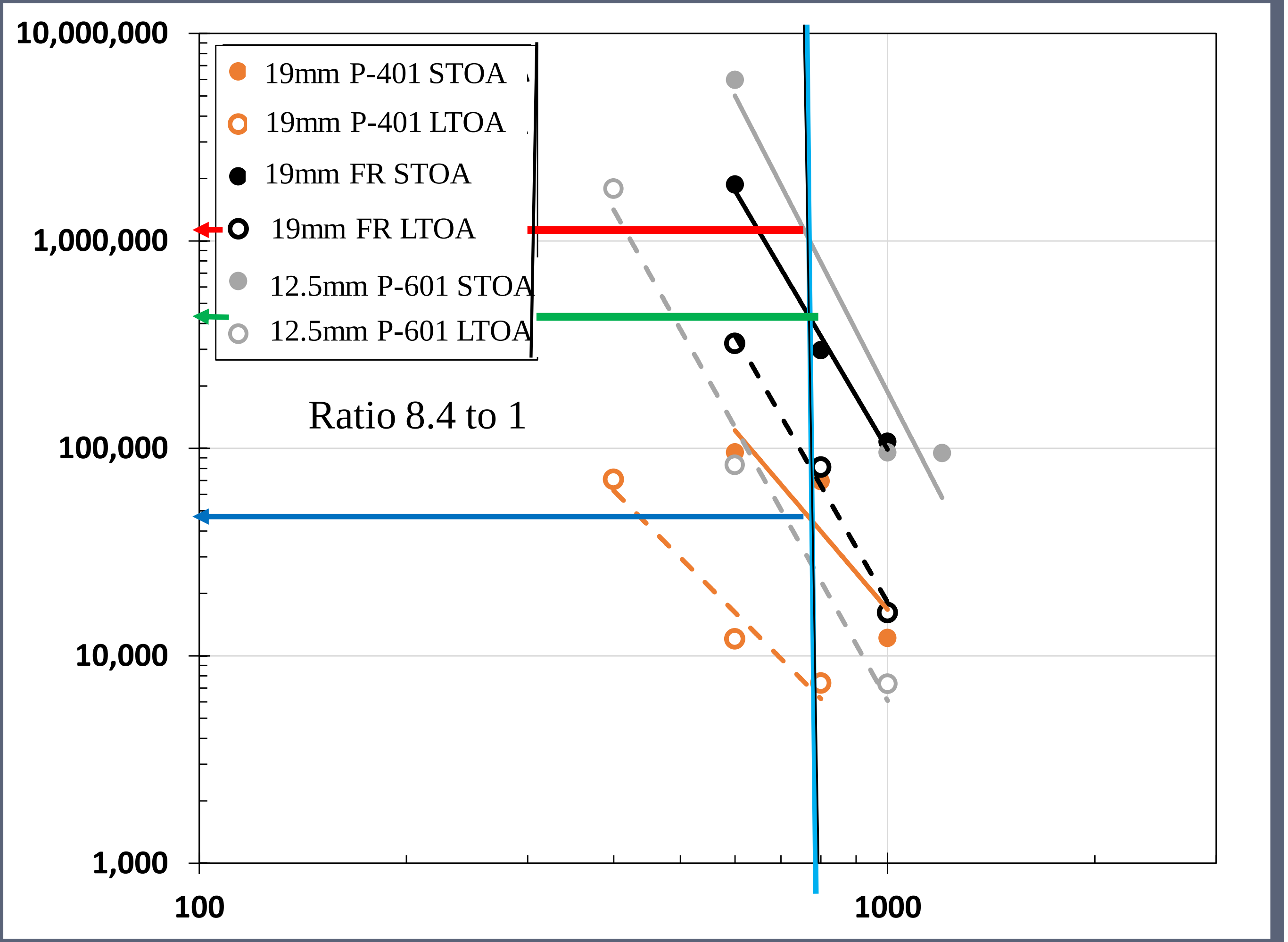
AMPT Repeated Load Flow Number Results

19mm Fuel Resistant Mix



Asphalt Pavement Analyzer (APA) Rutting Performance

¾” Fuel Resistant Mix



Beam Fatigue Cycles to Failure @ 800 <u>microstrain</u>

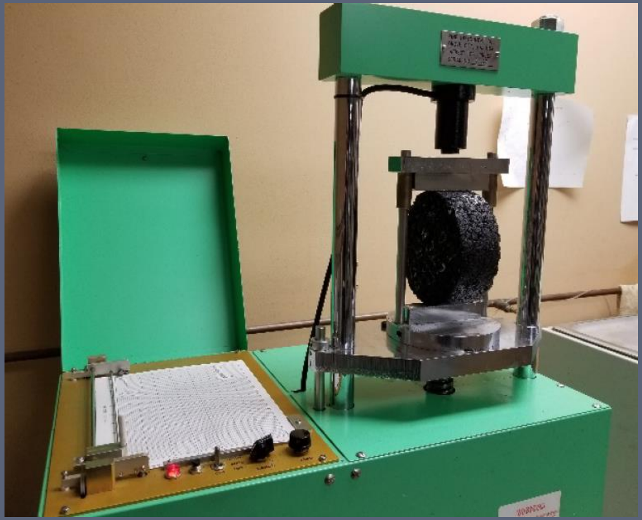
19mm P-401 mix- 45,000 cycles

19mm FR mix – 380,000 cycles

12.5mm P-601 – 1,000,000 cycles

Flexural Fatigue Life for 19mm FR, 19mm P401 and 12.5mm P-601 Asphalt Mixtures

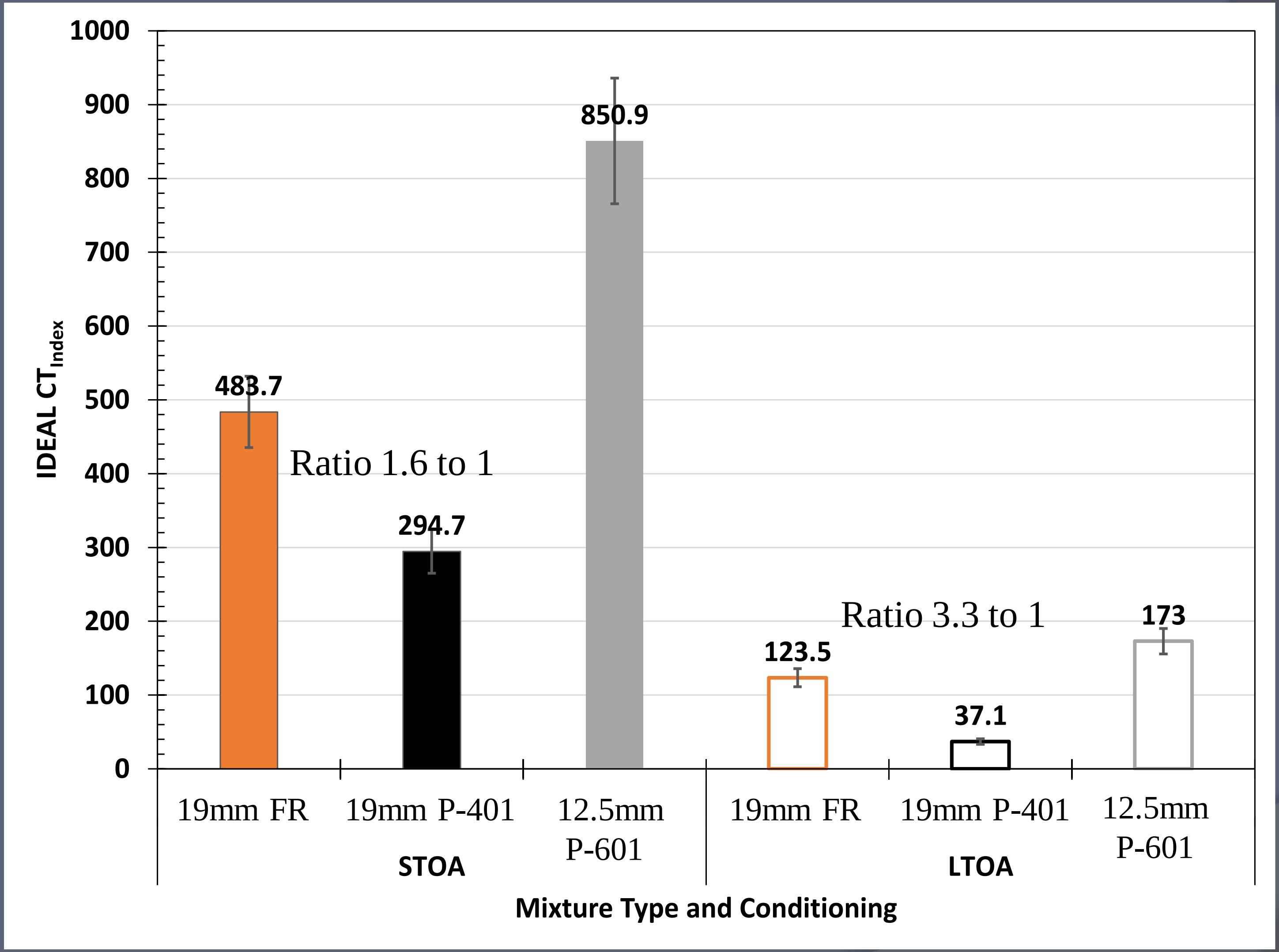
Intermediate Temperature Cracking Resistance Test (IDEAL-CT Test)



IDEAL-CT

- Performed at 25°C
- Gyratory-sized (150 mm diameter)
- Thickness range of 38 to 75 mm
- No need for cutting or notching
- Vertically loaded at a rate of 50 mm/min

19mm Fuel Resistant Mix



IDEAL CT$_{Index}$ Test Results

Summary

- Lab and field proven benefits of increased asphalt content in improving fatigue and durability.
- Combination of PMA-FR with higher AC content can be used to increase resistance to all potential airfield pavement damages – longer pavement life and lower life cycle cost analysis.
- More focus on volumetric properties combined with mixture performance criteria
- Benefits of using higher PG grade in combination with improved volumetric properties to combat extremely heavy loadings.
  - Airfield pavements
  - Heavily-loaded highways with high volumes of trucks
  - Fueling/gas stations and fuel storage tank areas
  - Truck and bus lanes
  - Seaports
  - Commercial loading/off-loading areas

Questions?

A small plane carrying six people made an emergency landing on a Calgary street (April 2018)

Sina Varamini, PhD, P. Eng.
Research & Development Manager
(McAsphalt Industries Limited)
svaramini@mcasphalt.com

Ron Corun, P.E.
Specialty Products Manager
Associated Asphalt Partners, LLC
rcorun@associatedasphalt.com