

FAA P-404 Fuel-Resistant Asphalt – More than Fuel Resistant



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Asphalt is Our Business

Background



**Indentations in Taxiway GG at
LaGuardia Airport**

- Fuel and oil spills soften asphalt pavements and can lead to permanent deformations and failures
- P-404 Fuel Resistant Asphalt Mix is designed to withstand fuel and oil spills, but the asphalt binder formulation and the mix design provide much more than fuel resistance – enhanced performance and longer life in all airfield pavements.

Fuel-Resistant Pavement Sealers



- Coal tar sealers were 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
- Coal tar sealers are carcinogenic
 - SDS – “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



- CITGO Asphalt (currently Ergon) recognized dangers of coal tar sealers and formulated a safe, environmentally-friendly alternative using a highly polymer-modified asphalt binder in 2001
 - PG 76-22 typically contains 3% polymer
 - Fuel-resistant asphalt binder contains 7.5% polymers
- Objective – make the asphalt pavement surface course fuel-resistant and eliminate the need for sealers

Development of Fuel-Resistant PMA



- Developed test to measure fuel resistance
- Weigh 4 Marshall or Gyratory 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 PMA



- Standard Unmodified Asphalt (PG 64-22) mix loses 10% weight from 24 hour soak in jet fuel
- Standard Polymer Modified Asphalt (PG 76-22) mix loses 5-6% weight after 24 soak in jet fuel
- Fuel-Resistant PMA – less than 1.0% weight loss



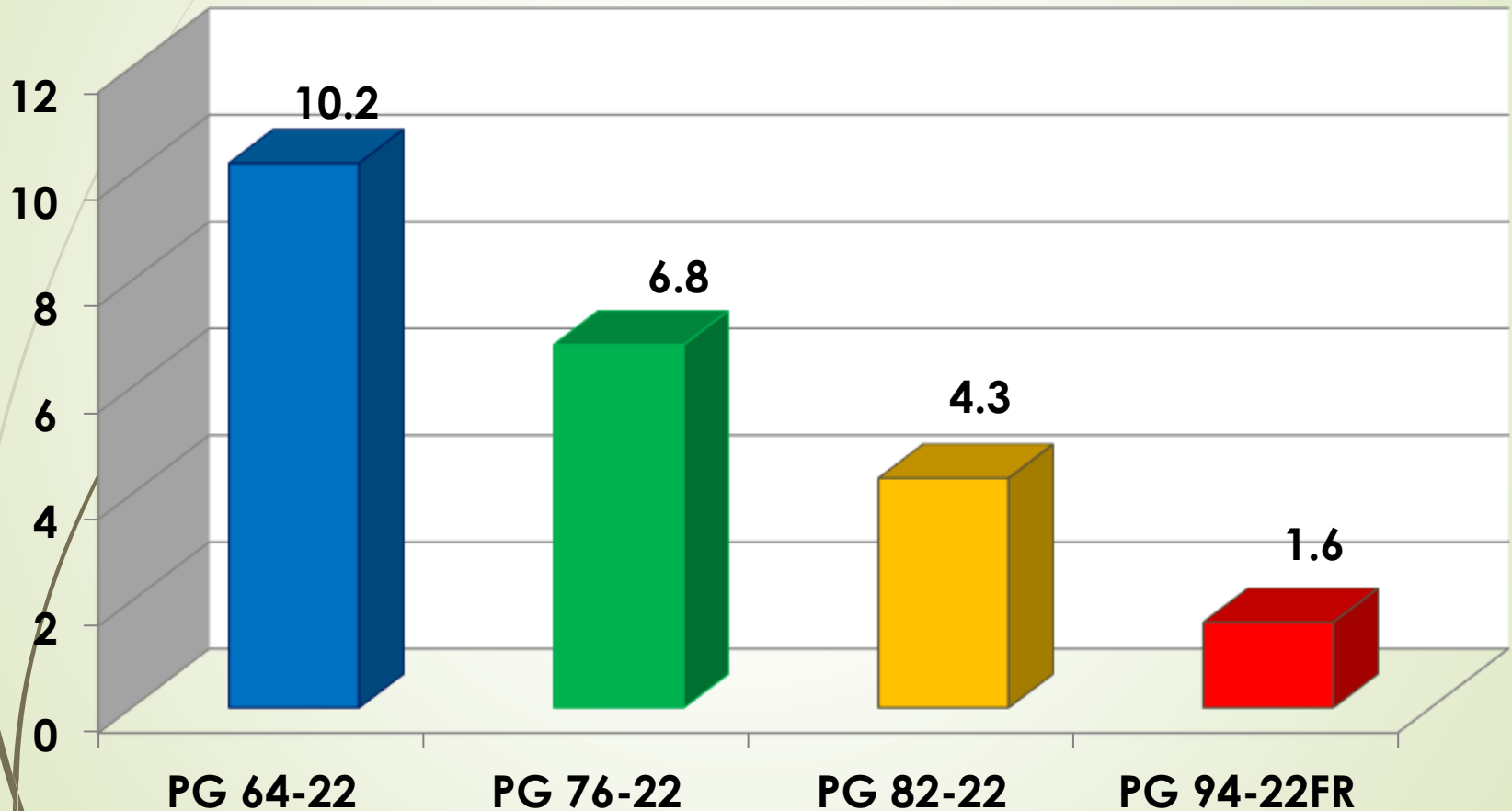
First Fuel-Resistant Mix Usage



- First Fuel-Resistant mix construction project at La Guardia Airport in 2002
 - Test section on Taxiway GG – 450 tons
- Before first use of FR mix, the Port Authority of New York and New Jersey wanted some mix performance testing to justify the usage
 - Rut testing
 - Crack testing

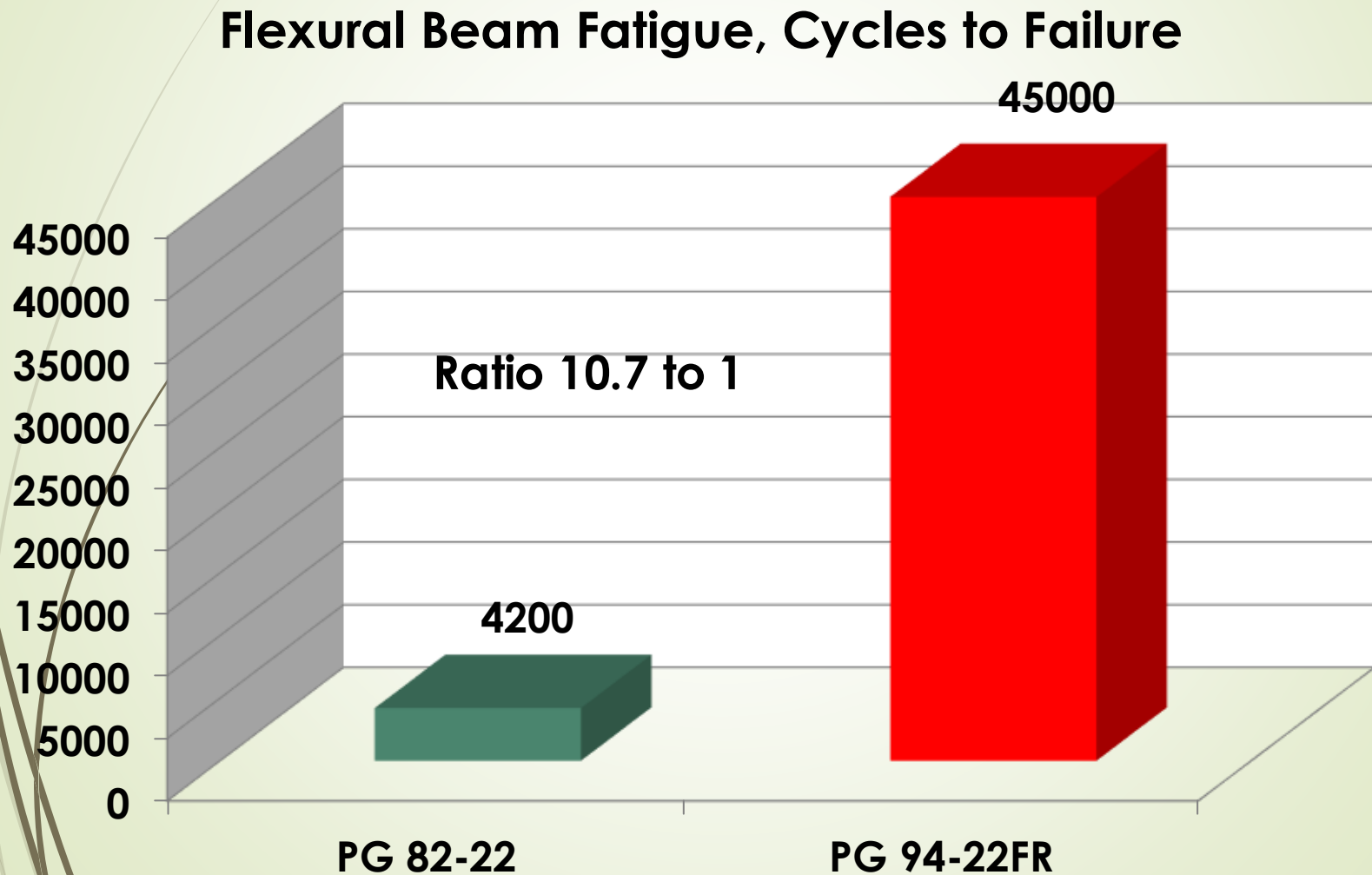
Fuel-Resistant Mix – Rut Resistance

APA Rutting, mm



PANYNJ Airfield Mix with Various Asphalt Binders

Fuel-Resistant Mix– Crack Resistance



Fuel-Resistant Mix Usage – La Guardia Airport



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

Fuel-Resistant Mix Usage – La Guardia Airport



- 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 Mix from standard P-401 mix containing PG 76-22

Fuel-Resistant Mix Usage – La Guardia Airport



- Inspected Fuel-Resistant pavement in October 2003
- Excellent condition
 - No rutting
 - No cracking
 - No surface deterioration
- 2018 – still performing well, a pavement condition survey found Taxiway GG the only pavement at LaGuardia not rutted

Fuel-Resistant PMA Usage – La Guardia Airport



- Rutting in pavements surrounding Taxiway GG

Fuel-Resistant Binder Specification



- Worked with engineers at Massachusetts Port Authority (Logan Airport) to develop a generic specification for Fuel-Resistant HMA
 - FR binder is a PG 94-22 liquid asphalt, but ASTM D6373 specification had a table with PG 82-22 the highest grade listed
 - Minimum PG 82-22 polymer modified asphalt
 - Minimum 85% Elastic Recovery
 - Separation test
 - Pass fuel resistance test
- Standard test method for fuel resistance

Fuel-Resistant Mix Specification



- How do you make an asphalt pavement last longer during the mix design?
- Use the existing P-401 mix gradations
- Increase the asphalt content to make the mix more flexible (crack resistant) and last longer
 - Design at lower air voids – 2.5% instead of 3.5%
 - Reduce lab compaction – specify 50 Marshall blows or 50 gyrations for all pavement areas and aircraft weights

Fuel-Resistant Mix Specification

- How do you make an asphalt pavement last longer during construction?
 - Achieve better density when compacting the pavement
 - Many studies link higher densities with longer pavement life – 1% increase in density equals 10% increase in pavement life
 - Lower in-place air voids reduce penetration of air, water and jet fuel into the pavement
 - Designing the mix at lower air voids with higher asphalt contents make the mix easier to compact - liquid asphalt is a lubricant until it cools
 - P-401 density lower limit is 92.8% (7.2% air voids)
 - P-404 lower density limit is 96.0% (4.0% air voids)



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 (FR) mix on Taxiway N and Runway 4L-22R at Logan Airport in June 2004

Fuel-Resistant Mix – Logan Airport

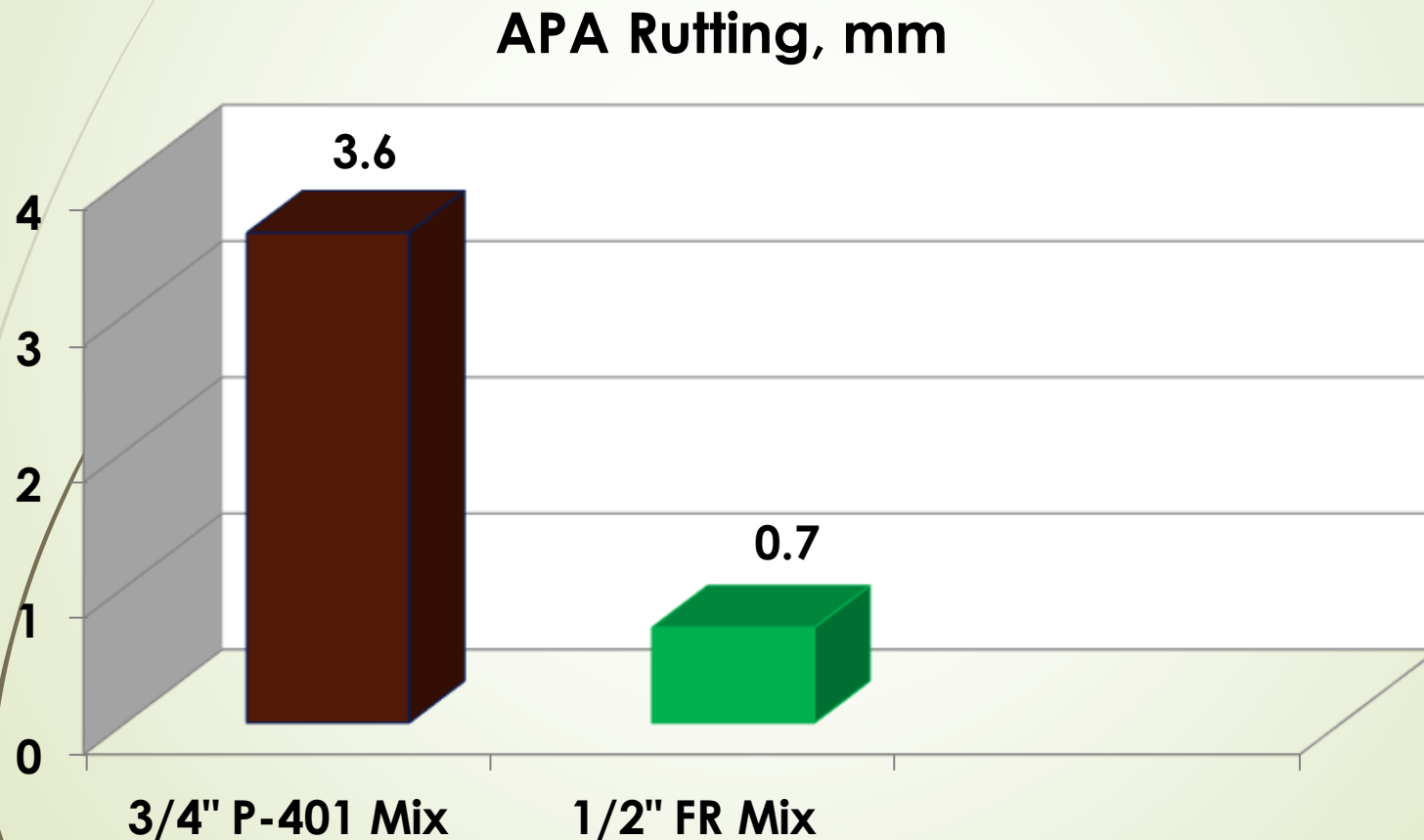


Fuel-Resistant Mix – Logan Airport



- FR Asphalt graded as PG 94-22
- 1/2" P-401 mix designed at 2.5% air voids with 50 Marshall blows
- 7% asphalt content design target
- MassPort engineers concerned about rutting
- APA testing at Worcester Polytechnic Institute

Worcester Polytechnic Institute – APA Rut Testing



Fuel-Resistant Mix – Logan Airport



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

Fuel-Resistant Mix – Logan Airport



Fuel-Resistant Mix – Logan Airport



FR Mix at Logan Airport - 2014



10 year old FR Pavement

FR Mix at Logan Airport - 2014



10 year old FR Pavement

FR Mix at Logan Airport – Why did the Joints Open Up?



FR Mix at Logan Airport - 2014



10 year old FR Pavement

FR Mix at Logan Airport - 2014



10 Year Old P-401 Pavement with PG 76-28

FR Mix at Logan Airport - 2014



10 year old FR



10 year old P-401

FR Mix at Logan Airport - 2014



9 year old FR Alleyway Pavement

FR Mix at Logan Airport



- De-icing at Logan Airport is done at the gates
- Alleyway FR pavement in picture has been exposed to de-icing chemicals for 15 winters – no visible damage to date
- 2020 - “It does not need replacing anytime soon”

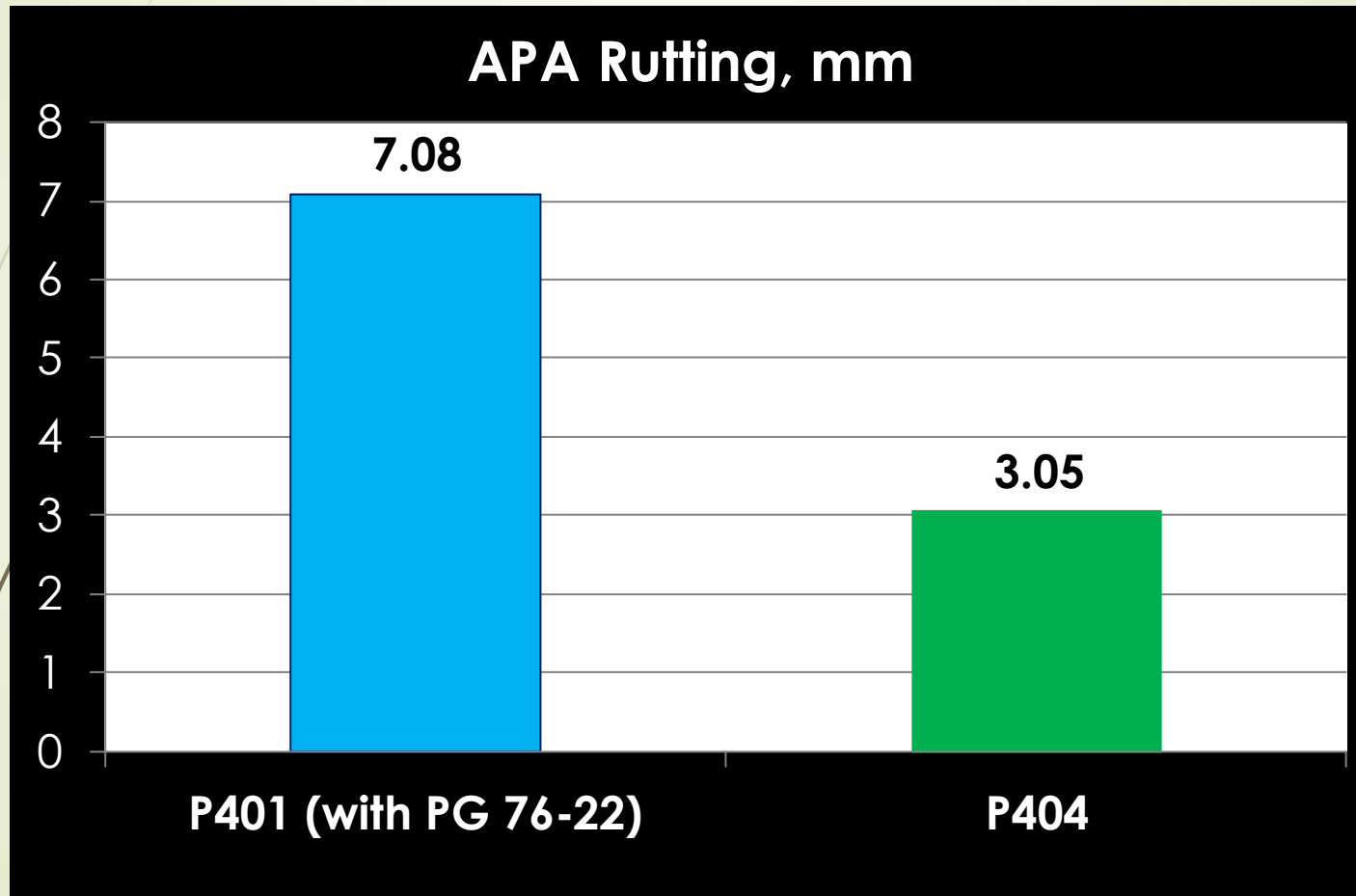
NCAT Study - P404 vs. P401 (76-22)

❑ Research conducted by NCAT with Alabama Aggregates

- Asphalt Pavement Analyzer – Required for all FAA mix designs and a good predictor of rutting
- Hamburg Wheel Tracking Test – Good predictor of rutting and stripping
- IDEAL-CT – Good predictor of cracking

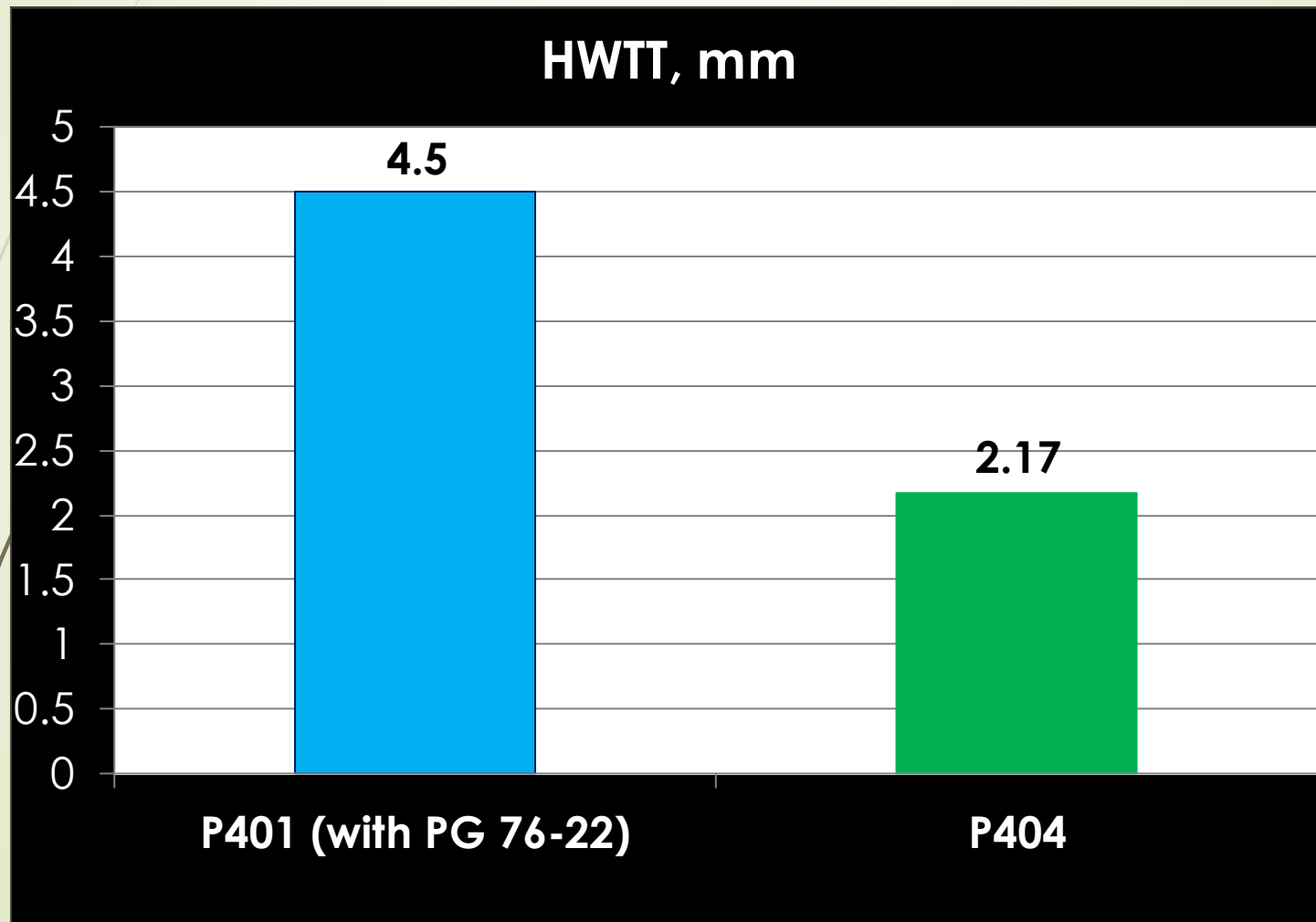
P401 vs. P404 – Rut Resistance

*Data obtained by NCAT using Alabama Aggregates



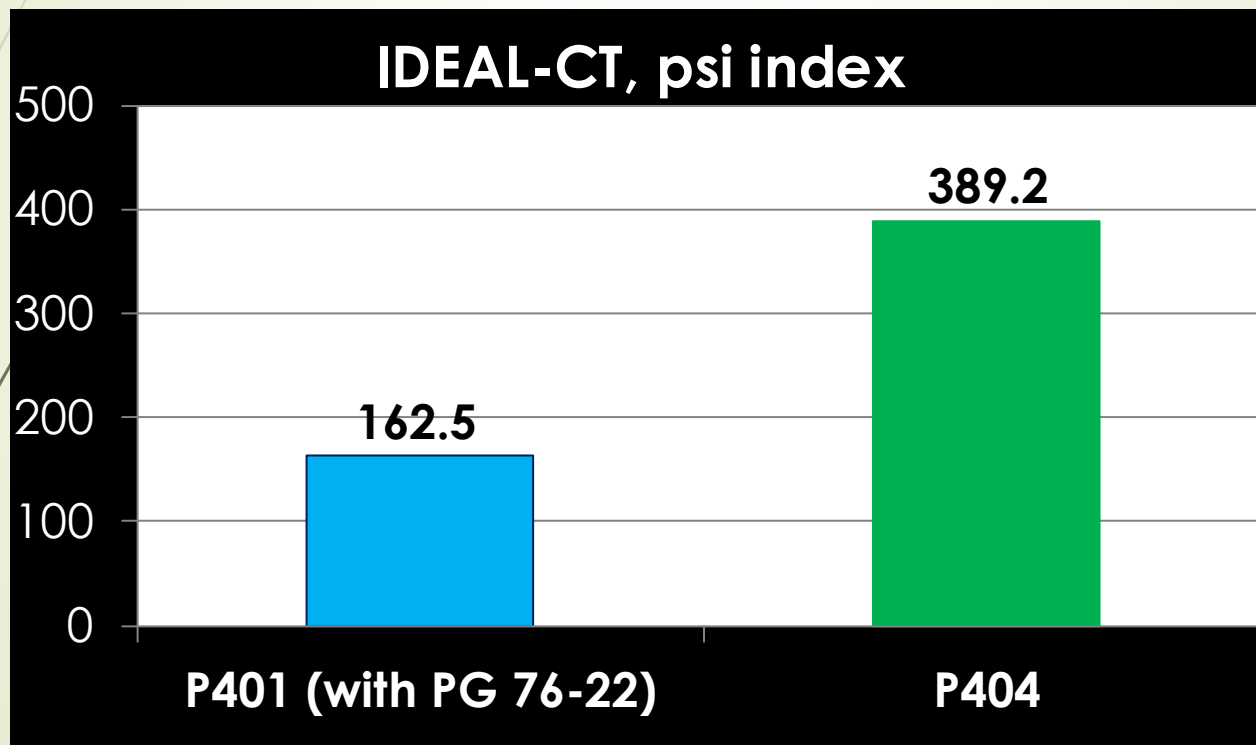
P401 vs. P404 – Rut Resistance and Moisture Susceptibility

*Data obtained by NCAT using Alabama Aggregates



P401 vs. P404 – Cracking Resistance

*Data obtained by NCAT using Alabama Aggregates



Fatigue Cracking Analysis: P-404 vs P-401

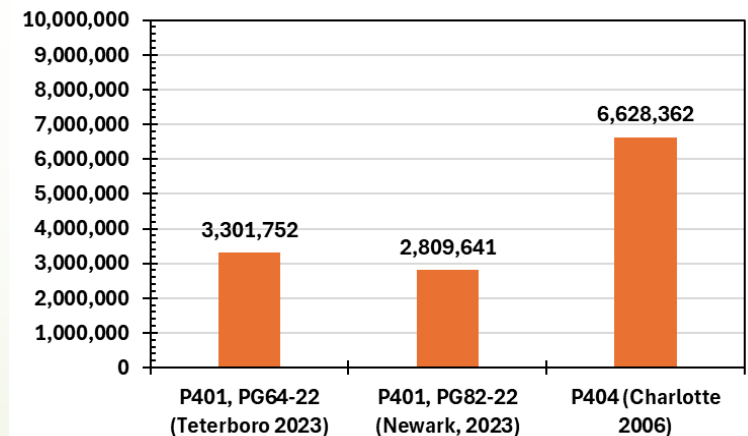
➤ Fatigue cracking analysis used approach detailed in FAARFIELD appendix

- Based on Ratio of Dissipated Energy Change (RDEC) approach
- Mixture specific data used for volumetric parameter and gradation parameter inputs
- Tensile strain at bottom of HMA again modeled in WinJULEA

➤ Use of P404 doubled the bottom-up fatigue cracking life of the pavement section over the P401, PG64-22 and PG82-22

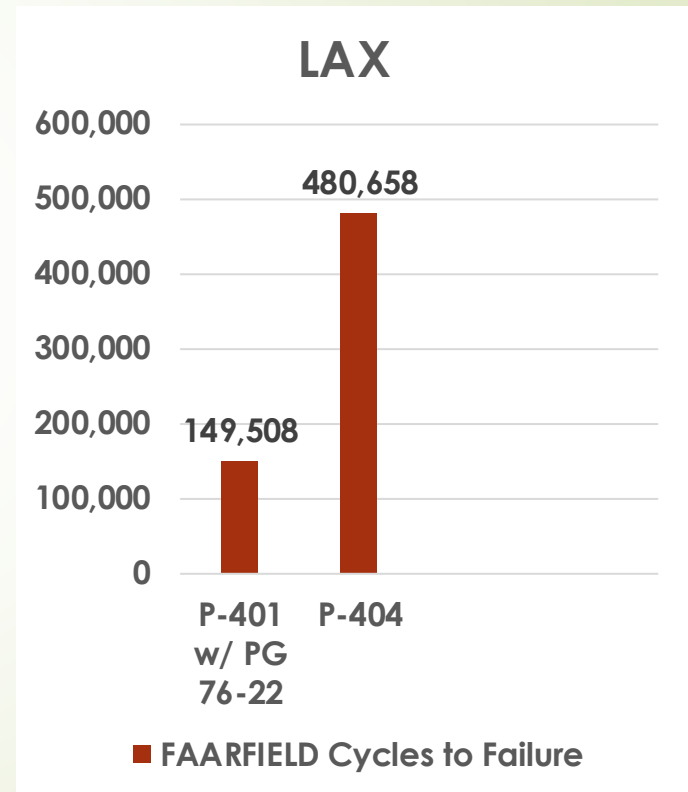
- Higher effective asphalt content in P404 significantly increased fatigue life for pavement scenario (ELA) and all tensile strains evaluated
- High, binder stiffness at high temperature results in lower permanent deformation

PV for 70F		Nf		
Speed (mph)	ϵ_h	P401, PG64-22 (Teterboro)	P401, PG82-22 (Newark, 2023)	P404 (Charlotte 2006)
4	5.00E-05	10,705,519,313	5,877,231,652	14,616,837,729
4	1.00E-04	432,473,871	237,424,178	590,480,500
4	2.00E-04	17,470,768	9,591,291	23,853,807
4	3.00E-04	2,673,500	1,467,727	3,650,278
4	4.00E-04	705,772	387,462	963,629
4	5.00E-04	251,194	137,903	342,969
4	ELA	3,301,752	2,809,641	6,628,362



Fatigue Cracking Analysis: P-404 vs P-401 for LAX

- Calculations from FAARFIELD used to compare P-401 and P-404 Mixes from LAX
- P-404 tripled the fatigue life of a P-401 mix with PG 76-22 binder



Fuel-Resistant Mix – Logan Airport



Fuel-Resistant Mix – New Projects



- Boston, MA - Logan Airport
 - Alleyway Projects – 2005, 2006, 2007
- Charlotte, NC - Douglas International Airport
 - Runway Project – 2006
- Florida DOT
 - Truck Inspection Station – 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
- Toronto International Airport – Apron, 2020

Fuel-Resistant Mix – Charlotte Airport



- **Charlotte Douglas International Airport, Charlotte, NC**
 - Runway 18L – 36R
 - Full depth asphalt runway in dire need of rehabilitation
 - In 2006, Charlotte only had two runways – could not afford to remove one from service for rehab
 - Plans to build a third runway in five years – needed to postpone major repairs until then
 - Needed to put the best available Band-Aid on the runway to make it last five years
 - Selected FR mix used by Logan Airport

Fuel-Resistant Mix – Charlotte Airport



- **Charlotte Douglas International Airport, Charlotte, NC**
 - Repaved Runway 18L – 36R in August 2006
 - Night work – Runway available from 11:00 pm until 6:00 am
 - Mill 2"
 - Pave with 2" FR Mix
 - FR pavement lasted eleven years before the runway needed rehabilitation

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 StellarFlex FR mixes**
 - **Adopted Logan Airport FR specification as P-601 “Fuel-Resistant Hot Mix Asphalt Pavement” specification in July 2014**
- **P-601 usage is eligible for FAA funding**

FAA P-601 Specification



- **FAA issued Advisory Circular # 150/5370-10G , dated 07/21/2014**
- **Contained new specification item P-601 Fuel-Resistant Hot Mix Asphalt Pavement**

FAA P-601 Specification

➤ Asphalt Binder Specification

- ASTM D6373 - Minimum grade of PG 82-22
- ASTM D6084 Elastic Recovery Test Method A – test at 25°C, Elastic Recovery $\geq 85\%$
- ASTM D7173 Separation Test - Maximum temperature difference of 4°C when using ASTM D36 Ring and Ball apparatus

FAA P-601 Specification

➡ Mix Specification

- ➡ P-401 Mix #3 ($\frac{1}{2}$ " mix)

- ➡ Target air voids = 2.5%

- ➡ 50 blow or 50 gyration mix compaction regardless of aircraft type

- ➡ Maximum Weight loss by fuel immersion 2.5% as measured by test procedure in FAA P-601 Specification Section 601-3.3

FR Mix General Aviation Project at Herlong, Florida Airport - 2012



**Fuel Spill Causes Discoloration, But No Damage to
FR Pavement**

P-601 Mix General Aviation Project at Williston, FL Airport - 2015



P-601 Mix at Baltimore/Washington International Thurgood Marshall (BWI) Airport - 2016

- New asphalt pavement for additional freight apron area at BWI



P-601 Mix at Bob Hope Airport Burbank, CA - 2019



1" P-601 Surface Course

First Military Fuel-Resistant Mix Project – Hurlburt Field AFB, Florida



- Repaved apron and taxiway area in July 2018 using FAA P-601 specification
- Taxiway used by military aircraft and helicopters

First Military Fuel-Resistant Mix Project – Hurlburt Field AFB, Florida



- Project is monitored by US Army Engineer Research and Development Center (ERDC)
- Existing pavement had substantial cracking
- After five years, Corps of Engineers reports that none of the cracks have come through the P-404 surface mix

Second Military Fuel-Resistant Mix Project – Hunter Army Airfield Savannah, GA



- DOD has adopted a fuel-resistant specification almost identical to FAA P-404
- Draft Unified Facilities Guide Specification – UFGS 32 12 17 .19

FAA P-404 Specification



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

FAA P-404 Specification

➤ Asphalt Binder Specification

- ASTM D6373 - PG 88-22FR or PG 82-28FR as dictated by project location climate
- ASTM D6084 Elastic Recovery Test Method A – test at 25°C, Elastic Recovery $\geq 85\%$
- ASTM D7173 Separation Test - Maximum temperature difference of 4°C when using ASTM D36 Ring and Ball apparatus

FAA P-404 Specification

➤ Mix Specification

➤ Mix design criteria

- P-401 Mix #3 gradation (1/2" mix) and/or Mix #2 gradation (3/4" mix)
- 2.5% target air voids
- 50 Marshall blows or 50 gyrations compaction

➤ Adds Asphalt Pavement Analyzer (APA) rutting requirement

- APA Rut Depth <10mm @ 4000 passes, hose pressure 240 psi
OR
- APA Rut Depth <5mm @ 8000 passes, hose pressure 100 psi
OR
- Hamburg Wheel Tracking < 10mm @ 20,000 passes
- Allowable lift thickness: 1 1/2" – 3"
- Maximum Weight Loss Fuel Soak Test = 1.5%
- In place density – Maximum 4% air voids compared to P-401 7.2% maximum air voids

Lynchburg VA Regional Airport



- National Guard V-22 Ospreys land at Lynchburg Regional Airport on a regular basis
- Apron area was repaved with P-404 mix in Fall 2020
- V-22 sits stationary for approximately 30 minutes with engines running during “hot refueling”

V-22 Osprey on P-404 Pavement



- Note slight discoloration beneath engine exhaust
- I believe it is small amount of unburned fuel
- Walked out to area immediately after takeoff – darkened area was too hot to touch with your hand
- No damage to P-404 pavement to date

P-404 Mix Apron Project at Toronto International Airport - 2020



**FAA P-401 Mix #2 Gradation (100% passing $\frac{3}{4}$ ")
with PG 82-28FR Binder**

Fuel-Resistant Mix 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 FR mix in bus lanes to solve the problem

P-404 Cost



- P-404 mix costs approximately 20-25% more than P-401 mix
- Two factors contribute to increase
 - Two to three times more polymer in the liquid asphalt
 - $\approx 1.0\%$ more liquid asphalt in the mix

P-404 Cost



- P-404 mix cost increase affects only one item in the project cost – the surface layer
- Unaffected items typically found on airfield paving projects
 - Milling
 - Patching
 - Base and intermediate pavement layers
 - Striping
 - Electrical work
- Cost increase to total project cost (depending on scope of work) is typically 5-7%

Benefits of FAA P-404 Mix

- **FR highly polymer-modified asphalt provides:**
 - Outstanding rut resistance
 - Improved fatigue resistance
 - Resistance to fuel and oil damage – eliminates need for coal tar sealers
 - Excellent workability
 - Longer life
- **P-404 mix design has increased asphalt content, which provides:**
 - Improved fatigue (cracking) resistance
 - Increased pavement life (durability)
- **Combination provides resistance to all potential airfield pavement damages – results in longer pavement life and lower life cycle cost**

Contact Information

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Questions?

