FORTA-FI®

High Tensile Strength Synthetic Fiber Reinforcement for Asphalt Pavement

Go Stronger…Go Longer…
Get **FORTA***fied*®!

Program

- Sustainability / Udržitelnost
- Criteria for sustainable pavements / Kritéria pro udržitelné vozovky
- Transportation and climate change / Doprava a klimatické změny
- Fiber reinforced asphalt / method and benefits / Vlákny vyztužený asfalt – metoda a přínosy

Importance of Sustainability

- Why now?
- With increased CO_2 emissions, limited resources and the need for environment protection worldwide, Sustainability has become a key word in the building industry today

TRB on Transportation and Climate Change

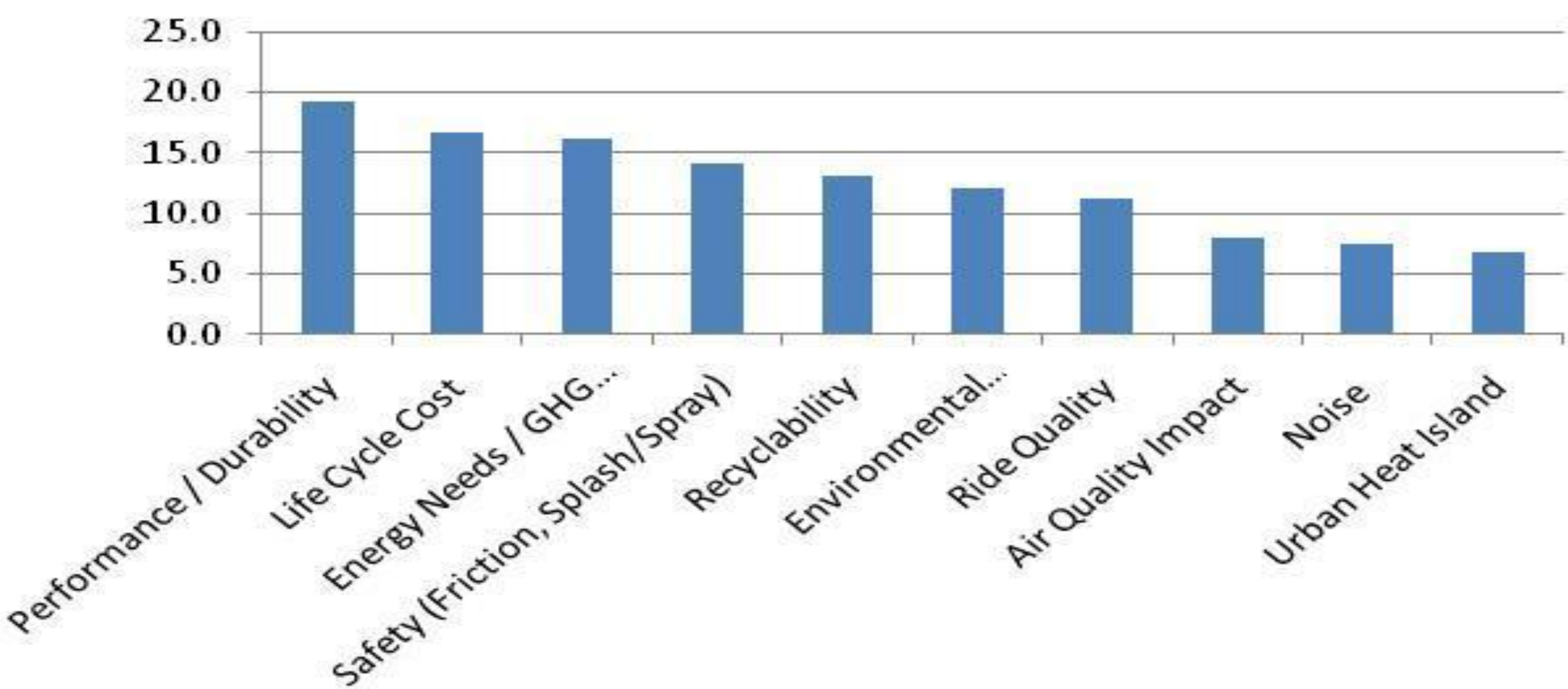
- “Reducing transportation-related emissions of carbon dioxide--the primary greenhouse gas--that contribute to climate change and adapting to the consequences of climate change will be among the biggest public policy challenges facing the transportation profession over the coming decades.“

Criteria for Sustainable Pavements?

- Performance / Durability
  - Material / Design
- Safety
- Ride Quality or Comfort
- Life Cycle Cost
- Energy Consideration
- Quality of Life Issues
  - Highway Noise
  - Air Quality
  - Urban Heat Island
- Recyclability

Factor Weighting

- In the USA, a panel of experts were asked about the above criteria and their relative weight in sustainability considerations, the results they produced were as follows.



Model

- To allow more precise evaluation of the pavements building contribution prof. Kaloush at the conference in Hawaii offered the following model:

$$Total \cdot annual \cdot kgCO_2.Eq / km = \frac{\sum \left[T * W * 1000 * Dn * \left(\left(Pn + Mn \right) + \left(Di * Tp \right) \right) \right]}{Y}$$

Where,
T = thickness of pavement layer, meters
W = width of road, meters
Dn = density of pavement material, kg/m^3
Pn = material production value, kg CO2 Eq. /kg
Mn = material mixing value, kg CO2 Eq. /kg
Di = distance from material production site to application site, km
Tp = transport from production site to application site value, kg CO2 Eq. /kg material-km
Y = road life, years

Equation Implications

- From the equation it is clear that the reduction of GHG generation in pavement construction can be achieved by simply changing two values in the equation
  - Increase in road life. (Y)
  - Reduction in Asphalt thickness (T)

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Fibers in Asphalt Concrete

- Enhance load carrying capacity
- Rutting resistance
- Resistance to cracking and fatigue
- Resistance to moisture damage & aging
- More flexibility, lower strength and stiffness
- Asphalt drain down reduction



FORTA Corporation

- FORTA Corp. has extensive experience with Polyolefin / Polypropylene fibers for concrete reinforcement.
- The problem with the use of these fibers for asphalt mixes is their melting point, which is in the range of 160 – 180°C
- Mixture of Aramid fibers that are thermally stable to 450°C and polyolefin fibers that facilitate the mixing of aramid fibers in the aggregate.

Polyolefin

- Chemically Inert
- Non-Corrosive
- Non-Absorbent

Aramid

- High Tensile Strength
- Non-Corrosive
- High Temperature Resistance

Research and testing Objectives

- Testing of the FORTA-FI fibers was primarily carried out at Arizona State University but tests have also been conducted by NCAT, Federal Highways Administration (FHWA) and a number of other universities in the USA and worldwide

- The detailed test descriptions and results are far beyond the scope of this paper and can be obtained upon request from eMZet s.r.o.

- The executive summary of the tests are as follows.

ASU ARIZONA STATE UNIVERSITY

Physical Characteristics of the Fibers

Materials	Polyolefins	Aramid
Form	Twisted Fibrillated Fiber	Monofilament Fiber
Specific Gravity	0.91	1.45
Tensile Strength (MPa)	483	3000
Length (mm)	19.05	19.05
Color	Tan/yellow/black	Yellow
Acid/Alkali Resistance	inert	Inert
Decomposition Temperature (C)	157	>450

Testing Narrative

- A field test was conducted by ASU in the the City of Tempe, Arizona,
- A mixture that contained ½ Kg of fibers per tonne of asphalt was compared to a control section that had no reinforcement fiber
- Mixtures for laboratory testing were sampled during construction and brought back to the Arizona State University (ASU) laboratories.

Testing Narrative continued

- Laboratory experimental programs included:
  - triaxial shear strength
  - dynamic (complex) modulus, and repeated load for permanent deformation characterization
  - flexural beam tests along with flexural toughness tests for fatigue cracking evaluation
  - indirect diametral tensile tests for thermal cracking mechanism evaluation
  - C* Integral test for crack growth and propagation evaluation.

Aerial view of Testing Area

Pavement Section Prior to Testing

Triaxial Shear Strength Test

- The FORTA-FI asphalt concrete mixture showed higher residual energy compared to the control mix.
    - Indicating that the fiber-reinforced mixture shows higher resistance to crack propagation.

Flexural Strength Test

- The flexural strength and corrected flexural strength are increased by 14% and 25%

Dynamic (Complex) Modulus Test

- The modulus of the FORTA-FIed mixture was higher than the control mixture.
  - Indicates that the reinforcing fibers in the mixture enhance the modulus of the mixture and therefore its resistance to permanent deformation.

Fatigue Cracking Testing

- Comparing the initial stiffness for the FORTA-FI mixture at 21°C and 250 micro-strains.
  - it was noted that the fiber-reinforced mixture showed higher stiffness values compared to the control mixture.
  - Comparing the fatigue life for the FORTA-FI mix at 150 micro-strains, it was observed that the fiber-reinforced mixture had the highest fatigue life.

Permanent Deformation Tests – Static Creep / Flow Time Test

- Two important characteristics were observed for the FORTA-FI mixture when compared to the control mixture.
  - The endurance of the post crack, secondary stage.
  - The gradual/less accumulation of permanent strain.

- Both were attributed to the presence of the reinforcing fibers in the mixture, as this behavior is not typically observed in conventional mixtures.
- The fiber-reinforced mixture had higher Flow Time values than the control mixture (over 900% higher), and 700% lower slope values.
- These indicate that the FORTA-FI mixture has a much higher potential to resist permanent deformation than the control mixture.

Repeated Load Flow Number Test

- The Flow Number for the FORTA-FI mixture was 1,150% higher than the control mix.
- The FORTA-FI mixture had a much lower strain slope compared to the control mixture post crack
  - This indicates that the mixture has higher potential to resist shear failure and shows a lower rate of permanent deformation and rutting.
  - Due to the lower strain slopes of the fiber-reinforced mixture, the mixture is capable of storing more energy than conventional mixtures before and during tertiary flow.

Indirect Diametral Tensile Test

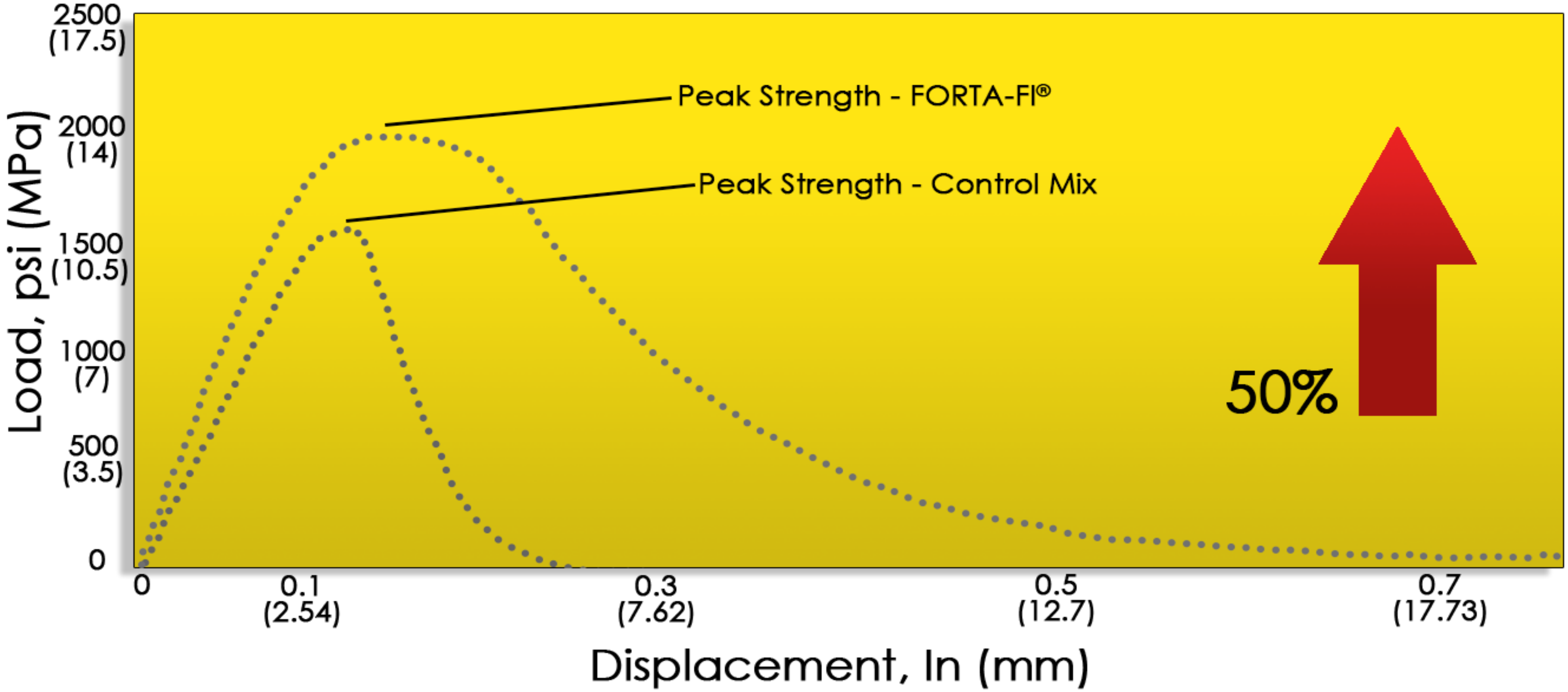
- The tensile strength of ½ kg/Tonne dosage of FORTA-FI mixture increased as the temperature decreased.
  - fiber-reinforced asphalt mixture had about 150% higher strength than the control mixture.
  - At all temperatures 10°C, 0°C, -10°C, the 1/2 kg/Tonne dosage of FORTA-FI showed energies averaging 200% higher than the control mixture.
  - At the lowest temperature of -10°C, where susceptibility of crack initiation and propagation is the highest the fiber-reinforced asphalt mixture had higher energy values than the control mixture.

Crack Propagation test – C* integral

C=1dU*BdC*

- *(dU*=Change in energy rate for a load P and a crack extension dC, B=thickness)*

C* Test results



Additional FORTA-FI testing

- In 2010, A subsequent battery of tests was performed at the accredited laboratory in Czech Republic.
- Work was performed in conjunction with the Road Laboratory of the Civil Engineering Faculty of the Czech Technical University and Central Laboratory of EUROVIA
- This battery of testing obtained results that confirmed the results obtained at ASU

Sustainability

- At the beginning of this paper we mentioned several different possible approaches to the sustainability considerations.
- The two approaches that we think are most important and relevant to this exercise are:
  - Environmental sustainability
  - Economic sustainability

Environmental sustainability

- To demonstrate the positive contribution of the use of aramid fibers as asphalt concrete reinforcement we use a simplified and yet very real example of benefits achievable in reduction of Greenhouse gases production in road and airport construction

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CO_2 EQUIVALENT EMMISSION COMPARISON

$$Total \cdot annual \cdot kgCO_2.Eq/km = \frac{\sum\left[T * W * 1000 * Dn * \left(\left(Pn + Mn\right) + \left(Di * Tp\right)\right)\right]}{Y}$$

- The transport distance (Tp) was assumed to be 25 km (15.5 miles).
- The density (Dn) of asphalt concrete was taken as 2275 kg/m^3 (142 lb/ft^3) and a runway width (W) of 45.7 m (150 feet).
- The use of FRAC as the FAA P-401 surface course can result in a 33% decrease in total kg of annual CO2 equivalent per km of runway. This is based on the assumption that the dynamic modulus increases by 50% to 300,000 psi (1,723) for FRAC and is also limited by the current FAA design procedures.

Economic sustainability

- Every government in the world works with limited resources and developing and maintaining the transportation infrastructure represent a serious challenge.
- As the test results prove, using the aramid fiber reinforcement offers two possible ways of saving:
  - Allows for the reduction of thickness of the asphalt by up to 35% without compromising the useful service life time.
  - Using fiber reinforced mixtures extends the service life of the pavement by up to 50%.

Economic sustainability cont'd

- Considering that the use of aramid fibers does not require any modifications of the existing equipment, mixture or the process of production, one may say that reinforcement by aramid fibers is not a cure-for-all, it is a very important step forward in road construction.

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for Asphalt Pavement

Thank You

Dave Huddleston
International Business Development Mgr
dhuddleston@fortacorp.com
(724) 372.9983 or (800) 372.9983 x144

FORTA Corporation
100 Forta Drive
Grove City, PA 16127 USA

Phone: (800) 245-0306
Fax: (724) 458-8331

www.forta-fi.com

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