Improvement of Open-Graded Friction Course Performance and Durability through Materials, Design, and Maintenance

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Open-Graded Friction Course

• Open-graded asphaltic mixture
  • Percentage of Fine Aggregate: decreased
  • Percentage of Coarse Aggregate: increased

• Porous
  • Contains a high percentage of interconnected air voids
  • Allows for lateral drainage of storm water

• Primarily used as a thin wearing course
OGFC: Benefits

• Safety Improvements
  • Large air voids content allow water to drain through the pores
  • Possibility of hydroplaning decreases
  • Skid resistance increases during wet weather conditions
  • Improves visibility

• Economic Benefits
  • Reduced fuel consumption due to enhanced smoothness

• Environmental Benefits
  • Noise reduction of highway noise levels
  • 3 to 6 dB(A) reduction compared with dense-grade HMA
OGFC: Drawbacks

• Durability Issues
  • Raveling – Main distress
  • Cracking
  • Stripping

• Functionality Issues
  • Loss of permeability / clogging of pores
  • Loss of noise reduction capabilities
Objective

• Provide an implementable guideline on the design, performance, and maintenance of OGFC

1. Evaluate maintenance methods through literature review and state DOT survey

2. Evaluate alternative materials, such as epoxy asphalt to improve the elasticity of asphalt mixtures and prevent premature failure
   ▪ Support Study - Development of a Standard Practice for the Design of Durable Open-Graded Friction Course (OGFC) Mixtures with Epoxy Asphalt

3. Evaluate a new generation of permeable pavements with improved mechanical characteristics, superior drainage capacity, and enhanced pavement performance
   ▪ Support Study - A New Generation of Porous Asphalt Pavement
Maintenance Methods – De-Clogging

- Preventing clogging is difficult
  - Costly to restore permeability once clogging occurs
  - Cleaning techniques should begin while the layer is still permeable
  - Regular maintenance should maintain permeability of the layer for a longer time

- Maintenance methods to restore permeability include:
  - Cleaning the pavement with a fire hose or high pressure cleaner and a specially equipped vacuum truck.
  - There is a belief that pressure washing and vacuuming may be more harmful to OGFC pavements
  - Restoration of permeability is higher at the non-wheel path than in the wheel path
  - Pavement may need to be cleaned three to four times for traffic lanes with high severity of clogged pores.
Asphalt binder in OGFC pavements is more susceptible to oxidation due to its increased exposure to harmful elements.

Fog seals, which are a 50:50 mixture of asphalt emulsion and water, are believed to extend the service life of OGFC pavements.
- Provide a thin film of unaged asphalt at the surface
- Concern: it may reduce porosity and pavement friction
- Some research has concluded that the mixtures still retain porosity and keep the macrotexture related to its capability to reduce the potential for hydroplaning
- Immediately after fog seal application, a decrease in pavement friction is noticed; however, it increases considerably in the first month due to traffic passing over it.

Chip seals
- Some agencies use a seal coat to stop raveling for a short period of time in order to maintain pavement serviceability until a contractor can repair the severely raveled areas.
Maintenance Methods – Corrective Maintenance

- Repairing or patching a delaminated or potholed section
  - Another OGFC mixture should be used if the section is big enough to justify the OGFC production
  - Dense graded hot mix asphalt can be used when the patch size is small enough to not disrupt flow through the OGFC layer
  - When patching occurs, it should be diamond shaped and oriented in a direction to allow water to drain along the patch at 45 degrees

- Cracks:
  - Care needs to be taken as to not impede the lateral flow of water
  - Transverse cracks can be sealed using the normal techniques because the flow will not be obstructed
  - Longitudinal cracks can be problematic since they can cut off drainage in the top layer of the OGFC pavement
  - One possible solution to this problem is to mill the cracked strip of pavement and replace in kind with more OGFC
Development of a Standard Practice for the Design of Durable OGFC Mixtures with Epoxy Asphalt

Support Study 1
Objective – Support Study 1

The objectives of this research project are to:

1. Determine if EA can significantly improve the durability (life span) of OGFC mixtures

2. Determine the optimum epoxy dosage rate based on performance evaluation and life-cycle cost analysis

3. Develop a mix design protocol for OGFC mixtures with diluted EA based on the current Louisiana OGFC mix design procedures
Preliminary Findings – Support Study 1
Preliminary Findings – Support Study 1
A New Generation of Porous Asphalt Pavement

Support Study
Objective – Support Study 2

• The objectives of this research project are to:
  1. Evaluate current practices; aggregate type and gradation, additives, and fiber type and content

  2. Investigate the effects of three warm mix additives on the laboratory performance and physical characteristics of OGFC.

  3. Evaluate the use of hydrophobic nanomaterials to accelerate rainwater drainage to the sides of the road and the incorporation of luminescent materials into paving materials in order to improve the visibility at night.

  4. Ensure that the new generation of OGFC will be environmentally friendly and cost-effective by testing and evaluating different fiber types, recycled products such as crumb rubber.
Warm Mix Additives - Preliminary Findings

- 4 Mixtures Evaluated:
  - Control: HMA-OGFC (CM)
  - 2 Chemical Additives (Che1-OGFC & Che2-OGFC)
  - 1 Organic Additive (Org-OGFC)

- Materials
  - 78 Limestone & 67 Sandstone
  - PG 76-22 SBS
Warm Mix Additives - Preliminary Findings

• Testing:
  • Permeability:
    • Florida Method of Test for Measurement of Water Permeability of Compacted Asphalt Paving Mixtures (FM 5-565)
  • Draindown:
    • Draindown Characteristics in Uncompacted Asphalt Mixtures (AASHTO T 305-97)
  • Cantabro Abrasion Test
    • Standard Method of Test for Determining the Abrasion Loss of Asphalt Mixture Specimens (AASHTO TP 108-14)
  • Hamburg Wheel-Track Test (AASHTO T 324)
  • Modified Lottman (AASHTO T 283)
  • Boiling test (DOTD TR 317)
Preliminary Findings - Permeability

- WMA additives resulted in a reduction of the permeability
- Control mix (CM) had a $k$-value of 426 ft/day (130 m/day)
- 363, 198, 198 ft/day for Che1-OGFC, Che2-OGFC, and Org-OGFC
- ANOVA results showed that Che2-OGFC and Org-OGFC had $k$ values that are significantly different from those of the control mix
- Che1-OGFC and CM mixes exhibited statistically equivalent $k$ values.
- All mixes would pass the NCHRP-recommended permeability criterion for OGFC mixes.

- NCHRP Recommends 164 ft/day (50 m/sec)
Preliminary Findings - Draindown

- All mixes satisfied LaDOTD requirement for draindown (i.e., 0.3%)
- Org-OGFC had the least draindown of 0.01%, which was significantly different from the other mixes
- Che1-OGFC mix showed the highest draindown value of 0.11%, which was statistically similar to those values of the CM
- Che2-OGFC also exhibited an acceptable draindown value, which was significantly less than those of the CM
Preliminary Findings – Cantabro Abrasion

- In general, WMA additives enhanced the raveling resistance of the mixtures at the different testing conditions.

- Unaged specimens:
  - Che2-OGFC and Org-OGFC mixes showed the best raveling resistance as indicative from the low Cantabro loss value.
  - Both CM and Che1-OGFC mixtures showed an inferior resistance to raveling.
  - ANOVA indicated that the addition of chemical additive (Che2) decreased the Cantabro loss values significantly as compared to the CM and the remaining mixes had similar raveling resistance to CM.
Preliminary Findings – Cantabro Abrasion

- Aged samples:
  - WMA mixes showed high raveling resistance compared to the control mix.
  - The results indicate that the control mix failed to satisfy the 30% limit on aged samples; all WMA mixes did meet this requirement.
  - Chemical additive (Che2) and the organic additive (Org) reduced the Cantabro loss value significantly compared to the CM.
  - ANOVA results indicated that both Che1-OGFC and CM mixes exhibited similar resistance to raveling.

- Moisture-conditioned samples:
  - All WMA mixtures satisfied the maximum Cantabro loss requirements.
  - Control mix failed to achieve the desired raveling resistance.
  - ANOVA results showed that all WMA mixes were statistically equivalent as they significantly improved the durability and raveling resistance of OGFC mixes on moisture-conditioned samples.
Preliminary Findings – HWTT

• 5,000 Passes:
  • In general, compared to the CM, WMA-OGFC mixes showed similar permanent deformation resistance.
  • Org-OGFC had the smallest rut depth after 5,000 passes,
  • CM showed the lowest permanent deformation resistance
  • ANOVA results showed that Org-OGFC had significantly improved resistance to permanent deformation compared to the other mixes
  • All mixes satisfied LaDOTD requirements of 12.5 mm after 5,000

• 20,000 Passes:
  • Org-OGFC was the only mix that satisfied NCHRP 1-55 requirements
  • CM, Che1-OGFC, and Che2-OGFC did not achieve this
  • Statistically, Org-OGFC rut depth values that were statistically different from the other mixes.
Preliminary Findings – Modified Lottman

Dry ITS:
- Dry ITS value decreased slightly when chemical additives (Che1 and Che2) were used.
- The incorporation of the organic additive in the OGFC mix resulted in an increase of dry ITS by 24% compared to the CM.
- Since dry ITS value is typically used as an indication of fatigue crack resistance, it may be noted that the organic additive improved the fatigue crack resistance.
- Both chemical additives did not provide the same level of improvement in terms of cracking resistance.
- Statistically, the impact of chemical additive (Che1) on fatigue crack resistance was insignificant.
- NCHRP 1-55 recommends that the unconditioned ITS values should not be less than 70 psi to ensure desirable crack resistance; Org-OGFC was the only mix to satisfy this threshold.

Conditioned ITS:
- Org-OGFC showed the highest conditioned ITS value; this is significantly different from the other mixes.
- The remaining mixes exhibited comparable conditioned ITS of about 50 psi.
- According to NCHRP 1-55, the minimum acceptable conditioned ITS should be 50 psi. The results indicate that both CM and Org-OGFC satisfied the NCHRP requirements, while the other mixes did not.

TSR:
- TSR value is typically used to evaluate the moisture-damage resistance of the different mixes.
- According to NCHRP 1-55, a TSR value of 0.7 is the minimum value of OGFC mixes; all mixes satisfied the minimum TSR value.
- The results of TSR alone showed that all mixes had similar performance. However, by considering the minimum values of the conditioned and unconditioned ITS, the Org-OGFC mix showed superior moisture resistance.
Preliminary Findings – Boil Test

- Regardless of the mixture type, the visual inspection indicated that no stripping occurred to the aggregate.
- This indicates acceptable moisture damage resistance for all mixes.
Preliminary Findings – Conclusions

- WMA additives reduced the coefficient of permeability
  - All the mixes satisfied the requirement of coefficient of permeability. Given the notable reduction in production temperature (23°F), WMA-OGFC mixes achieved the desired density at a lower compaction energy effort compared to the control mix.
- WMA-OGFC significantly enhanced both raveling and permanent deformation resistance of the mix as compared to the control OGFC mix
- Organic WMA enhanced the cracking resistance of OGFC as compared to the control mix based on the ITS (dry and wet) test results
- On the other hand, both chemical WMA additives reduced OGFC resistance to cracking
- The results of Tensile Strength Ratio (TSR) and boil test showed that all mixes had acceptable moisture damage resistance
  - Considering the minimum values of conditioned and unconditioned ITS, the Org-OGFC mix showed superior moisture resistance
To be continued!

Questions?