LOUISIANA TRANSPORTATION RESEARCH CENTER

Technical Summary

LTRC Report 696

SIO No. DOTLT1000384
LTRC Project No. 21-4B

Development of a Standard Practice for the Design of Open-Graded Friction Course (OGFC) Mixtures with Epoxy Asphalt

Introduction

Open-graded friction course (OGFC) is a surface layer of thin, gap-graded asphalt mixture characterized by a high proportion of coarse aggregates and minimal fines. This composition results in a higher interconnected air void percentage and asphalt binder content. OGFC offers numerous advantages, including efficient water drainage, reduced hydroplaning and splash/spray, and enhanced visibility and safety on roads. However, conventional OGFC mixtures have been identified with durability issues, leading to raveling distress and the subsequent development of rough pavement surfaces, diminished ride quality, and increased traffic noise.

Addressing the durability concerns of OGFC mixtures involves enhancing the properties of the asphalt binder. This can be achieved by incorporating additives such as styrene-butadiene-styrene (SBS), crumb rubber, and epoxy asphalt (EA). Studies indicate that asphalt mixtures utilizing these modified asphalt binders exhibit improvements in draindown, rutting, durability, and moisture resistance. Additionally, these asphalt binders were found to possess enhanced rheological and chemical properties, including increased elasticity and stiffness, improved high, intermediate, and low performance grading, and enhanced bonding between the asphalt binder and aggregate.

Figure 1. Typical Dense-Graded Mixture (left) vs. OGFC (right)

EA has gained much attention due to its successful application in pavements. EA binders do not melt after complete curing (thermoset), demonstrating excellent anti-aging and rheological properties. Consequently, this study aimed to investigate the impact of different asphalt binder types on the performance of both asphalt binders and OGFC mixtures, with a focus on assessing their durability, rheological characteristics, and overall effectiveness in road applications.

Objective

The objective of this study was to evaluate the durability and performance of OGFC mixtures containing various types of asphalt binder. Specific objectives included:

- Determine if EA binder can significantly improve the durability and performance of OGFC mixtures at multiple dilution rates
- Compare the effect of various modifiers (SBS, SBS/CRM, and EA) on asphalt binders' rheology and OGFC mixture performance
- Determine the effect of different asphalt binder contents on the physical and mechanical performance of OGFC mixtures
- Ascertain the cost-effectiveness of various asphalt binder types.

Scope and Methodology

A 12.5-mm OGFC mixture was designed following ASTM D7064 "Standard Practice for Open-Graded Friction Course (OGFC) Mix Design." Three aggregate gradations based on DOTD and literature were utilized, and the optimum aggregate structure was selected based on the minimum required air voids and voids in coarse aggregate. Two asphalt binder contents (P_{bS}) were considered, 6.5% and 7.0%. Asphalt binder PG 76-22M at a P_b of 6.5% was selected as a baseline for the selection of optimum aggregate structures and a P_b of

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Funding
SPR: TT-Fed/TT-Reg - 6

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7.0% to ascertain the effect of increased asphalt binder content on the durability of OGFC mixtures.

Six types of asphalt binders were utilized: unmodified PG 67-22 asphalt binder; conventional styrene-butadiene-styrene (SBS)-modified PG 76-22M asphalt binder; high-SBS content PG 88-28 asphalt binder; diluted epoxy-modified asphalt (EA) binder prepared at two dosage rates (i.e., 25% and 50%, by weight of asphalt binder); and a hybrid PG 76-22G modified asphalt binder prepared with SBS and crumb rubber modifier (CRM).

The compatibility between multiple asphalt binder sources and the EA binder was first determined, followed by a suite of rheological and chemical tests to evaluate the modified asphalt binders: performance grading (PG); multiple stress creep recovery (MSCR); frequency sweep (FS); linear amplitude sweep (LAS); Fourier-transform infrared (FTIR) spectroscopy; and SARA fractions analysis. Further, a suite of physical and mechanical tests was conducted to assess OGFC mixtures: namely, draindown, permeability, loaded wheel track (LWT) test for rutting, LWT and modified Lottman for moisture susceptibility, and Cantabro abrasion loss test for durability. Triplicate samples were tested, except for LWT, where four specimens were used. Finally, a cost-effectiveness analysis was conducted for the evaluated asphalt binder types.

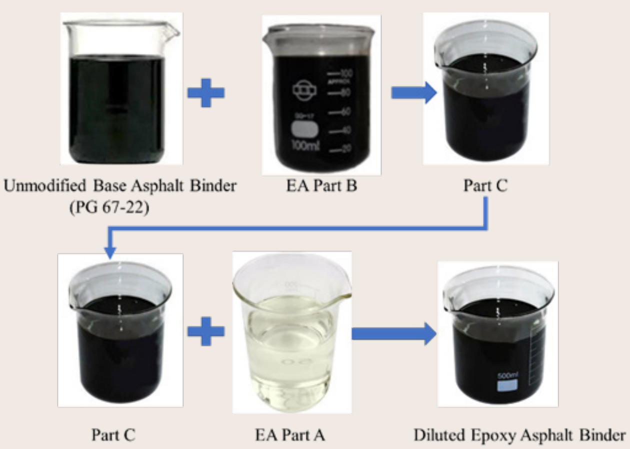

Figure 2. Process of Producing Epoxy Asphalt (EA) Binder

Conclusions

The following conclusions were drawn based on the results of this research:

- Chemical compatibility and microscopic analyses showed that base asphalt binder source 1 was most compatible when diluted with EA binder. Results showed that asphalt binders with similar performance grading (PG) but different sources may show different compatibilities. Therefore, it is recommended to evaluate the compatibility of base asphalt binder used to dilute EA binder.
- Results from SARA fractions and Fourier Transform Infrared Spectroscopy tests showed that EA binders had the highest aging resistance.
- Minimum air voids and VCA parameters were key factors in determining a suitable mix design for OGFC mixtures. Based on these results, Gradation 1 had the optimum aggregate gradation and was selected.
- All studied OGFC mixtures met the requirements for physical testing, namely, draindown (< 0.3%) and permeability (>100 m/day). Mixture with 50%EA binder had significantly lower draindown values compared to other mixtures.
- All OGFC mixtures evaluated complied with DOTD specification of maximum LWT rut depth requirement of 12.5mm at 5,000 passes. Mixtures containing 50%EA and PG 88-28 binders showed the lowest rut depth at 20,000 passes, followed by those with 25% EA, PG 76-22G, and PG 76-22M.
- OGFC mixtures evaluated were found to be moisture resistant, as they exhibited LWT rut depth values of less than 12.5mm at 5,000 passes after freeze-thaw moisture conditioning. Also, results from the modified Lottman test exhibited similar findings, as measured by their high TSR values.
- Studied OGFC mixtures complied with ASTM D7064 specification of maximum abrasion loss requirements of 20% and 30% for unaged and aged samples (5-days), respectively. Mixtures containing 25%EA and 50%EA binders showed an improvement in abrasion loss as aging duration increased from 5- to 15-days.
- Cost-effectiveness ratio (CER) results showed that EA mixtures have higher effectiveness compared to the conventional OGFC mixture with PG 76-22M when tested for 30-days aged moisture-conditioned Cantabro specimens.
- High-temperature stiffness ranking from asphalt binder tests (i.e., PG) did not match the ranking from loaded wheel track test for the evaluated asphalt binders and asphalt mixtures.

Recommendations

Based on the results of this research, the following additions to 501 Thin Asphalt Concrete Applications of the Louisiana DOTD specifications for Road and Bridges are recommended:

- Allow asphalt binder grade of 50%EA of PG 88-28.
- Develop optimal aggregate structures to ensure a stone-on-stone contact based on voids in coarse aggregate (VCA) requirement.
- Implement the LWT test for water susceptibility on moisture-conditioned samples, according to AASHTO T 283. Maximum rut depth at 5,000 passes is 12 mm.
- Implement Cantabro abrasion test for durability, compacted specimens aged for 5-day at 85°C, according to ASTM D 7064. Maximum loss value is 30%.