Design, Construction and Performance of New-Generation Open-Graded Friction Course Mixes

RESEARCH SYNOPSIS–NCAT REPORT 00-01

Problem Statement

Open-graded friction course (OGFC) mixes improve the surface drainage of asphalt pavements, thus reducing hydroplaning, splash and spray behind vehicles, and improving wet-pavement friction and surface reflectivity during wet-weather conditions. However, many states stopped using OGFC mixes due to unacceptable performance of the mix and its lack of durability. The OGFC mix design procedure developed in 1974 by the Federal Highway Administration (FHWA) is still commonly used despite improvements in gradation and asphalt binder types. A better mix design procedure was needed to develop OGFC mixes with improved resistance to raveling and delamination and to maintain the excellent permeability characteristics of this mix type.

Objective

The objective of this study was to evaluate the laboratory performance of OGFC with different gradations and types of additives and, based on this work, recommend a rational mix design system for a new-generation OGFC. Additionally, the construction and performance of six already constructed OGFC pavements were discussed and considered in the mix design system recommendation.

Description of Study

The research study included a series of lab experiments and a field evaluation study. The first phase of the laboratory work was conducted to evaluate different OGFC gradations and types of additives. Blends of aggregate were prepared to have gradations similar to and coarser than the FHWA-recommended gradation for OGFC mixes. Mixes were prepared from these blends with an unmodified PG 64-22 asphalt binder, and optimum asphalt content was selected based on the FHWA procedure. The four blends were evaluated for stone-on-stone contact with voids in the mineral aggregate (VMA) and in the coarse aggregate (VCA) plots, and by VCA data from dry-rodded tests with the coarse aggregate fractions only. Samples were then tested for draindown potential, permeability, abrasion resistance, aging potential and rutting. The primary objective of phase one of the laboratory study was to evaluate changes in mix characteristics when the FHWA gradation is made coarser.

In the second phase of the laboratory study, mixes were prepared with the coarsest gradation and six different binders: PG 64-22, PG 64-22 plus Styrene-Butadiene-Styrene (SBS), PG 76-22 plus Styrene Butadiene (SB), PG 64-22 plus cellulose fiber, PG 76-22 containing SB and slag wool, and PG 64-22 plus slag wool. Both SBS and SB were added at 4 percent by weight of binder, and cellulose and mineral fiber (slag wool) were added at 0.37 percent by weight of the total mix. The objective of this phase was to evaluate the effects of various additives in the OGFC mix. These mixes were prepared with 6.5 percent asphalt binder and compacted with 50 gyrations to match air void contents of OGFC core samples obtained from the field where a similar gradation was used. In addition to volumetric properties, draindown, permeability, abrasion resistance, aging and rutting tests, these mixes were also tested for resistance to moisture damage.


Figure 1 Close-up of OGFC on NCAT Pavement Test Track.

The field study entailed identifying OGFC pavement sections that would closely resemble OGFC mixes resulting from the recommended mix design system and documenting construction and performance. Six OGFC pavement sections were located on I-75 south of Atlanta. Constructed in 1992, these sections were characterized as a coarse OGFC (D), coarse OGFC with 16 percent crumb rubber (D16R), coarse OGFC with cellulose fiber (DC), coarse OGFC with mineral fibers (DM), coarse OGFC with SB polymer (DP), and coarse OGFC with SB polymer and cellulose fibers (DCP). Construction of these six pavements was documented in a Georgia Department of Transportation (GDOT) report. Six years after construction, NCAT researchers performed a visual distress survey to evaluate rutting, cracking and raveling. During the survey, three 150 mm cores were also obtained from each section and used to determine the laboratory permeability.

Key Findings from Laboratory Study

1) A gradation with no more than 20 percent passing the 4.75 mm sieve is required to achieve stone-on-stone contact condition and provide adequate permeability in OGFC mixes.
2) Gradations with 15 percent passing the 4.75 mm sieve are susceptible to significant binder draindown, so a suitable stabilizer such as fiber is needed in the mix to prevent excessive draindown.

3) Abrasion loss of OGFC mixes resulting from aging was reduced by adding either polymer-modified binder or fiber to the mixes.
4) Although the rutting potential of the OGFC mixes, as measured with the Asphalt Pavement Analyzer (APA), was not greatly influenced by the binders in this study, mixes with modified binders did significantly improve rutting resistance compared to mixes with unmodified binders. A higher PG binder grade seemed to have a great impact on reducing rutting, and polymer-modified asphalt with fiber experienced the least rutting.
5) Moisture susceptibility, as measured by tensile strength ratio (TSR) values, was lower for mixes with modified binders than mixes with unmodified binders. Each modifier, except slag wool (with PG 64-22), produced mixes with TSR values exceeding 80 percent.

Key Findings from Field Study

1) All six test sections had experienced some coarse aggregate pop-outs six years after construction. Another surface-texture issue was the appearance of small fat spots on the surface of each section. However, none were larger than approximately six inches in diameter.
2) None of the sections showed significant rutting.
3) The primary form of cracking on all six sections was reflective from a Portland Cement Concrete pavement underlying each section. Five of the six sections had low- to medium-severity reflective cracking. Mixes containing only fibers experienced the least cracking, and the D16R section had the highest amount and severity of cracking.
4) All six sections showed some signs of raveling. However, all raveling was minimal except in the D16R section, which showed medium-severity raveling next to some cracks.
5) Statistically, no significant differences existed between the permeability values of the extracted cores from each section. However, the DC and DCP sections did have the highest average permeability at 74 and 70 m/day, respectively. In-place air void contents ranged from 15 to 19 percent.
6) It appears that the mix design procedure GDOT used in this experiment resulted in OGFC mixes with stone-on-stone contact, even though it was not specifically tested.

Conclusions and Recommendations

Overall, this study showed that a coarser gradation of OGFC mixes as well as the addition of polymer or fiber modifiers enhance the performance of an OGFC pavement.

Based on this study, the following four-step mix design system is recommended for new-generation OGFC mixes. However, the system can be refined as more experience is gained in OGFC mix design.

1) **Materials selection**: Guidance on suitable aggregates for OGFC mixes can be taken from recommendations for stone-matrix asphalt (SMA). The binder selection should be based on factors such as environment, traffic and expected functional performance of OGFC. High-stiffness binders, such as PG 76-22, made with polymers are recommended for hot or cold climates with freeze-thaw cycles, medium to high traffic conditions and for mixes with high air void contents (in excess of 22 percent). Adding fiber is also desirable under such conditions and has been shown to reduce draindown. For lower-traffic conditions, either polymer-modified binders or fibers may be sufficient.
2) **Selection of design gradation**: The following master gradation band is recommended.

Sieve	Percent Passing
19 mm	100
12.5 mm	85-100
9.5 mm	55-75
4.75 mm	10-25
2.36 mm	5-10
0.075 mm	2-4

3) **Determine optimum asphalt content**: Prepare OGFC mixes at three binder contents in increments of 0.5 percent. Conduct a draindown test, Cantabro abrasion test on aged and unaged samples, a laboratory permeability test and, if possible, a rutting test with the APA. Compact mix using 50 gyrations of a Superpave gyratory compactor and determine air void contents. The optimum asphalt content meets the following criteria: 1) a minimum of 18 percent air voids (higher values desired), 2) abrasion loss on unaged specimens not exceeding 20 percent, 3) abrasion loss on aged specimens not exceeding 30 percent and 4) a maximum draindown of 0.3 percent by total mixture mass. If none of the binder contents meet all criteria, remedial action is necessary.
4) **Evalulate mix for moisture susceptibility:** The mix designed with steps 1 through 3 should be evaluated for moisture susceptibility using AASHTO T283 with five freeze/thaw cycles. The retained tensile strength should be at least 80 percent.

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