LOUISIANA TRANSPORTATION RESEARCH CENTER

Technical Summary

LTRC Report 687

SIO No. DOTLT1000386
LTRC Project No. 21-6B

A New Generation of Porous Asphalt Pavement: OGFC Support Study

Introduction

Open-Graded Friction Course (OGFC) has been used as a surface course mix in Europe and the U.S. for decades, as it provides unique safety and environmental benefits. OGFC typically contains a high percentage of air voids (AV), between 18 and 24%, compared to 2.5 and 4.5% for conventional hot-mix asphalt (HMA). Due to its large AV content, water will not only drain over the OGFC surface but also through its pores; therefore, the possibility of hydroplaning decreases, and the skid resistance improves during wet weather conditions. For this reason, many researchers and practitioners have championed OGFC to address splash, spray, visibility, and noise issues. Despite these benefits, the use of OGFC as a wearing surface course has faced several challenges, mostly due to its inferior durability compared to dense-graded HMA. Raveling is the most serious challenge with OGFC; once this distress manifests, OGFC deteriorates rapidly, and its replacement is inevitable after only a few years.

Objective

The objective of this study was twofold. First, it aimed at designing and evaluating a new generation of Open-Graded Friction Course (OGFC) that would provide superior durability while preserving the functional benefits of the mix. This study also evaluated different additives and industrial byproducts such as warm-mix asphalt (WMA), crumb rubber (CR) from recycled tires, and different pozzolanic fillers (i.e., Portland cement and fly ash, a byproduct from coal-fired electric and steam-generating plants).

Second, this research evaluated the seepage characteristics of a pavement structure constructed with an OGFC surface layer. This evaluation considered the effects of traffic wear and the reduction in permeability on the long-term hydraulic performance of a pavement structure constructed with an OGFC surface layer. Additionally, the effects of OGFC thickness, the coefficient of permeability of OGFC, and the permeability of the underlying pavements on the seepage behavior of the pavement structure were evaluated under various rainfall intensities using finite element (FE) analysis.

Scope

To fulfill the laboratory objective of the study, different additives were evaluated by modifying an approved and practically used OGFC mix (i.e., control mix). These modifications included three WMA additives, one recycled product (crumb rubber), and two different pozzolanic fillers (Portland cement and fly ash). Additionally, a mix with a reduced nominal maximum aggregate size (NMAS) of 9.5 mm was considered. The newly developed mixes were then evaluated in the laboratory to determine the effects of these modifications on their performance at three different stages: production, construction, and field performance.

To achieve the second objective, an FE model was developed to investigate the effects of OGFC thickness, coefficient permeability, and traffic wear on the seepage characteristics of a pavement structure constructed with an OGFC layer under different climatic conditions. These results were analyzed statistically to determine the most significant factors that affect the drainage performance of the pavement structure. Following this analysis, the most significant

Principal Investigator
Mostafa A. Elseifi, Ph.D., P.E. (VA)

LTRC Contact
Moses Akentuna, Ph.D., P.E.
225-767-9151

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

Read final report online:
www.ltrc.lsu.edu/publications.html

design factors were used to develop an artificial neural network (ANN) model to predict the time needed to reach overflow conditions under heavy rain, without the need for FE modeling. Finally, the developed FE model was used to propose new AV guidelines for OGFC applications in Louisiana.

Methodology

To achieve the study objectives, the research activities were divided into six tasks. The laboratory test factorial was designed to investigate the performance of OGFC mixes at three different stages: production, construction, and in-service performance. For the production stage, the draindown test was used to evaluate the impacts of different additives by measuring the amount of asphalt binder that drains out of a loose OGFC mix. In the construction stage, the Compaction Energy Index (CEI) was used to compare the required compaction effort during construction. In terms of in-service field performance, the Cantabro test, Hamburg Wheel-Tracking Test (HWTT), Indirect Tensile Stress (ITS) test, Texas Overlay Test, Tensile Strength Ratio (TSR), and boil test were used to evaluate the mix's resistance to raveling, permanent deformation, fatigue cracking, reflective cracking, and moisture damage, respectively. A cost-effectiveness analysis was also conducted to provide a quantitative assessment of the benefits gained from the evaluated additives in OGFC.

To evaluate the seepage characteristics of OGFC, a theoretical analysis was conducted using a field-validated FE model. The FE model allowed the researchers to evaluate the effects of traffic wear and the reduction in permeability on the long-term hydraulic performance of a pavement structure constructed with an OGFC surface layer. Different factors were varied in the FE analysis: the OGFC layer thickness, OGFC coefficient of permeability, underlying layer coefficient of permeability, rain intensity, and traffic volume. For the different conditions, FE results were used to calculate the time at which water overflow occurs. The results of the FE model were statistically analyzed to investigate the factors that significantly affect the time to reach overflow conditions. The results of the FE model were then used to train and validate an ANN model for the prediction of seepage behaviors, without the need for FE modeling. Additionally, the results of the developed FE model were used to propose new AV guidelines for OGFC applications in Louisiana.

Discussion of Results

Results of the laboratory program indicated that WMA additives, 9.5-mm NMAS, and crumb rubber (CR) reduced the total air void content of the OGFC mix, which in turn reduced the coefficient of permeability. Nevertheless, all the mixes satisfied the requirements of both the AV content and the coefficient of permeability set forth by NCHRP 1-51. Performance testing showed that Che1, Che2, CR, Portland cement, fly ash, and 9.5-mm NMAS enhanced the raveling resistance of OGFC compared to the control mix (CM) in the Cantabro abrasion loss test conducted on unaged samples. In terms of permanent deformation, all the mixes satisfied the maximum allowable requirement for 5,000 passes, including the control mix. At 20,000 passes, the mixes that contained organic WMA, CR (without Che1), Portland cement, fly ash, and 9.5-mm NMAS satisfied the permanent deformation requirement set forth by NCHRP 1-51. Based on the results of the Cantabro test and rut depth at 5,000 passes, the most cost-effective OGFC mixes were 9.5-mm NMAS, OGFC with fly ash, WMA OGFC with Che2, and Org-OGFC, in this order. On the other hand, considering the results of the Cantabro test and rutting performance at 20,000 passes, the most cost-effective OGFC mixes were OGFC with fly ash, 9.5-mm NMAS, Org-OGFC, and OGFC with Portland cement, in this order.

Results of the FE model indicated that, as the thickness of OGFC, the permeability coefficient of OGFC, and the permeability coefficient of the underlying layer increased, the time at which the pavement structure reached the overflow condition also increased. Results of a parametric study indicated that for a 30-min. rainstorm of 0.04 in./hr., an OGFC layer with an AV content of 14% would drain all rainwater without reaching overflow conditions, even after significant traffic wear. For a 60-min. rainstorm of 0.04 in./hr., an OGFC layer with an AV content of 16% would drain all rainwater without reaching overflow conditions, even after considerable traffic wear.

Conclusions & Recommendations

Based on this project's findings, revision of the Louisiana specifications is recommended to address durability issues with OGFC mixes. The results of the study demonstrated that high AV content has a negative effect on OGFC durability. In Louisiana, OGFC mixes are required to have an AV content between 18 and 24%, which is higher than the AV content recommended by other states. Based on the results of this study, it is recommended that the lower limit of AV requirements for OGFC mixes be decreased from 18 to 16%. The high limit of AV requirements should also be decreased from 24 to 20% to enhance the durability of the mix. Additionally, the specifications should be modified to incorporate and permit the use of OGFC mixes with 9.5-mm NMAS. The use of WMA additives in OGFC mixes is also recommended for enhanced durability. The replacement of the fillers with Portland cement and fly ash in OGFC mixes is also recommended for enhanced performance and durability.