Construction and Building Materials 189 (2018) 131–143

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Evaluation of the benefits of open graded friction course: Case study

Fan Gu *, Donald Watson, Jason Moore, Nam Tran

National Center for Asphalt Technology, Auburn University, 277 Technology Parkway, Auburn, AL 36830, United States

HIGHLIGHTS

- Lab tests are performed to assess durability, rutting and moisture damage of OGFC.
- Field tests are conducted to evaluate permeability, friction and noise of OGFC.
- OGFC is cost-effective in rural highways but impractical in urban or town areas.

ARTICLE INFO

Article history:
Received 25 April 2018
Received in revised form 10 August 2018
Accepted 28 August 2018

Keywords:
Open graded friction course
Dense graded hot mix asphalt
Laboratory evaluation
Field evaluation
Cost-benefit analysis

ABSTRACT

This study evaluated the benefits of Open Graded Friction Course (OGFC) via two field projects constructed by the Nevada Department of Transportation: one project was in Elko, and the other was in Las Vegas. Each project included both the OGFC and Dense-Graded Hot Mix Asphalt (DGHMA) sections. The Elko project was located in the town area of Elko while the Las Vegas project was constructed in a rural area on I-15 interstate highway. Laboratory tests were performed to evaluate the durability, rutting, and moisture-susceptibility of OGFC mixtures. The selected test methods included the Cantabro test, Tensile Strength Ratio test, and Hamburg Wheel-Track test (HWTT). The laboratory test results showed that the Las Vegas OGFC mixture passed all the performance criteria, but the Elko Mixture failed to satisfy the HWTT criterion.

The field performance tests were conducted to assess the permeability, friction, and noise functionality over time. The selected test methods included the NCAT falling head permeameter test, locked-wheel skid trailer test, and On-Board Sound Intensity test. The field performance results demonstrated that the Las Vegas OGFC pavement exhibited benefits in permeability, friction, and noise reduction compared to the DGHMA pavement, while the Elko OGFC pavement showed comparable performance with the DGHMA pavement after 2-years of service. Finally, a cost-benefit analysis was conducted to monetize the advantages and disadvantages of OGFC pavements. As demonstrated in the economic analysis, the OGFC pavement in Las Vegas reduced the net present value of OGFC costs by 36%, while the OGFC pavement in Elko increased the net present value of costs by 86%. This indicates that the implementation of OGFC is cost-effective in rural highways but impractical in urban or town areas. High speed traffic is generally needed to help keep the interconnected voids of an OGFC pavement from becoming clogged over time. As a result of the reduced speed on the Elko project, the permeability functionality was lost after one year and the noise reduction benefit was lost after thirty two months.

1. Introduction

Open graded friction course (OGFC) is a gap-graded asphalt mixture that contains a high percentage of air voids (i.e., usually 15–22%) [1]. It is also known as Permeable European Mix (PEM), Porous Friction Course (PFC), and Porous Asphalt (PA) that has been widely used in Europe (e.g., The Netherlands, France, and Germany), Asia (e.g., China, Japan, and Korea), and the United States for decades [2]. OGFCs are usually paved as the final riding surface on roadways because of the safety and environmental benefits associated with this mixture. Despite the benefits, the use of OGFC has diminished over the years due to durability and service life issues [3–5]. The durability problems are generally evidenced by raveling, and once the distress begins, it progresses rapidly [6,7]. A 1998 survey conducted by the National Center for Asphalt Technology (NCAT) showed that 22 states had discontinued use of OGFC [8]. A 2015 survey conducted by NCAT showed that only half of 41 responding agencies (40 states and Puerto Rico) were using

* Corresponding author.
E-mail addresses: fzg0014@auburn.edu (F. Gu), watsode@auburn.edu (D. Watson), moore02@auburn.edu (J. Moore), nht0002@auburn.edu (N. Tran).

https://doi.org/10.1016/j.conbuildmat.2018.08.185
0950-0618/

OGFC mixtures. Fig. 1 depicts the results of the 2015 survey regarding OGFC usage. The survey revealed that agencies that did not use OGFC were concerned that OGFC may not be a cost-effective application. The following paragraphs focused on summarizing the benefits and disbenefits of OGFC mixtures.

The safety and environmental benefits of OGFC mix have been documented in many studies. In regard to safety, one of the obvious abilities of OGFC mixtures is to channel water through the pavement structure. The reduction in water standing or flowing across the pavement surface during wet weather is a significant improvement over the performance of dense graded hot mix asphalt (DGHMA) layers [9–11]. Thereby, the use of OGFC mixture as a surface layer is effective in improving the friction resistance of pavement in wet weather, reducing splash and spray from surrounding vehicles, reducing glare from on-coming headlights during rainy conditions, and enhancing the visibility of pavement markings. Because of these safety benefits, the OGFC treatment has been shown to lower wet weather vehicle crashes or accident rates and reduce the economic costs of accidents. Shimeno and Tanaka [12] conducted a traffic study in Japan and they found that the OGFC significantly reduced the fatality rate in rainy weather by 4.6% when compared to standard DGHMA. Hernandez-Saenz et al. [13] asserted that these safety-related benefits were the main reason for using OGFC mixtures in the United States. However, some studies challenged that the safety effectiveness of OGFC was limited and inconclusive [14,15]. They claimed that the road user usually drives faster on OGFC surfaced pavements, which might result in a higher accident rate as compared to the conventional pavements. Thus, there is an urgent need to thoroughly review these studies in order to evaluate the safety effectiveness of OGFC pavements.

In terms of environmental benefits, OGFC is effective in reducing the tire/pavement noise and improving the water runoff quality. The majority of highway noise comes from the pavement-tire interaction, especially when the traffic speed is above 72 km/hour. The noise can become an annoyance to human beings, which leads to negative impacts on the quality of life. It can also have an economic impact on real estate by keeping properties from being developed or sold [16]. Because of its high interconnected air void content, the OGFC mixture acts as a resonant cavity structure that efficiently absorbs sound energy generated from the tire-pavement interface. The existing studies indicate that the use of OGFC reduces the tire/pavement noise by 3–6 dBA, which is equivalent to diminishing the traffic volume by 50% or comparable to the construction of a noise barrier wall [17]. Due to its considerable noise reduction, OGFC has been used as a strategic means of meeting environmental noise regulations in Europe.

In addition, a few studies also pointed out the water runoff generated from OGFC surface was of better quality than that from conventional DGHMA surfaces [18,19]. It was found that water runoff from OGFC layers had a significant lower concentration of total suspended solids, total metals, and phosphorus. This benefit of OGFC was attributed to the reduction of splash and spray that reduced the amount of pollutants derived from the bottoms of vehicles, and a large amount of pores in the surface layer that were able to retain these pollutants.

Although these safety and environmental benefits are attractive, the use of OGFCs is also associated with several shortcomings. One great shortcoming is its high material cost. The material cost of OGFC is usually 20–40% higher than that of conventional mixes used in highway construction [13,20].

Winter maintenance is another serious problem for OGFC pavement. Compared to the conventional pavement, OGFC pavement has earlier and more frequent frost and ice formation due to its low thermal conductivity caused by a porous void structure [21]. To maintain a desirable ride quality in winter, OGFC pavement requires more deicing agents and more frequent maintenance activities, which means OGFC pavement has higher maintenance costs than the conventional pavement.

In addition, OGFC mixture is often associated with poor long-term performance or durability. The OGFC mixture normally has a higher potential for raveling when compared to conventional mix due to additional oxidation from channeling water through the pavement layer. This results in a shorter service life for OGFC pavements (e.g., typically 7–10 years for OGFCs and 12–15 years for conventional mix) [20,22,23]. Apparently, the durability and service life issues diminish the use of OGFC treatment in asphalt pavements.

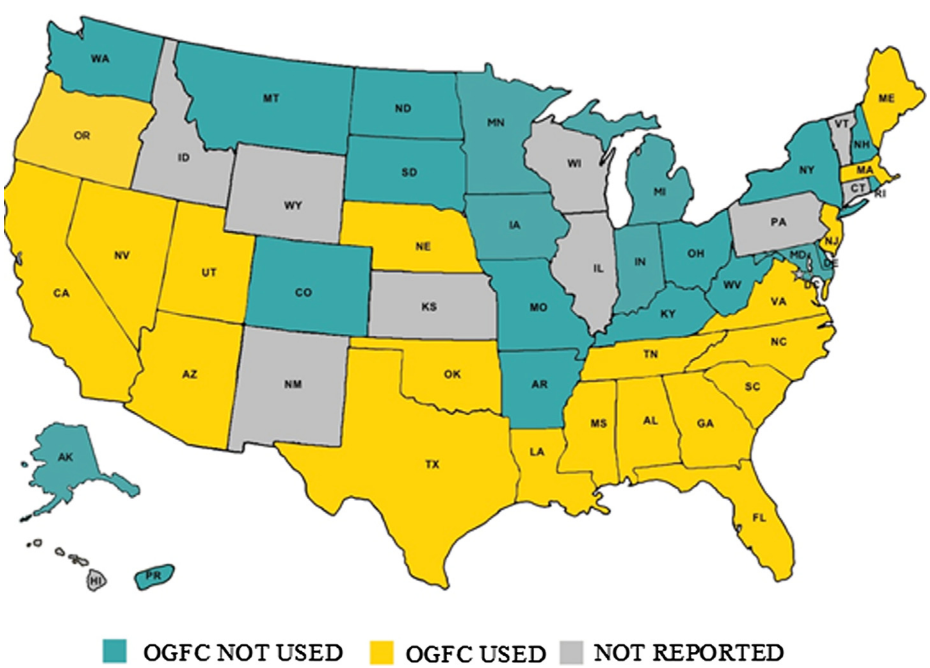

Fig. 1. Use of OGFC mixtures by state highway agencies in 2015.