Construction and Building Materials 101 (2015) 527–535

Contents lists available at ScienceDirect

Construction and Building Materials

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

Factors affecting shear strength between open-graded friction course and underlying layer

Weimin Song [a], Xiang Shu [a,*], Baoshan Huang [a], Mark Woods [b]

[a] Department of Civil and Environmental Engineering, The University of Tennessee, Knoxville, TN 37996, United States
[b] Materials and Tests Division, Tennessee Department of Transportation, Nashville, TN 37243, United States

HIGHLIGHTS

- Shear strength of open-graded friction course and underlying layer was tested.
- Three factors affecting the shear strength were considered.
- Surface texture depth was measured and correlated to shear strength.
- Statistical analysis was performed to compare the factors.

ARTICLE INFO

Article history:
Received 18 April 2015
Received in revised form 11 August 2015
Accepted 12 October 2015

Keywords:
Open graded friction course
Shear strength
Tack coat
Temperature
Friction
Surface texture depth
Underlying layer

ABSTRACT

This study investigates the factors that affect the bonding strength between open-graded friction course (OGFC) and underlying layer through laboratory testing. The direct shear strength test was performed to obtain the shear strength between OGFC and different underlying layers. Three factors were considered in the study: mixture type of underlying layer, tack coat application rate, and temperature. Two types of dense graded surface mixture and one type of stone matrix asphalt (SMA) were selected as underlying layer. The shear strength was evaluated at four tack coat application rates and three test temperatures. To investigate the friction between OGFC and underlying layer on the shear strength, the surface texture depth of underlying layer was also measured. Results from the study showed that underlying layer mixture type, tack coat application rate, and temperature all played a significant role in the shear strength, with temperature as the most significant factor followed by surface texture depth of underlying layer. At low temperatures, high stiffness of asphalt made both tack coat rate and surface texture depth of underlying less significant. At intermediate to high temperatures, surface texture depth of underlying layer had a significant effect on the shear strength, indicating that selection of appropriate underlying layer with adequate friction with OGFC is critical for a good bonding shear strength. Surface texture depth of underlying layer can be used as an indicator of the friction between OGFC and underlying layer.

Published by Elsevier Ltd.

1. Introduction

Open graded friction course (OGFC) is a thin permeable asphalt layer placed on the top of traditional dense graded asphalt pavement. OGFC mixtures designed for the requirement of stone-on-stone contact and high connected air void content are a special type of asphalt mixture characterized by the use of high quality open-graded aggregate [1–5]. The stone-on-stone structure of coarse aggregate provides a good resistance to permanent deformation, and the high air voids provide good functional properties, such as drainability and noise reduction [1–4].

Since its creation from experimentation with plant seal mixes (PSMs) in 1944 in California [1], there has been great development in OGFC all over the world. Different terminologies have been used by different agencies around the world (Table 1). In the United States, since its first use in California, the use and performance OGFC has been highly variable [2]. In 1998, the National Center of Asphalt Technology (NCAT) conducted a survey on OGFC practice in the United States and the results were shown in Fig. 1. Thirty-eight percent of the states used OGFC while the same number of states had stopped its use because of unfavorable experience [3]. By including the assessment of both functionality and durability, a new generation OGFC mix design method was developed by NCAT in 2000 [4]. Since then use of OGFC has been expanded. A later survey showed that 61% of the states used OGFC (Fig. 2) [2].

* Corresponding author.
E-mail address: xshu@utk.edu (X. Shu).

http://dx.doi.org/10.1016/j.conbuildmat.2015.10.036
0950-0618/Published by Elsevier Ltd.

Table 1
Use of OGFC in different countries [6].

Country	Agency	Terminology	Binder type/grade	References
United States of America	American Society of Testing and Materials (ASTM)	Open-graded friction course (OGFC)	Performance grade (PG) asphalt cement	[5]
	Federal Aviation Administration (FAA)	Porous friction course (PFC)	Viscosity grade asphalt cement (AC-20)	[7]
Australia	Australian Asphalt Pavement Association (AAPA)	Open-graded asphalt (OGA)	Viscosity graded asphalt cement (C 320), and polymers modified bitumen (PMB)	[8]
New Zealand	Transit New Zealand (TNZ)	Porous asphalt (PA)	Penetration grade 80–100 and 60–70	[9]
South Africa	Southern African Bitumen Association (Sabita)	Porous asphalt (PA)	Penetration grade of 80–100, and polymer modified bitumen (PMB)	[10]
Japan	Japan Highway Public Corporation (JHPC)	Porous asphalt (PA)	High-viscosity improved asphalt (HVIA)	[11]

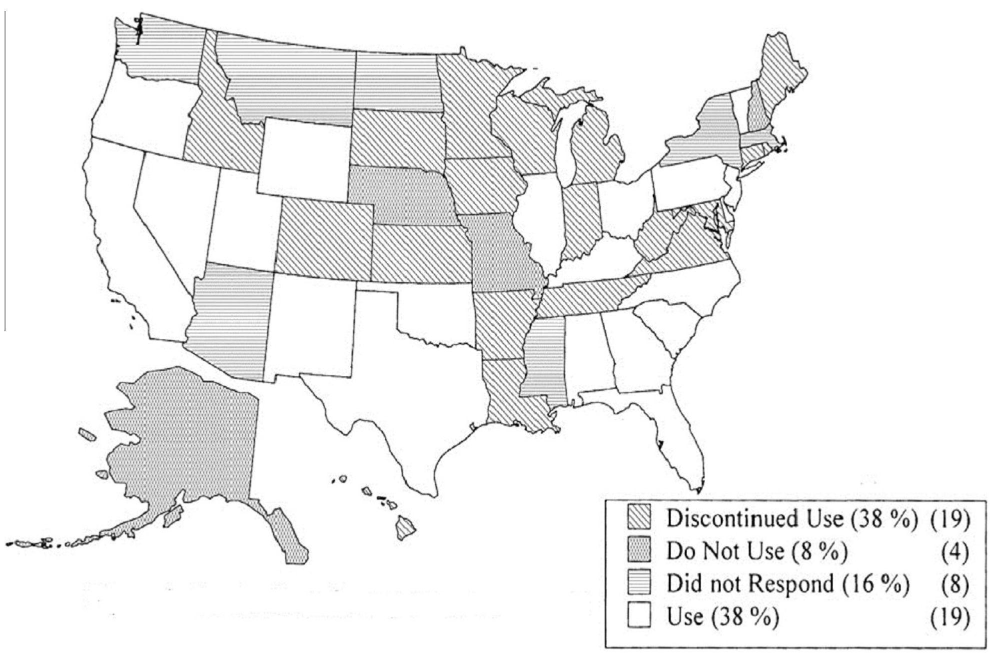

Fig. 1. Results from 1998 survey on use of OGFC in US [3].

With the increased application of OGFC, many studies have been conducted to evaluate its performance [4,6]. One of the major factors that affect the performance of OGFC is the adhesion between OGFC and its underlying layer because bonding properties between pavement layers are vital to ensure all layers behave as a monolith system, which can reduce pavement distresses and increase its service life.

Many researchers have evaluated the factors that affect the bonding properties between different asphalt pavement layers, including tack coat, mixture type, temperature, surface characteristics [12–19]. However, these studies are conducted mostly for conventional pavement layers. Little has been done on the bonding between OGFC and its underlying layer. Raposeiras et al. [12] and Mohammad et al. [13] evaluated the effect of different tack coat dosages and concluded that there exists an optimal tack coat dosage at which the shear strength reaches the maximum value. However, Collop et al. [14] found that better results can be obtained even without tack coat application and Gong [15] obtained similar findings. Mohammad et al. [13] and West et al. [16] concluded that tack coat type is one of the factors that influence the bonding properties of pavement layers and different types of tack coat result in different bonding properties. Some researchers also took into account breaking time of tack coat in their studies of bonding properties of pavement layers [17–19].

Asphalt mixture type plays an important role in the bonding strength between pavement layers [12,16,19,20]. West et al. [16] evaluated the bonding properties of fine- and coarse-graded mixtures and found that the shear strength of fine-graded mixture with a 4.75-mm nominal maximum aggregate size (NMAS) is larger than that of coarse-graded mixture with a 19-mm NMAS. Chen et al. [19] tested the bonding strength of the specimens combined by dense-graded asphalt concrete (DGAC), stone matrix asphalt (SMA), and porous asphalt concrete (PAC). Their results showed that DGAC-DGAC (upper layer-lower layer) system generally exhibits the best bonding performance, followed by PAC-DGAC and PAC-SMA. They attributed the different performance to the difference in the adhesion of different systems. Raposeiras et al. [12] investigated the influence of surface macro-texture of asphalt mixtures on the adhesion between pavement layers and found that a rough texture of 0.17 mm gives the maximum shear strength in their study. Raab et al. [20] evaluated the interlock of aggregates between pavement layers by using steel balls with different