

Long-term rutting and stripping characteristics of foamed warm-mix asphalt (WMA) through laboratory and field investigation

Biswajit K. Bairgi^{a,*}, Rafiqul A. Tarefder^a, Mesbah U. Ahmed^b

^a Department of Civil Engineering, University of New Mexico, MSC01 1070, 1 University of New Mexico, Albuquerque, NM 87131, United States

^b Gemini Technologies, Inc. 3153 Fire Rd, Egg Harbor Township, NJ 08234, United States

HIGHLIGHTS

- Foamed WMA exhibits higher rutting and stripping potentials in its early life.
- Densification, aging, and layer thickness contribute to rutting and stripping.
- WMA overcomes its initial higher damage potentials with field aging and densification.

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ABSTRACT

Injected water and low production temperature during foaming make foamed warm-mix asphalt (WMA) more prone to rutting and stripping. Though foamed WMA is reported to exhibit higher rutting and stripping potentials in its early life, it is not clear how these characteristics change with field experienced aging and densification. This study evaluates long-term rutting and stripping potentials of both field (five years experienced) and short-term aged laboratory compacted foamed WMA specimens. In addition, field rut data have been evaluated through Mandli's pavement profile scanner. It is noted that field WMA pavements were surfaced with 15 mm of rubberized open-graded friction courses (ROGFC). Laboratory tests: Hamburg-wheel tracking (HWT) and indirect tensile strength (ITS), have been conducted on selected specimens. Two different moisture conditioning methods have been employed on ITS test specimens. A newly developed HWT test analysis has been performed to eliminate the existing limitations of the conventional method of HWT analysis. The study found that densification and long-term field aging contribute to improvement in rutting and stripping characteristics.

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1. Introduction

Warm mix asphalt (WMA) technologies yield numerous mechanical, environmental, economic, and operational benefits through lowering its production temperature by 10–38 °C from conventional hot mix asphalt (HMA) [1–5]. Due to these numerous potential benefits, WMA usage has been rapidly increased over the last decade. Among 30 different WMA technologies, foamed WMA accounts for about 90% of all produced WMA [6]. In foamed WMA technology, asphalt binder is mechanically foamed through water injection into hot asphalt binder at a high air pressure. Foamed asphalt binder exhibits reduced viscosity and that allows foamed WMA to be produced and compacted at significantly lower temperatures than HMA. Instead of direct water injection,

water-bearing additives such as Aspha-min, Advera etc. can also be incorporated for asphalt foaming. These additives contain approximately 21% water (by wt.) that contributes to asphalt foaming [1,3,6,7].

Rutting and stripping are two common damages associated with the flexible pavement. Rutting in asphalt pavement is associated with consolidation and lateral movement of pavement mixtures due to repeated load at high ambient temperatures. It appears as longitudinal depression along wheel path and small upheavals to the sides [8]. It provides a reduced level of serviceability and significant safety hazards as well. Several factors such as design aggregate structure, binder grade, aging, environments, etc. contribute to the rutting characteristics. Stripping is a progressive deterioration of binder-aggregate compatibility due to the action of water in an asphalt mixture. No pavement is impermeable to moisture due to existing air voids in asphalt mixtures. Though asphalt mixtures are designed at 4% air voids, it varies from mostly 6% to 8% in field condition [9,10]. These air void structures

* Corresponding author.

E-mail addresses: bkumar@unm.edu (B.K. Bairgi), tarefder@unm.edu (R.A. Tarefder), mesbah.ahmed@gemitek.com (M.U. Ahmed).

provide necessary access for moisture ingress into asphalt mixtures. The inhibited moisture causes several adverse effects such as loss of cohesion of binder, loss of adhesion between binder and aggregates, pore pressure development, and hydraulic scouring. Because of these drawbacks, various moisture damages such as stripping, bleeding, raveling, etc. occur in asphalt pavements [10–12].

Foamed WMA is being questioned about its long-term performance characteristics, particularly in terms of stripping and rutting. In foaming process, injected water forms into vaporized air bubbles, hence, long-term stripping behavior is a concern for foamed WMA. Again, lower production and compaction temperature associated with WMA technology is another concern for rutting behavior. Zhao et al. [13] found that lower production temperature of WMA increases rut susceptibility due to less aging. Recent studies found that aging is also related to stripping performance of asphalt mixtures [14,15]. Cucalon et al. [15] stated that aging improves stripping resistance in WMA. Several studies on foamed WMA performance have been reviewed [1–7,15–22]. These studies reported foamed WMA as an equivalent to conventional HMA in terms of rutting behavior. Stripping performance was found not satisfactory as rutting. It is noted that majority of these studies were conducted on testing and evaluation of short-term aged laboratory-compacted specimens. Thus, such evaluations may not reflect the long-term mechanistic properties of WMA. Because air void consolidation during initial field compaction and substantial aging might cause a significant change in its mechanistic properties. Cucalon et al. [23] conducted moisture damage study on WMA on both short-term oven-aged and long-term oven-aged specimens. They stated that foamed WMA may exhibit more stripping potential compared to HMA in early life, but it can be equivalent to HMA after one or more summer aging in the field under real-time traffic loading. Thus, a mechanistic evaluation is required to find the effect of real-time traffic loading and aging on WMA performance characteristics.

Use of open-graded friction courses (OGFC) over dense-graded asphalt mixtures have become a common practice in last few decades. Major purposes of using OGFC are faster drainage, improved surface friction, reduced traffic noise, less splash from traffic, and improved driver visibility [24–25]. While most of states department of transportation (DOTs) are using OGFC layers, some of the DOTs have stopped using OGFC due to its poor performance [26]. A survey conducted by the national center for asphalt technology (NCAT) reported that half of the surveyed agencies experienced a good performance of OGFC [27]. Most of the OGFC evaluation studies have been conducted on mix design, construction practice, and maintenance [28–33]. OGFC is being also placed over WMA pavements in recent years. However, there is a lack of research on OGFC performance characteristics over WMA pavements. Additional research is required to investigate long-term performance characteristics of OGFC surfaced WMA pavements.

This study focuses on an in-depth evaluation of rutting and stripping performance of foamed WMA that experienced five years

in the field. Field cores of foamed WMA have been collected from a five years old pavement. The WMA pavement contained dense-graded foamed WMA surfaced with 15-mm of rubberized open-graded friction courses (ROGFC). The field cores have been evaluated through Hamburg wheel tracking (HWT) and indirect tensile strength (ITS) tests. Loose foamed WMA were also collected during construction of the pavement for laboratory evaluation in short-term aged condition. A recently developed HWT test analysis method has been implemented for a comprehensive analysis of rutting and stripping characteristics.

2. Objectives

This study aims to evaluate long-term rutting and stripping potentials of foamed WMA surfaced with ROGFC. To accomplish the study goal, specific tasks are: (i) evaluation of five years field experienced WMA cores through HWT and ITS (with two moisture conditioning) tests analysis; (ii) evaluation of short-term aged representative foamed WMA and differentiation with five years of field experienced cores; and (iii) validation of laboratory findings with field evaluated distress.

3. Research outline and test methods

Several field WMA cores have been collected from two sections of Interstate (I-25) freeway in the state of New Mexico in March 2017 (Fig. 1a). These pavement sections were constructed in September 2012. Loose mixtures were also collected during pavement construction for laboratory performance evaluation. A 15-mm layer of ROGFC was overlaid about three months later of foamed WMA placement. Thus, collected cores contained 15 mm ROGFC as shown in Fig. 1b and 1c. This study named field cores as plant-mix and field-compacted (PMFC) specimens and short-term aged laboratory specimen as plant-mixed and laboratory-compacted (PMLC) specimens. Air voids of all specimens were evaluated in laboratory based on bulk specific gravity (G_{mb}) and theoretical maximum specific gravity (G_{mm}). The specimens have been experimented through HWT and ITS tests. ITS test specimens were conditioned with wet conditioning as per AASHTO T 283 [34] and moisture induced sensitivity tester (MIST) conditioning method (Fig. 2). Field rutting has been measured through Mandli's Pavement Profile Scanner (PPS) system. Mandli's PPS is a laser-based pavement distress evaluation technology that collects phase measurements data from a vehicle traveling at highway speed [35].

3.1. Study materials

Two different foamed WMA have been used in this study. Both mixtures were water injected foamed WMA produced by Astec Green foaming process. The Astec Green system uses a multi-nozzle device to microscopically foam the asphalt binder with typically, 2% water content (approximately 1 lb water per ton of mix)

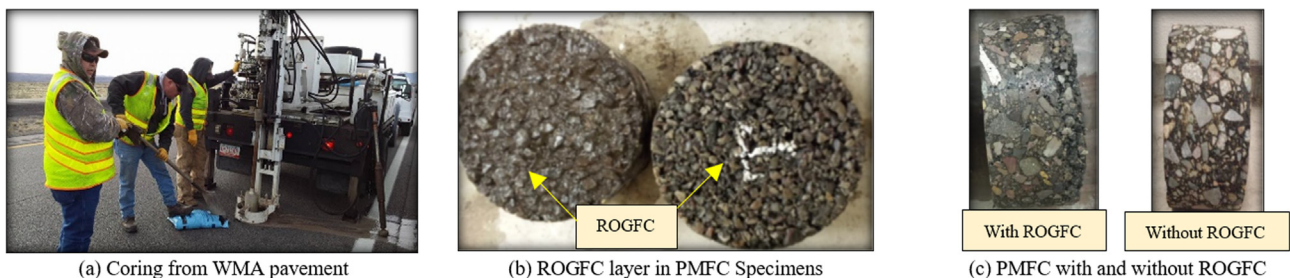


Fig. 1. HWT sample preparation from field cores.

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