Construction and Building Materials 158 (2018) 481–489

Contents lists available at ScienceDirect

Construction and Building Materials

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

Comparing layer types for the use of PavementME for asphalt emulsion Full Depth Reclamation design

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HIGHLIGHTS

- Asphalt emulsion FDR is a composite material created by recycling asphalt pavements.
- FDR mixtures were evaluated as asphalt concrete and unbound granular material.
- Dynamic modulus may be more useful for design of FDR than resilient modulus.
- Considering FDR as different materials significantly affects distress predictions.
- FDR as asphalt concrete seemed to more accurately account for structural benefits.

ARTICLE INFO

Article history:
Received 30 January 2017
Received in revised form 10 October 2017
Accepted 10 October 2017

Keywords:
Full Depth Reclamation
Asphalt emulsion
Rehabilitation
Pavement
Structural design
PavementME
MEPDG

ABSTRACT

While Full Depth Reclamation (FDR) has many potential cost and environmental benefits, it is necessary to ensure that the pavement with recycled materials will perform adequately. One way this can be accomplished is understanding how to best complete the structural design of FDR pavements. Because FDR is a composite material, it does not fit neatly into any of the existing material characterization models considered by the AASHTOWare Pavement ME design (PavementME) software. Until a new layer type is developed that considers the unique properties of these recycled, stabilized base courses, it is essential to understand how to use existing structural design tools to model FDR in a way that accurately captures its structural benefits. In this research, three different FDR mixtures were tested to obtain all necessary material properties required as inputs for PavementMe to consider this material as both asphalt concrete (AC) and unbound granular material (UGM). Using traffic information from the two Arkansas highways climate data, two different MEPDG models were created for each mixture, one characterizing the FDR layer as AC and the other as UGM. A stronger correlation was found to exist between temperature and modulus, rather than stress state and modulus. All distress predictions by PavementME were higher for the FDR as UGM except AC rutting for one mixture and bottom-up fatigue cracking. Overall, considering FDR as AC seemed to more accurately account for the structural benefits of FDR.

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1. Introduction

As America's infrastructure ages and is faced with an increasing population and heavier traffic demands, the condition of the country's roadways are deteriorating. Unfortunately, the funds available are insufficient to return these pavements to the desired level of performance [1]. Therefore, there is a need for an increased understanding of maintenance and rehabilitation techniques that can restore the long-term condition of a pavement in a cost-effective and environmentally friendly manner. One such technique that holds promise of providing this type of solution is Full Depth Reclamation (FDR).

1.1. Full Depth Reclamation

FDR is a pavement rehabilitation technique in which all of the asphalt pavement section, as well as a predetermined amount of underlying base material, are treated, pulverized, mixed and compacted to produce a thicker, stabilized base course [2]. FDR is typically performed to a depth of 100–300 mm. There are several major advantages to this technique. It completely eliminates and corrects pavement distresses extending below the surface layer, unlike many other maintenance techniques, and can actually increase the structural capacity of the pavement [3]. Additionally,

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https://doi.org/10.1016/j.conbuildmat.2017.10.054
0950-0618/Published by Elsevier Ltd.

the use of in-situ material can result in about 30–50 percent cost savings and cut down on greenhouse gas emissions by about 50 percent as well. Along with cost and emission savings, in-place recycling procedures, such as FDR, can be constructed in less time than a full reconstruction project [4].

Unfortunately, there are some hindrances to the implementation of FDR as well. Because the entire pavement section is incorporated, a single layer of subgrade soil, base aggregate, and asphalt concrete material is created. FDR falls somewhere in between a fully bound asphalt concrete layer and an unbound granular material because, while it is treated with some type of stabilizing additive, it is not quite as stiff as asphalt concrete, but stiffer than unstabilized material. This composite layer is much more difficult to characterize because distinctly different material properties are typically used for performance prediction and design of each of these types of materials. Therefore, there is uncertainty regarding which laboratory tests and procedures are most necessary and most appropriate for this new, recycled base layer created through the FDR process. An immediate problem with these questions is the issue of the structural design of these recycled and rehabilitated pavements.

1.2. Structural design

The structural design of pavements involves determining the thickness of the layer or layers that make up the pavement structure. The method historically used for design in the United States is an empirical method developed by the American Association of State Highway and Transportation Officials (AASHTO). This design guide, known as the AASHTO Design Guide, was developed based upon a series of road tests conducted in the late 1950's in Ottawa, Illinois. Structural layer coefficients (SLC) have been developed for different materials within a pavement layer. The SLC specific to the materials used are used to determine the thickness required for each layer to achieve a structural number, which can calculate the thickness.

This guide has gone through several iterations since its initial publication, but there are significant limitations to this method of design based primarily on observed performance of a small scope of materials, climate conditions, construction practices, and traffic applications [5]. One instance of these limitations is the lack of consideration of recycled base materials, like FDR. From literature, there is a large variation in SLC's used and accepted for FDR materials, ranging from 0.25 to 0.41 [6–9]. This variance illustrates the difficulty of selecting one standardized SLC for a composite material such as FDR, and consequently, the difficulty of designing FDR in a way that adequately captures its structural contribution to a pavement. However, at this point, using an AASHTO SLC is most frequently used for the structural design for FDR [10].

1.3. Mechanistic empirical design guide

The Mechanistic-Empirical Design Guide (MEPDG) was developed as an improvement from the previous AASHTO Design Guide. While MEPDG is the generic name for the design guide, AASHTO-Ware Pavement ME design (PavementME) is the proper, current name for the pavement design computer program, so this term will be used in this document due to its prevalent use and common understanding in the industry.

While PavementME is a considerable improvement over the AAHSTO design guide, research has indicated that PavementME does not currently consider the unique properties of the composite layer created by FDR using asphalt stabilization [9]. Thomas and May identified several limitations of the PavementME regarding the design of new and innovative asphalt bound mixtures like FDR, including the need for more flexibility in data entry for low temperature cracking and fatigue cracking, along with allowance for entry of thinner wearing courses that may be used with FDR. The current practice is to treat asphalt stabilized FDR as an unbound granular base layer, specifically as in place recycled asphalt pavement (RAP), but this does not account for the strength added by stabilizing the reclaimed material. Additionally, the current default resilient modulus associated with this unbound characterization is far too low [11]. PavementME does provide the option of a stabilized base course, however, the stabilization methods are only those used in chemical stabilization. Therefore, FDR materials stabilized using either asphalt emulsion are not directly considered. Another study found that there is a significant impact on the performance predictions when treating FDR as either an unbound layer or as an asphalt concrete layer [12], but this research did not use both unbound and asphalt concrete tests as inputs. Rather, relationships were used to estimate the unbound material properties based on measured dynamic modulus values. In terms of rutting and fatigue cracking, treating the FDR as an asphalt concrete layer yielded accurate performance predictions. However, the question arises as to whether or not this is accurately predicting the fatigue cracking and rutting performance of FDR if considered asphalt concrete, but the unbound granular material models may underestimate the contribution of FDR. Until a new layer type is developed to fully consider the unique properties of asphalt stabilized FDR, it is necessary to understand the effects of characterizing the composite FDR layer with the existing layer types, either asphalt concrete or unbound granular materials, and how these material property inputs affect performance prediction.

1.4. Objectives

This paper addresses the following objectives:

- Using the same asphalt emulsion FDR material, perform both bound (AC) and unbound (UGM) performance tests to provide inputs into PavementME.
- Perform PavementME simulations utilizing data from the performance tests to compare the same FDR material as AC and UGM material to determine the influence of the way asphalt emulsion FDR is characterized on IRI, rutting, and cracking predictions.

2. Laboratory plan

The results of using the existing PavementME material characterization were evaluated for the design of asphalt emulsion stabilized FDR pavements by comparing the effects of considering FDR as an asphalt concrete material or as an unbound granular material. FDR incorporates both of these types of materials, creating a recycled, composite material. Within PavementME, different material properties are used to characterize asphalt concrete than those used for unbound granular materials. Both sets of properties were obtained for three different FDR mixtures stabilized with asphalt emulsion. Two different PavementME models were then created for each FDR mixture in order to evaluate the effects of characterizing asphalt emulsion stabilized FDR as an asphalt concrete material versus characterizing it as an unbound granular base.

2.1. Materials

Three different FDR mixtures were designed and tested in this research. The North Carolina Department of Transportation's (NCDOT) mix design procedure for asphalt emulsion stabilized FDR was followed in this research based upon procedures found in literature [9,13,14]. The first mixture was created using 50% Recycle B RAP and 50% Arkansas Class 7 aggregate base course