ANALISYS OF THE EVOLUTION OF PERMANENT DEFORMATION ON ASPHALT MIXTURES AND THE SSR (STRESS SWEEP RUTTING) TEST METHODOLOGY

Aline Cavalcanti Fialho Vale
Jorge Barbosa Soares
Juceline Batista dos Santos Bastos
Programa de Pós-graduação em Engenharia de Transportes
Universidade Federal do Ceará

ABSTRACT
Efforts in Brazilian control and transportation agencies driven to the prevention of permanent deformation in asphaltic pavement surface courses are mainly for test methodologies that allow ranking asphalt mixtures for application in roadways according to the designed traffic volume. For this purpose, it is used primarily the Flow Number (FN), resulting from the unconfined repeated uniaxial test. This parameter has limitations with respect to the prediction of rutting evolution. A step further is the use of test methodologies that consider the confinement of the material in the laboratory along with evolution models. The research herein aims to replicate the triaxial test in its simplified version, using adjustments at the applied stresses and at the choice of test temperatures. Moreover, it intends to analyze and verify the shift model used in data treatment, and to verify the sensitivity of the model coefficients to the input parameters in computational pavement design programs.

1. INTRODUCTION

1.1. Research problem

Rutting (permanent deformation in the wheel-path) in asphalt pavements is a common distress in Brazilian roadways. It directly affects not only the pavement structure, but users comfort and safety. When it comes to the surface layer of asphalt concrete mixtures, researchers identified that rutting occurs mainly through densification or shear flow due to repetitive traffic loads.

With the need for a more thorough investigation about rutting, new test methodologies have been proposed to extract the mechanical properties of asphalt mixtures and to evaluate how the asphalt layers perform with time. These tests procedures apply a load on the specimen that can represent traffic solicitation. It is important to mention that the selection of aggregate size and binder content are not enough to define the ideal solution to balance a good performance with the optimization of construction costs.

DNIT (*Departamento Nacional de Infraestrutura de Transportes*), the Brazilian agency responsible for inspection and control of national roadways, has been updating its specifications for pavement design. This research aims to assist on the comprehension of the phenomenon of permanent deformation on asphalt mixtures to serve as a reference for future developments of a mechanistic pavement design procedure.

1.2. Objectives

The objective of this research is to investigate the sources and to enhance tests and models for predicting the mechanical properties in HMA (Hot Mix Asphalt) related to permanent deformation. The specific objectives are as follows:

- Implement the new simplified methodology of the triaxial test proposed by Kim (2015) and Kim et al. (2017), the Sweep Stress Rutting test.
- Determine the temperatures to use for the SSR test protocol considering Brazilian HMA mixtures.
- Investigate the influence of cutting and coring the 100 mm diameter x 150 mm tall specimen from a 150 mm diameter x 180 mm tall gyratory sample.
- Investigate the sensibility of the Shift Model parameters (ε_0, N_1 and α) on the pavement design.
- Determine the interaction between the FN parameter and the results from the SSR test.
- Investigate the predictive capacity of the test methodology on laboratory scale.

2. LITERATURE REVIEW

The Uniaxial repeated load test, which provides the Flow Number (FN), is a test whose result is either a failure criterion or a maximum value of FN which it is assumed that the permissible failure will not occur for a given time of pavement service (ABNT, 2016). The Triaxial Stress Sweep (TSS), through the LVECD (Layered ViscoElastic Pavement Analysis for Critical Distresses) program, is capable of simulating the mechanical behavior of a particular mixture, and the data treatment provides a prediction of the evolution of rutting throughout pavement service for different situations of pavements conditioning. Since the development of these tests, scientists have been using different models to predict the evolution of rutting. The Francken model, proposed by Bonaquist (2012) to represent the FN parameter, has shown to be the most accurate model for the Uniaxial Repeated Load test.

Choi (2013) proposed the Triaxial Stress Sweep test (TSS), which adopted the protocols of the TRLPD and MSS tests combining both tests principles, using the shift model on the LVECD program. In order to perform the TSS test, the specimen must be confined inside the equipment, covered by a membrane with the application of a confinement stress of 69 kPa and application of a deviatoric pulse of 483, 689 and 896 kPa for every 200 cycles, with resting frequency and load application.

Kim (2015) and Kim *et al*. (2017) proposed a simplified TSS test, the SSR. For this simplified version, the time of the test procedure has drastically decreased by several factors. Among the main ones is the decrease on the amount of samples, reduced from nine to four, considering only two testing temperatures (high and low), where the reference curve is plotted from the first 200 cycles of the high temperature test. Table 1 describes the SSR test configuration comparing to the specifications on TSS. Moreover, it demonstrates the main differences between both tests methodologies.

Table 1: TSS and SSR comparison.

Test Method		**SSR**	**TSS**
Strain Measure		Machine Displacement	LVDTs
	Reference	-	1 (T_H)

Number of tests	TSS	2 (T_H and T_L)	3 (T_H, T_I and T_L)
Total samples		4	10
Total test time (h)		2	8.3
Pulse time (s)		0.4	0.4
Rest Period (s)		3.6 (T_H) and 1.6 (T_L)	10 (T_H) and 1.6 (T_I and T_L)
Deviatoric Stress (kPa)		689, 483 and 896 (T_H) 483, 689 and 896 (T_L)	483, 689 and 896
Number of cycles		200	

Source: adapted from Kim (2015).

In Brazil, Bastos *et al.* (2016) were able to adjust the confining stress to Brazilian HMA conditions for the TSS procedure, since most pavements in Brazil have a thin asphalt layer. The refinement allowed a better understanding of regional specifications. However, the temperatures pre-defined to test conditioning are chosen by a simple assumption and there is no specific explanation for the choice of the high testing temperature (reference temperature).

The definition of testing temperatures to the SSR test starts from the high temperature (T_H), established through an empirical equation, considering a database from LTPPBind, v. 3.1. (CHOI, 2013 and KIM, 2015).

For data treatment, Choi (2013) proposed the shift model, also used by Kim (2015) and Kim *et al.* (2017). It is a viscoplastic model to analyze permanent deformation using the superposition of the time-temperature and time-strain effects as principles, as shown in Equation 1. It is a derivate from the incremental model previously proposed by Subramanian *et al.* (2013).

$$\varepsilon_{vp} = \frac{\varepsilon_0 . Nred}{(N1 + Nred)^{\beta}} \tag{1}$$

Where:
ε0, N1 and α = model coefficients;
Nref = number of load cycles adjusted to reference load time and vertical stress.

3. MATERIALS AND METHODS

In conducting this research, besides the partnership with other Brazilian Universities through the *Rede Temática* program, the author designed two HMA mixtures using aggregates from Itatiba-CE, one of which has a small part of fly ashes. In addition, other two HMA mixtures were designed at *CT Asfalto – NE* (*Centro de Tecnologia em Asfalto – N/NE* at UFC), using local aggregates and binders from two different refineries: REFAP (Refinery from Rio Grande do Sul) and LUBNOR (Refinery from Fortaleza). In summary, this research will test fourteen different mixtures, of which, seven are connected to field monitoring and the other seven are mixtures produced in the laboratory.

The binder characterization is performed by the MSCR (Multiple Stress Creep Recovery) test, following standard AASHTO M332 (2018). The aggregate grading curve will be defined using the boundaries determined by DNIT 031 (2006). For the development of the experiments, the specimen will be fabricated to be 100 mm diameter and 150 mm tall. For at least two mixtures, the specimen will also be fabricated to be cut and cored from a 150 mm diameter and 178 mm tall gyratory-compacted specimen (KIM, 2015), so that it can be possible to identify the impact on the uniformity of the specimen and on the results for the FN and for the rutting prediction.

As the main part of the experimental plan, the samples will be subjected to the uniaxial test and to the SSR test. For the SSR test, the applied tensions are described in Table 2.

Table 2: SSR test tensions applied

		Cycles 01 through 200	Cycles 201 through 400	Cycles 401 through 600
T_H	Confining stress		138 kPa	
	Loading stress	620 kPa	414 kPa	827 kPa
T_L	Confining stress		138 kPa	
	Loading stress	414 kPa	620 kPa	827 kPa

Sources: Kim *et al.* (2017) and Bastos *et al.* (2016).

For the choice of the testing temperatures, the initial test will follow the instructions of Bastos *et al.* (2016), adopting 47°C as the high temperature (T_H) and 17°C as the low temperature (T_L).

4. FINAL CONSIDERATIONS

As final considerations, it was identified that Brazilian mixtures used in this study have their particularities, such as aggregate and binder availability and asphalt layer thickness that need to be considered, and it can be pointed that the definition of the testing temperatures needs further investigation. On preliminary tests on three mixtures, it was not possible to obtain a complete rutting prediction curve since the test protocol could not be finalized. It is expected from the present research to contribute to adapting the SSR testing protocol to regional HMA mixtures, also correlating the results from design programs and field monitoring for some of the HMA mixtures used in this research, reinforcing the use of SSR test and increasing regional database for rutting evolution on asphalt layers.

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