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# Investigation of top-down cracking performance of in-situ asphalt mixtures based on accelerated pavement testing and laboratory tests

Zexin Ma, Liping Liu, Lijun Sun *

*The Key Laboratory of Road and Traffic Engineering, Ministry of Education, Tongji University, Shanghai 201804, PR China*

## HIGHLIGHTS

- Top-down cracking appeared during the APT tests on an in-situ asphalt pavement.
- An equation was proposed to model the PSPA modulus evolution process.
- UPT and IDT tests were carried out on field cores taken from APT test sections.
- APT loading reduced the shear and the tensile resistance of asphalt mixture.
- APT loading made a more significant influence on the wearing course mixture.

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## ABSTRACT

Top-down cracking is one of the major types of distresses in asphalt pavements. Although important, the mechanism of top-down cracking is complicated and the results are sometimes controversial. This paper presented a comprehensive case study to investigate the top-down cracking performance of an in-situ asphalt pavement based on accelerated pavement testing (APT) and laboratory test. To induce top-down cracking, a series of full-scale APT tests were conducted on two field test sections from an abandoned expressway ramp located in Shanghai, China. During the APT tests, a portable seismic property analyzer (PSPA) was used to monitor the modulus reduction as a representation of the pavement deterioration. After the APT test, asphalt concrete cores were taken from the APT test sections for laboratory uniaxial penetration tests and indirect tensile tests. Based on the PSPA test results, an equation was proposed to describe the evolution of the asphalt mixture moduli with APT loading passes. According to the laboratory test results, the uniaxial shear resistance, the indirect tensile strength and the indirect tensile fatigue resistance all showed a reduction at some level for the wearing course mixture. It was believed that both the shear effect and the tensile effect contributed to the appearance of top-down cracking. In addition, it was found that there was an exponential relationship between the uniaxial shear resistance and the indirect tensile fatigue life of the wearing course mixture.



## 1. Introduction

Top-down cracking is one of the major types of distress in hot mix asphalt (HMA) pavements, which has been reported and studied in many countries [1,2]. In top-down cracking, crack initiates at the surface of an asphalt concrete pavement and propagates to the bottom of the HMA layer. Top-down cracking has been a hot topic and studied with advanced methods in recent years. Chen et al. [3] evaluated top-down cracking performance of HMA mixture based on inventive laboratory test and Shen et al. [4] established top-down cracking prediction model through a statistical based framework. However, it is still hard to reveal the mechanisms of top-down cracking.

The mechanisms of top-down cracking are complicated [1,5]. The major view for the cause of top-down cracking is tensile strain at the top of the asphalt layer. Myers et al. [6–8] performed the stress analysis using finite element method and found that near-surface stress distribution could explain initiation of longitudinal surface cracks. Kim et al. [9] utilized viscoelastic analysis to identify critical tensile strains and their time-dependent responses and found that tensile strain at the top of the asphalt layer is related to top-down cracking performance.

On the other hand, some researchers believed that shear performance of the mixture also contributed to the appearance of

* Corresponding author.
*E-mail addresses:* 12mzx@tongji.edu.cn (Z. Ma), llp@tongji.edu.cn (L. Liu), ljsun@tongji.edu.cn (L. Sun).

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top-down cracking. Wang et al. [10] investigated the causes of top-down cracking using micromechanics and found that both tensile-type and shear-type cracking could initiate top-down cracking. Wang and Al-Qadi [11] evaluated the failure potential of pavement near the surface and found that the shear-induced surface cracking could start from some distance below the pavement surface in conjunction with the distortional deformation at high temperatures.

Accelerated pavement testing (APT) has been widely used to help improve the understanding of pavement performance within an accelerated period of time. Damage of field asphalt mixture under APT loading can be traced by the reduction of HMA modulus in the field using non-destructive testing methods such as a portable seismic property analyzer (PSPA) [12,13]. In previous papers [14–16], many researches have been made to evaluate the fatigue and rutting performance of asphalt pavements. Very few focused on the top-down cracking phenomenon. Zou et al. [17] evaluated the effects of ageing and healing on top-down cracking performance based on three full-scale accelerated pavement tests and found that ageing and potential healing appeared to play key roles in the cracking performance of the asphalt pavement. Wen and Bhuasl [18] developed a phenomenological top-down cracking initiation model for mechanistic–empirical pavement design according to the data collected from the Federal Highway Administration's accelerated loading facility.

Although the mechanisms of top-down cracking were complicated and controversial, it was generally believed that top-down cracking tended to occur at high temperature and at the surface course with more aging effect. The primary objective of this study was to investigate the top-down cracking performance of in-situ asphalt mixtures based on APT testing and laboratory tests. To accomplish this objective, four tasks as listed below were performed and discussed in the following sections:

- A series of APT tests were conducted on an in-situ asphalt pavement to achieve different HMA damages of in-situ asphalt mixtures and induce top-down cracking by applying different loading passes.
- The PSPA was used to monitor the pavement modulus reduction during the APT testing. Damage in the HMA layer was analyzed based on the measured PSPA modulus.
- Field cores were taken from the APT test sections after different APT loading passes and then tested under the uniaxial penetration test (UPT) and indirect tensile (IDT) test in the laboratory.
- Shear effect of APT loading on HMA was presented by the uniaxial shear resistance from UPT tests. Tensile effect of APT loading on HMA was analyzed with the indirect tensile strength and indirect tensile fatigue lives from IDT tests.

## 2. Experimental design

### 2.1. Full-scale APT on in-service expressway

The full-scale APT testing was conducted on an abandoned expressway ramp in Shanghai, China. As shown in Fig. 1, the selected in-situ pavement consisted of a 150 mm thick HMA, a 450 mm thick semi-rigid base treated with fly ash, a 150 mm thick sand-gravel subbase, and subgrade. Note that this is a typical pavement structure widely used on expressways in China. Specifically, the 150 mm HMA layer was composed of a 40 mm thick wearing course, a 50 mm thick binder course, and a 60 mm base course. For the wearing surface course, polymer modified asphalt binder was used and regular asphalt binders were used in the two other HMA layers.

The Mobile Load Simulator (MLS) 66 machine shown in Fig. 2 was employed to induce top-down cracking for the in-situ asphalt mixtures. A 75 kN load with dual-tire wheels and 1 MPa tire pressure was applied to the in-situ pavement at an average speed of 6000 passes per hour. In each day, around 70,000 loading passes were applied.

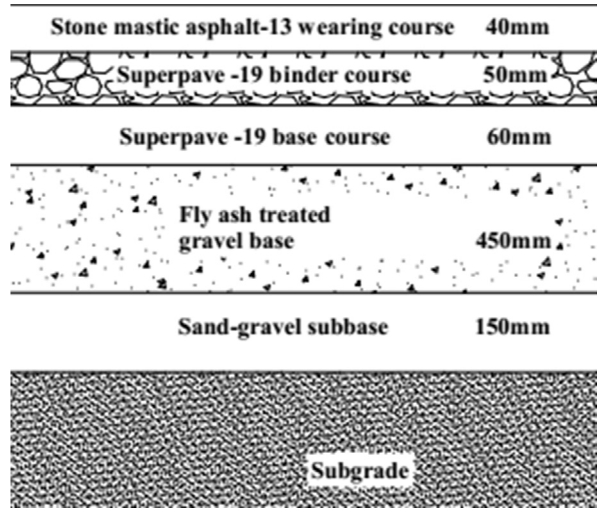


**Fig. 1.** Pavement structure for the field test section.

**Fig. 2.** The MLS66 machine at the field test section.

The APT testing included two field test sections with different accelerated loading patterns. For the first test section, 550,000 APT passes of loading were applied. The effective length of the loading area was 6.6 m. The second test section was loaded a little bit differently. After the MLS66 machine applied the first 250,000 passes of loading, it was stopped and moved half machine length forward along the traffic direction. Then, another 150,000 passes were applied. Thus, for the second section, its effective length of the loading area was increased to 9.9 m through the machine moving, and a total of 400,000 passes of loading were applied to the overlapping area with a length of 3.3 m. The purpose of moving the APT machine was to create in-situ asphalt mixtures with four different levels of damage under the loading passes: 150,000, 250,000, 400,000, and 550,000.

### 2.2. Portable seismic property analyzer test

PSPA was used to measure the modulus of the HMA layer during APT testing. As shown in Fig. 3, the PSPA consists of a source and two transducers packaged in a portable system to perform seismic tests in the field. During the APT testing, the PSPA test was performed every day before starting the APT loading. The PSPA