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Review

A review on solutions for improving rutting resistance of asphalt pavement and test methods

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HIGHLIGHTS

- The anti-rutting efforts focus on improving the rheological properties of asphalt.
- Semi-flexible and cool asphalt pavements can help reduce rutting depth.
- The applicability of wheel tracking test was systematically analyzed.
- It is unnecessary to perform rutting tests at a rather high temperature.
- Multiple-stress mode should be considered in performing laboratory rutting test.

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ABSTRACT

Permanent deformation, mainly referring to rutting, is one of the main distress modes of asphalt pavement. Exploring effective methods to mitigate the rutting distress is of great significance for providing a long-life and safe road. The rutting solutions were first reviewed. It was found that the efforts from academic and engineering industries focused on enhancing the rheological properties of asphalt binder by adding modifying powder, fiber or mixture into binder or mixture, as well as strengthening aggregate interlock and applying novel pavement structure. Semi-flexible asphalt pavement was suggested to be a promising method to fight the rutting distress, because it has a high mechanical property without scarifying the flexibility of asphalt pavement. In order to consider the influence of temperature on rutting occurrence, cool asphalt pavements, especially heat-transfer induced structures, were reviewed and deemed to be a new strategy for reducing rutting susceptibility of asphalt pavement. In order to evaluate the effectiveness of above rutting solutions, many tests, such as multi-stress creep recovery test for asphalt binder and wheel tracking test for asphalt mixture, were reviewed. By linking the reported results of wheel tracking test with high-temperature rutting mechanism it was advised to develop a test method that could reproduce the real field pavement environment, including multiple stress mode, temperature gradient control system and pavement structure, to assess the rutting response of asphalt mixture. This review is expected to provide an overall insight on the existing rutting solutions and test methods, and recommend future studying areas relevant to rutting distress.

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1. Introduction

Rutting, usually occurring in both asphalt layers and underlying unbound layers, is one of the main pavement distress modes [1–4]. For asphalt pavements where water is not allowed to pass through unbound layers, approximately 85 ~ 95% of rutting accumulate in asphalt layers [5]. Rutting usually appears in a form of surface depression in wheel paths. Especially in intersections and bus stops of urban roads, horizontal loading created by tire-pavement friction during frequent vehicle braking and accelerating actions often cause large shear stress and strain in pavement structure [6–8]. And in long and steep sections of highways, rutting is easy to occur according to the time-temperature superposition principle [9]. The rutting performance is highly dependent on weather and traffic conditions, such as traffic densities, heavy loads, slow traffic and high temperatures [10]. In addition, poor qualities of mixture material [11] and construction [12] are also crucial factors for rutting accumulation.

There are many social and pavement problems associated with rutting distress. For example, when water accumulates in the ruts, the water intrusion into the pavement structure can further deteriorate the pavement [13]. In addition, the water accumulating in the ruts will bring a hydroplaning safety hazard [14]. In China, approximately 80% asphalt pavement maintenances are related to rutting [15].

To cope with the rutting distress, many theoretical models were proposed to predict the rutting depth of various pavement structures by using the parameters obtained from laboratory test (i.e., Hamburg wheel test [16]) and accelerated pavement testing [17,18]. These rutting models provided guidance for pavement structure design and analysis. This paper aims at reviewing the engineered measures from levels of asphalt binder, asphalt mixture and pavement structure. Because asphalt mixture is temperature sensitive and rutting is significantly affected by temperature, cool asphalt pavements are also reviewed and are deemed as a potential strategy for mitigating rutting distress. On these bases, experimentally evaluating methods are reviewed and some recommendations are proposed to develop more feasible methods to reproduce the real on-site weather and loading conditions.

2. Mechanisms of rutting accumulation

In general, the overall rutting depth is composed of three rutting modes, named loss of materials, densification and lateral plastic flow, respectively [19]. Loss of materials, which usually occurs in low durable mixtures and presents raveling along wheel paths, occupies a small percentage of the rutting depth, while densification and plastic flow are the two primary deformation modes that control rutting accumulation [20]. The densification is an initial contributor to rutting at the very early stage of opening asphalt pavement. The asphalt mixture with higher air void content is expected to cause more densification related rutting [21]. The shear-related deformation dominates the long-term rutting accumulation [22]. So many studies focused on the shear properties of asphalt mixture to investigate rutting characterizations. Except from the above classic viewpoints on rutting accumulation, some recent studies considered a dilation behavior of asphalt mixture also contributing to the rutting depth, during which the asphalt mixture in the upheaval zone presented an increased volume or a higher air void content [23,24].

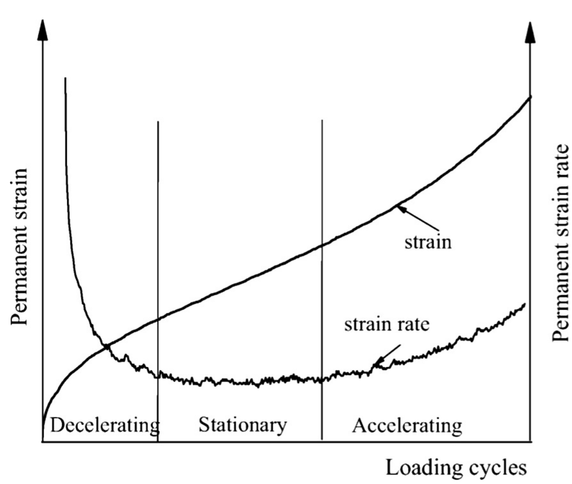

Fig. 1. Permanent strain vs loading cycle relationship [25].

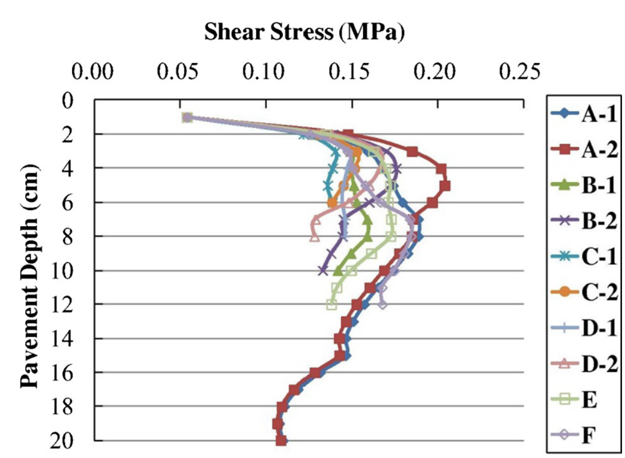

Fig. 2. Distributions of the shear stress in asphalt layers under the outer edge of tire [28].