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Degradation evaluation index of asphalt pavement based on mechanical performance of asphalt mixture

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HIGHLIGHTS

- Evaluate the degradation of pavement structure with properties of asphalt mixtures.
- Evaluate the combined effect of climate and traffic load on asphalt pavement.
- Develop a degradation index to show the aging degree of asphalt mixtures.

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ABSTRACT

Performance of asphalt pavement degrades after opening to traffic. The degradation of pavement structure is difficult to be evaluated because of the difficulties in *in-situ* testing and large scattering of testing results. Mechanical properties of asphalt mixtures were tested in this study to indirectly evaluate the degradation of pavement structure. Firstly, different testing methods were discussed from specimen preparation to testing results simulation of pavement structures. Indirect tensile test was finally chosen because of its easy testing process, clear stress state, stable testing results and convenience in preparation of field cored specimen. Secondly, asphalt mixtures with the same material and gradation as that of Nanjing Airport Expressway asphalt pavement were aged from 2 h to 24 h to simulate pavement at different aging period and tested. All testing results are sensitive to aging when the aging time is short and keep relatively stable when the aging time is longer. Elastic modulus of asphalt mixtures is more sensitive to aging time than that of strength and modulus at failure. Degradation Index (I_d) was defined as the ratio of elastic modulus of original asphalt mixture to that of aged mixture which shows the aging degree of asphalt mixtures. Thirdly, fatigue tests were conducted on mixtures of different aging time to determine their fatigue life. Indirect tensile tests were performed on specimens with 20%–80% of fatigue life and different aging time to check the combined effect of climate and traffic loading. I_d was modified based on the testing results.

1. Background

Performance of asphalt pavement degrades with the effect of traffic loads and surrounding climate. Maintenance or rehabilitation is required depending on the serviceability of pavement. According to Highway Performance Assessment Standard in China, the assessment of asphalt pavement performance includes assessing the pavement surface condition, riding quality, rutting depth, skidding resistance, and pavement structure strength [1]. The pavement surface condition is estimated by calculating the ratio of pavement area with distress, which include all types of cracking, corrugation and shoving, rutting, pot holes, bleeding, raveling, and patching to area of pavement surface with and without distress. Riding quality is represented by international roughness index. Skidding resistance is calculated through side-way force coefficient. Pavement structure strength is represented by the ratio of designed deflection to *in-situ* measured deflection, which is also known as the bearing capability of pavement. Normally the evaluation index of pavement serviceability for maintenance focus on the characteristics related to driving safety such as the pavement surface condition, riding quality, rutting depth, and skidding resistance [2–4].These four aspects of pavement performance are very easy tobe measured with automatic test equipment. Serviceability

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evaluation index for rehabilitation is closely related to the bearing capability of pavement, which is also one of the key input parameters for pavement rehabilitation design method. Benkelman beam deflectometer, falling weight deflectometer and plate bearing tests are often used in field to evaluate the bearing capability of pavement structures [5–8]. Traffic speed deflectometers are increasingly being used to measure pavement deflections caused by a moving load at a range of driving speeds [9–11]. However the testing results of deflectometer or bearing plate represent the strength of the whole pavement structures from the subgrade, base to surface layers, but not limited to the layers of interest. Furthermore, the data of deflectometer and bearing plate are quite scattered. One of our field studies showed that the variation coefficients of deflectometer data for 5 repeated testing points at a distance within 3meters are as high as 25%, with the maximum one being 63% [12].Pavement structural strength is affected by and closely related to the mechanical properties of the pavement materials and the interfacial adhesion of layers. Interlayer damages of asphalt pavement are usually caused by moisture and play an important role in the damage of pavement material [13,14].Therefore, the bearing capability of each layer can be obtained through performing proper mechanical tests on the pavement material. The purpose of this study is to evaluate the structure strength degradation of asphalt pavement through conducting tests on asphalt pavement mixtures of different aging and fatigue period.

2. Selection of testing method

The degradation of pavement structure is actually caused by the gradually accumulated damage of pavement materials under the combined action of traffic load, humidity, light and temperature in a long time period [15–19].Strength, stiffness and remaining life of asphalt mixtures decrease with time, which result in the lower bearing capability and degradation of pavement structure. Pavement fails once the damage in asphalt mixture reaches an unacceptable level. It is necessary to evaluate the strength, stiffness and residual fatigue life of existing asphalt pavement mixtures in order to evaluate the degradation of asphalt pavement. There are many testing methods used for mechanical properties evaluation of asphalt mixtures. Several rules must be obeyed to choose the proper testing method and evaluation index, which aresummarized as following:

(1) The testing results should have good reproducibility and repeatability.
(2) Mechanical properties obtained from the test should be the required input parameters in asphalt pavement design method.
(3) The stress state of the specimen should be as simple as possible.
(4) The stress and strain in the specimen should be easily measured.
(5) Testing conditions such as equipment and experimental environment should not be too harsh.
(6) Specimen should be easily cored from existing pavement.

Micro cracks occur and develop in asphalt mixtures under repeated load which cause the degradation of material properties. Popular tests used to show these material properties in laboratory are direct or indirect tensile test, flexural beam test and compression test.

Uniaxial compression test is a kind of old and matured test which shows the compressive characteristics of pavement materials. Specimens are easy to be fabricated in laboratory or be cored in field. Test is easy to perform and the equipment is available in most laboratories. Modulus determined through static compression loading test is one of the input parameters of current Chinese asphalt pavement design method. The forthcoming revised Chinese asphalt pavement design method turns to the use dynamic modulus and phase angle, which will be determined through repeated compression loading test.

Indirect tensile test is also an old and extensively used test to support the asphalt structure design and evaluate mixture properties. The indirect tensile strength is used to evaluate the fatigue stress at the bottom of continuous layers in the current Chinese asphalt design method. Most importantly, the cores obtained from existing pavement, even with thin layer, can be tested directly in the laboratory with this test method.

Flexural beam test is widely used to evaluate the fatigue characteristics of asphalt mixtures. Test is easy to perform and the equipment is available in most laboratories. However, the specimens for this test are cut from large size square slabs which are quite difficult to be cored in the field.

Direct tensile test shows clear stress distribution in asphalt mixture. But the test is hard to perform and the specimens for the test are as difficult to be prepared *in-situ* as that of flexural beam test.

Some tests cannot be chosen to evaluate the properties of asphalt mixture because the size of cored specimens cannot meet the testing requirement. Specimens for uniaxial compression test should be 100 mm in diameterand150 mmin height [20]. It is better to keep the ratio of height to diameter greater than 1.5 and the diameter of specimen as large as4 times of that of the largest aggregate to avoid the size effect. Normally the thickness of each asphalt pavement layer is around 40 mm to 80 mm and the corresponding diameter of a single largest aggregate is about 16 mm to 30 mm. It is thus a challenge to core a satisfactory specimen for compression test for each asphalt layer.

Indirect tensile test was finally chosen to evaluate the properties of asphalt mixture because of its easy testing process, clear stress state, stable testing results and ease in obtaining field cored specimens.

3. Specimen preparation

Nanjing Airport Expressway was under maintenance during the study. Mixture used in this study was the same as that of Nanjing Airport Expressway. Specimens were cored from the Airport Expressway to validate the testing results in the laboratory. Part of cored specimens are shown in Fig. 1. The cylindrical cores are used for uniaxial compression test directly or cut along the interface of two layers and used for indirect tensile test. The slab specimens are cut into beams and used for fatigue tests. Gradation of the dense asphalt mixture with 19 mm nominal maximum aggregate size (AC20) used in the study is shown in Table 1. 70# base binder (performance grade PG64-22) was used in the mixture. Basic tested properties of the binder are given in Table 2. The asphalt mixture was designed according to the Marshall mixture design method. The optimal binder content of the mixture was 4.6%.

Performance of asphalt mixture decreases with time because of the effect of weather and traffic load which cause the aging of asphalt binder, fatigue of asphalt mixture, permanent deformation on pavement and other distress. The aging and fatigue performance of asphalt mixtures were studied to simulate the structure strength degradation of in field pavement. All asphalt mixtures were put in the oven to be aged before molding a specimen. The temperature of the oven is set at 163 °C to accelerate the aging of asphalt mixtures. The aging time should be long enough to expose mixtures to different aging conditions. According to the