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The potential of using impact resonance test method evaluating the anti-freeze-thaw performance of asphalt mixture

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HIGHLIGHTS

- For IRT, 1.5 times the maximum particle size of aggregate is recommended.
- The first vibration mode is more sensitive to change of asphalt mixture properties.
- 4 cm thickness sample and 1st vibration mode are suggested to assess anti-FT property.
- Size of rubber powder and type of neat asphalt affect the anti-FT performance.

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ABSTRACT

Asphalt pavements around the world are generally subjected to water from different sources which may eventually make them susceptible to moisture damage. However, most of tests used to investigate the moisture damage are destructive, which will consume a lot of materials, energy and time to prepare the specimen. There is a need to find a simple and quick non-destructive test to evaluate the moisture damage of asphalt mixture. In this paper, the impact renounce test is employed and the possibility on evaluating the anti-freeze-thaw performance of asphalt mixtures is discussed. It is found that the dynamic modulus obtained by impact resonance test and repeated loading test method correlate very well, and using impact resonance test method we can well evaluate the anti-freeze-thaw performance of different asphalt mixtures. It is also found that the properties of neat asphalt have significant effect on the anti-moisture damage properties, and rubber asphalt mixture has better anti-freeze-thaw performance than neat asphalt mixture; the particle size of rubber powder also shows an impact on the resistance to freeze-thaw performance of asphalt mixture. Different specimen thicknesses and different tapping positions have significant effect on the repeatability of test results; it is recommended that using 4 cm thickness specimen and impacting on the edge of specimen to evaluate the degradation of asphalt mixture anti-freeze-thaw performance.

1. Background

Asphalt mixture has been widely used in the world as the main construction materials for pavement. The durability of this kind of material is the very most important property for pavement [1,2]. However, asphalt pavements around the world are generally subjected to water from different sources which may eventually make them susceptible to moisture damage. After moisture damage, many concurrent surface distresses will become much more susceptible, such as rutting, corrugations, shoving, raveling, cracking, etc., which will reduce performance, and increase maintenance cost of asphalt pavements. Therefore, moisture damage is the key factor related to the durability of asphalt pavements [3–7].

Though the method of asphalt mixture design and the asphalt mixture mechanism behavior now have been improved greatly during decades, but moisture damage is still hard to explain. Usually, moisture damage in asphalt mixtures can be defined as the loss of strength and stiffness of the mixture, which are caused by loss of adhesion and loss of cohesion [8–11]. The bond strength between asphalt and aggregate plays a fundamental role in evaluating the moisture sensitivity of HMA mixtures. Canestrar [12] found water affects the adhesive bond between asphalt and aggregate much more than the asphalt cohesion. Apeagyei [13] investigated the effects of moisture on the aggregate-mastic interfacial adhesive strength as well as the bulk mastic cohesive strength and found the aggregate-mastic interfacial bond appears to be

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more detrimental than the effect of moisture on the bulk mastic. Later, Apeagyei's [14] study results showed the influence of aggregate moisture absorption and diffusion on asphalt mixture moisture damage was found to be aggregate-type-dependent. Arambula [15] evaluated the moisture susceptibility of asphalt mixtures using dynamic analysis and a crack growth model and found good differentiation between the moisture-conditioned (wet) and unconditioned (dry) specimen behavior.

However, the mechanism and the degradation of the moisture damage are very complex, using the same test method to simulate the field behavior and predict moisture damage of asphalt pavement accurately is impossible. Several approaches have been attempted to accelerate the moisture effect in the laboratory such as freezing HMA specimens, placing HMA specimens in hot water, vacuum saturating HMA specimens, boiling loose mixtures and freeze-thaw specimens [16]. Considering the dynamic modulus test is nondestructive, unlike the indirect tensile strength test, the advantage would be that the same specimens could be used before and after moisture conditioning. So some researchers used dynamic modulus test to evaluate the moisture susceptibility of asphalt mixtures. Alavi [17], evaluated adhesion properties and moisture damage susceptibility of asphalt mixture with Bitumen Bond Strength and dynamic modulus ratio Tests. They found both BBS and dynamic modulus testing indicated that specific WMA additives could improve the mixture's moisture resistance and could offset any negative effects from the reduced production temperatures on moisture susceptibility. Nadkarni [18] found that the dynamic modulus ratio can potentially replace tensile strength ratio testing to assess field moisture damage for asphalt mixtures.

From the literature review it can be found that most of tests using to investigate the moisture damage are destructive, which will consume a lot of materials, energy and time to prepare the specimen. There is a need to find a simple and quick nondestructive test to evaluate the moisture damage of asphalt mixture.

The impact resonance test (IRT) which is described in ASTM C215 is a kind of nondestructive test method. This test method described in ASTM C215 is used to determine the elastic properties of Portland cement concrete. Whitmoyer and Kim [19,20] used different methods determining the stiffness of asphalt mixture. They employed the modified ASTM C215 to measure the material properties of asphalt concrete and they found the impact resonant method could detect different magnitudes of micro-crack healing. Ryden's [21] results showed that master curve, obtained by resonant frequency testing at different temperatures, compares well with reference values within the high modulus range. Lacroix [22] found that Impact Resonance Testing can be performed from 5° to 60 °C to produce the higher reduced frequency portion of the master curve. Kweon [23] determinated the asphalt concrete complex modulus with impact resonance test, and they thought the main advantage of these combinations of testing methods over conventional dynamic modulus testing is that they are much simpler and require less expensive testing equipment and setup.

As literature review shows, the impact resonance test) is a feasible way to determine the dynamic modulus of asphalt mixture. And because the change of dynamic modulus related to the damage of asphalt mixture [24,17], so using IRT method evaluating the anti-freeze-thaw performance of asphalt mixtures is possible.

2. Objective

Verifying the feasibility of using the impact resonance test to determine the dynamic modulus of asphalt mixture and discussing the potential of using IRT method evaluating the anti-freeze-thaw performance of asphalt mixtures.

3. Materials and methods

3.1. Materials used

3.1.1. Neat asphalt

Two different neat binders are used for the study. They are 70#, 90# according to Chinese Standard –Technical Specification for Construction of Highway Asphalt Pavement (JTG F40-2004). The base properties of different binders are shown in Table 1.

3.1.2. Rubber powder

The tire rubber powder with three different size distributions produced in Liao Nin province were used in this study, they are 28 Mesh and 60 Mesh and 20% rubber powder content (by weight of binder) are added into asphalt.

3.1.3. Rubber asphalt

Rubber, one type of polymer, is known to absorb solvents and swell. The extent of swelling is dependent on the temperature of system, nature and viscosity of the solvent and the type of polymers and the swelling of rubber is one of the key factors to prepare successfully the crumb rubber modified asphalt binder. So with the purpose of swelling of rubber, choosing a high shearing rate of 5000 r/min and blending the asphalt with a high temperature at 185 °C ± 5 °C for 60 min ± 5 min by wet process. Three different kinds of RA are prepared and are referred with different name, as shown in Table 1. It should be noted that 70–28 means adding 28 Mesh rubber powder into 70# base asphalt, the rest are similar.

3.1.4. Aggregate and Grading

Aggregate is obtained from one asphalt pavement plant in Heilongjiang Province located in the northern part of China. Fig. 1 shows the recommended gradation limits by Chinese specifications (JTGF40-2004) for SMA-16 mixtures and the selected gradation in this research was in the middle of the limits.

The properties of the aggregates, such as angularity value, toughness value, soundness value, water absorption value, and specific gravities are determined, and the test results are presented in Tables 2 and 3.

The filler used is limestone powder and it is brought from the same asphalt pavement plant. Limestone powder was passed through a 200 sieve and the specific gravity of it is 2.740. The cellulose fiber content added in SMA asphalt mixture is 0.4%. The properties of cellulose fiber meet the Chinese specification.

3.1.5. Mixture design

The mix design procedures for SMA-16 in this paper are determined as per the Chinese specification JTJ F40-2004. Locally available materials that meet the normal SMA-16 specifications are used to produce the mixes.

The optimum asphalt content (OAC) for SMA-16 mixtures is usually selected to produce 4% air voids. The results are shown in the following Table 4.

Table 1
The Basic Properties of Asphalts.

Index		70#	90#	70–28	90–28	90–60
PG		64–16	58–22	76–22	70–28	70–28
Penetration, 100 g, 5 s (0.1 mm)	5 °C	7.0	8.6	5.0	8.4	9.5
	15 °C	23.0	24.0	16.0	19.2	20.8
	25 °C	73.0	81.0	42.0	43.3	52.5
Softening Point $T_{R\&B}$ °C		48	47	62.5	63.0	56.1
Ductility 5 cm/min (cm)	15 °C	\	\	10.7	13.9	16
	15 °C	>100	>100	>100	>100	>100