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Investigation of influential factors on the tensile strength of cold recycled mixture with bitumen emulsion due to moisture conditioning

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HIGHLIGHTS

- Effect of moisture conditioning on the tensile strength of cold recycled mixture with bitumen emulsion is investigated.
- Factorial design is carried out using different factors.
- Specimen thickness is the most significant factor affecting the tensile strength followed by air voids content.
- Appropriate specimen thickness and air voids content should be selected to quantify the representative tensile strength during in-situ conditions.

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ABSTRACT

The present study attempts to investigate the effect of moisture conditioning on the indirect tensile strength (ITS) of cold recycled mixture with bitumen emulsion. Firstly, samples were prepared using a Superpave gyratory compactor. They were hence conditioned using moisture induced sensitivity tester (MIST) device. Factorial design was carried out considering four factors each at two different levels. These factors were specimen thickness, air voids content, pressure and number of cycles. In the MIST device, samples are cyclically subjected to water pressure through the sample pores. The MIST conditioned samples were tested for indirect tensile strength. The analysis of two-level full-factorial designed experiments revealed that all four factors have a negative effect on tensile strength of cold recycled mixture with bitumen emulsion. Specimen thickness was the most significant factor affecting the tensile strength followed by air voids content. In two-factor interaction, specimen thickness-number of cycles, air voids content-pressure, and pressure-number of cycles were significant. The most significant three-factor interaction was specimen thickness-pressure-number of cycles. The results from the study suggest that in measuring tensile strength, the appropriate specimen thickness and air voids content should be selected to quantify the representative tensile strength for in-situ conditions.

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1. Introduction

Tensile strength is one of the critical parameters that should be taken into consideration for pavement performance evaluation. It is playing an important role as design and evaluation tool for Superpave mixtures (Khosla and Harikrishnan, 2007). Pavement engineers have more interest on the tensile properties of bituminous because of the problem associated with cracking. The indirect tensile strength test is used to determine the tensile properties of the bituminous mixture which can further be related to the cracking properties of a pavement. It is an indicator of strength and adherence against fatigue, temperature cracking and rutting. This test involves preparing a compacted cylindrical asphalt mixture subjected to compressive load which is parallel to and along the vertical diametrical plane. Many factors affect the tensile strength of moisture conditioned asphalt mixtures when subjected to indirect tensile test. These factors include the specimen thickness, air voids content, number of MIST cycles and pressure. Numerous works have studied the effect of moisture on asphalt concrete. Its crucial effects on fatigue behavior and permanent deformation performance had already been demonstrated (Cheng et al., 2003; Cross et al., 2001; Wong et al., 2004). Previous works have extensively addressed changes in the stiffness of asphalt concrete (AC) due to moisture conditioning (Islam et al., 2014; Weldegiorgis, 2014). AASHTO T283 as well as EN 12697-12 has been used by scholars to see the influence of moisture on tensile strength of asphalt mixtures. Unfortunately, this test doesn't reflect the field condition because only one cycle of saturation and freezing thawing is performed (Tarefder and Ahmad, 2015). Therefore, there is a need for a method that can accurately determine moisture susceptibility of cold recycled mix with bitumen emulsion in the laboratory where field condition is simulated. In order to better simulate field conditions, it has been recommended to replicate the pumping action of traffic loading with a cyclic load rather than a constant load (Kandhal and Rickards, 2001). The moisture induced sensitivity tester (MIST), introduced by Instro Tek replicates the stripping mechanism in the field which is caused by cyclic loading and unloading of tire pressure on asphalt concrete mixtures.

Moisture damage is a common problem that has resulted in pavement failure. Research efforts have been directed to solve this problem by using numerous qualitative and quantitative tests methods (Hicks, 1991; Kandhal, 1992, 1994). The boiling water test (ASTM D3625) and static-immersion test (AASHTO T182) are qualitative tests, while the Lottman test (NCHRP 246), Tunnicliff and Root conditioning (NCHRP 274), modified Lottman test (AASHTO T283), Texas freeze-thaw pedestal test, and immersion-compression test (AASHTO T165) are quantitative strength tests (Roberts et al., 1996). Qualitative tests are applied on loose materials and are based on the visual inspection of samples after conditioning in order to determine the degree of moisture. The evaluation of moisture damage in these tests is quite subjective and depends on personal experience and interpretation. The quantitative method is performed on compacted asphalt mix samples. It usually prescribes measuring some property of asphalt mix sample, subjecting to moisture conditioning. Literature review emphasized both on the Tunnicliff and Root (1984) and the AASHTO T283-03 (AASHTO, 2007) as the two commonly used quantitative tests methods to evaluate moisture sensitivity. The only difference between AASHTO T283-03 and Tunnicliff and Root is that the curing of loose mixture at 60 °C in an oven for 16 h is eliminated in ASTM D4867. A minimum tensile strength ratio (TSR) of 0.70–0.80 is specified by highway agencies (Roberts et al., 1996) for AASHTO T283.

While setting up new moisture conditioning protocol, Varveri et al. (2014) determine the optimum number of MIST conditioning cycles on the basis of MIST tests on an AC mixture with sandstone aggregates and polymer modified binder. AC specimens were placed into the MIST without any prior conditioning. Such a procedure is meant to induce enough damage to distinguish among mixtures with different moisture damage susceptibility. Three sets of specimens were used in replicas of three. Thousand cycles were applied on the specimens from the first set whereas 4000 cycles have been applied on the specimens of the second and 8000 cycles on the third set. As expected, the accretion of cycle number led to more damage at the same temperature and pressure of 60 °C and 0.48 MPa were used respectively. Tests have shown that at 4000 cycles, specimens displayed a reduction in strength of about 25% which was considered sufficient for the evaluation and ranking of asphalt mixtures. Besides, it has been demonstrated that the use of cyclic pore pressures has a significant effect and can be used as an accelerated moisture conditioning procedure.

Mallick et al. (2003) conducted series of tests with open graded (OG) and thin particles (TP) mix samples, with similar gradation and asphalt content but different aggregates, using different number of cycles and temperatures and new equipment. Calcareous sandstone aggregate type is used in OG mixes whereas siliceous siltstone is used as aggregate type in TP mixes. Mixes TP are considered to be sufficiently resistant to moisture induced damage while the OG mixes are not. The new equipment is made of a system which is used as a supply of compressed air to load and apply vacuum to force air out and in (respectively) through a HMA sample, which is kept in water maintained at a constant temperature. Tests were conducted at 2000, 3000, 4000 and 6000 cycles mostly at 60 °C, and some at 40 °C. Results showed that the strength of the mixes decreases with the accretion of cycle number. The procedure is therefore, successful in simulating moisture induced damage in laboratories.

Researchers have found that reducing air voids content can increase mixtures engineering properties, both rutting and indirect tensile strength (ITS). In laboratory compaction, the air voids content which is the reserve of density is one of the main functions of compactive effort; the mixture is confined in a rigid mold, where more gyrations result in less voids in the mix (Zhao, 2011). Statistical analyses have been conducted by scholars based on air voids content effect. Those analyses showed that at different level of air voids content, rut depths were significantly different. Mixtures with higher air voids content have higher rut depths than the lower air voids content mixture. Thus, low air voids content in this study is the favorable rutting resistance end. Therefore, increasing the density of the pavement can reduce air voids content in the pavement, and will further increase rutting performance