Construction and Building Materials 30 (2012) 139–148

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Hydrated lime treatment of asphalt concrete to increase permanent deformation resistance

Celaleddin E. Sengul [a], Atakan Aksoy [b], Erol Iskender [c,*], Halit Ozen [d]

[a] General Directorate of State Hydraulic Works, Turkey
[b] Avrasya University, Engineering and Architectural Faculty, Civil Engineering Department, 61010 Trabzon, Turkey
[c] Karadeniz Technical University, Of Faculty of Technology, Civil Engineering Department, 61830 Trabzon, Turkey
[d] Florida International University, Department of Civil and Environmental Engineering, College of Engineering and Computing, Miami, FL, United States

ARTICLE INFO

Article history:
Received 30 September 2011
Received in revised form 22 November 2011
Accepted 4 December 2011
Available online 29 December 2011

Keywords:
Permanent deformation
Marshall Quotient
Repeated creep
Hydrated lime
Asphalt concrete
SBS

ABSTRACT

The aim of study is to evaluate rutting with Marshall Quotient (MQ) and repeated creep (RCT). Three hydrated lime (HL) mixtures were evaluated and compared with control mixtures (CMs) for conditioned samples (CSs). Filler was reduced and HL was substituted at 2%, 4% and 6%. Damage system (ECS) based on moisture was applied. For rutting with MQ approach also some mixtures were produced including SBS and HL. Modified and synergistic (SBS and HL) mixtures were interrogated. An observed damage level was exposed with the selected ECS. RCT was quite effective at different HL ratios for HL efficiency for dense gradation. HL was found beneficial due to moisture. Increasing of HL from 2% to 6% deformation resistance increased. Tertiary deformation was not revealed at 64,730 pulses for CM and HL ones. Expected results were obtained with the RCT for both HL mixtures and also SBS. MQ is not a good indicator of the deformation resistance because of the larger intervals between CM and others.

1. Introduction

Hydrated lime is one of potential fillers incorporating asphalt concrete, where filler is defined as aggregate particles smaller than about from being less than 0.075 mm to less than 0.063 mm. Properties of hydrated lime, including particle size, rugosity, and surface energy may prove that it is filler with a unique impact on the bituminous binder rheology and damage mechanics of asphalt concrete mastics.

Pavements built the lime-treated bitumen should have relatively greater resistance to rutting at the temperatures and also greater resistance to transverse thermally induced cracking at low temperatures. Based on the data at these two temperature extremes, it is tempting to speculate that, at some intermediate temperature, for example 25 °C, asphalt concrete mixtures containing the lime treated bitumen should have superior resistance to failure during repeated load cycling during fatigue testing and increased resistance to fatigue cracking in pavements [1]. A most effective method of adding lime is still under investigation. In recent investigations various lime addition techniques were the subject of study. Laboratory and 1-year old field mixtures revealed no significant differences in the moisture damage resistance of mixtures lay using various lime addition procedures [2].

The beneficial effects of lime in reducing the moisture damage in asphalt concretes is well recognized and lime is widely used as an additive to pavement mixtures to reduce moisture damage. Traditionally, and further for pragmatic reasons, the hydrated lime is either added to aggregate as a water slurry prior to mixture preparation or directly to the hot mix plant. Bitumen–lime chemical reaction showed that carboxylic acids and 2-quinolones are irreversibly adsorbed on the surface of hydrated lime particles. The adsorption should thus prevent their subsequent adsorption by siliceous aggregate surfaces to produce a moisture sensitive mixture. In short, lime treatment of the bitumen prior to mixing should produce a more moisture resistant mixture. To test the hypothesis on design pavement mixtures, the lime was mixed thoroughly with bitumen AAB-1 before preparing the mixtures for moisture damage testing. The data clearly demonstrate that lime is effective when added to the bitumen rather than the aggregate, and that lime added directly to the bitumen can produce significant resistance in mixtures for both aggregates [3].

The use of 2% hydrated lime added directly to the mix ingredients has given improvement but has far from eliminated the problem. It is expected that a better, but more costly method is the treatment of cold aggregates with hydrated lime slurry. This has not been tried. Additives can be added to the bitumen mix to reduce the potential for stripping. The addition of hydrated lime

---

* Corresponding author. Tel.: +90 462 7717250; fax: +90 462 7717251.
E-mail addresses: celensen@hotmail.com (C.E. Sengul), aaksoygmf@hotmail.com (A. Aksoy), eroliskender@gmail.com (E. Iskender), ozenh@fiu.edu (H. Ozen).

0950-0618/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2011.12.031

can be the most effective method. Effectiveness can be enhanced by pretreatment of aggregate. Typical amounts are 1–2% of the total mix by mass. The effectiveness of any additive, particularly adhesion agents, needs to be checked by such testing prior to use. The use of hydrated lime has been found to be the most effective additive at 1–2% by weight of the mix. The effectiveness of plant mix process, in ensuring the additive is uniformly included in the final mix, needs continued assessment. To avoid rutting and fatigue problems, heavy duty bituminous mixtures should be designed using the new Australian mix design procedure. This procedure is being refined currently and uses fundamental, rather than empirical test procedures, and includes having 3% air voids at maximum or refusal density. Following the ALF Asphalt Deformation Trials, consideration is being given to including a mixture laboratory wheel tracking test for level 3 heavy traffic mixes to validate and check the mix rut-resistance. Care needs to be taken to integrate the pavement and mix design [4,5].

Design decisions and performance predictions were made based on the results of such laboratory tests in the shear, tension, or compression mode of loading. The results clearly show that the designed index can distinguish between levels of inhomogeneity. By means of frequency sweep at constant height (FSCH) test, the shear stiffness and the fatigue susceptibility at test temperature of 25 °C and the shear stiffness and rutting susceptibility at test temperature of 50 °C were evaluated. The resistance of the material to cumulative shear deformation was measured using the repeated shear at constant height (RSCH) test at 50 °C. The effects of radial inhomogeneity on the shear properties of the specimens were investigated at the two test temperatures. As indicated from the FSCH test, the shear modulus increases, the rutting susceptibility, and the fatigue susceptibility in thick layers decreases, and the fatigue susceptibility in thin layers increases with increasing radial inhomogeneity. The correlation between the shear properties from the FSCH test and the inhomogeneity index is greater at the test temperature of 25 °C than at the test temperature of 50 °C. Although the RSCH test is conducted at 50 °C, the permanent deformations resulted from the test shows the highest correlation with the level of inhomogeneity. The permanent strain decreases significantly with the increase in the level of inhomogeneity. Predicting the performance of the same material in the field based on the properties of laboratory made specimens will lead to over prediction of the field performance and as a result under design of pavements [6].

The Transportek wheel tracking test (TWTT) device was developed to assess the rutting susceptibility of asphalt concrete mixtures. Slab dimensions are typically 340 by 620 mm. The load is applied with a solid rubber wheel, 400 mm in diameter and 100 mm wide. The standard test protocol for TWWT device is to perform the test at 60 °C at a load of 600 kg, which equates to a contact pressure of approximately 900 kPa. TWWT recommend the number of load repetitions to 10 mm of permanent deformation as a basis for comparison. For all the data, 10 mm of rut was achieved after initial bedding-in phase, i.e., the initial rapid accumulation of permanent deformation. A mix that does not reach 10 mm of rutting in 10,000 repetitions is considered to offer good resistance to permanent deformation. These limits have been validated with limited field data. According to the rutting resistance criteria for the dynamic creep test, almost all the mixes have a high rut resistance. The two mixes with a "low" rutting resistance classification are both stone skeleton mixes and, the Gilloolly's BRASO mix (F4) which also has a modified binder. Because the dynamic creep does not correctly determine the rutting resistance of all mixes, and the performance ratings do not agree with the TWTT, the dynamic creep test is not recommended for assessing the rutting potential of hot-mix asphalt concrete other than sand-skeleton mixes manufactured with unmodified binders, unless evaluated in conjunction with other rutting tests [7,8].

In the dynamic creep test, a cylindrical test specimen (a compacted briquette or field core) is subjected to repeated dynamic loads in the axial direction and the accumulated permanent deformation is monitored as a function of the number of load repetitions. Square wave load shape with load duration of one second and a rest period of one second is typically used. The applied load is typically 100 kPa and the test temperature is 40 °C. The test parameter used to evaluate dynamic creep results is the dynamic creep modulus, which is the applied stress divided by the permanent strain. Permanent strain is defined as the strain that accumulates between 30 and 3600 load applications. The permanent strain during the first 30 load applications is excluded to compensate for surface irregularities and to allow a 'settling in' period at the start of the test. Although, generally, wheel tracking tests appear to be well correlated with rutting in the field, there are at present no quantified relationships to link wheel tracking test results to rutting in the field under variable traffic loading and environmental conditions. For this reason, wheel tracking tests cannot as yet be used to provide a quantitative estimate of rutting in the field. The test does, however, provide a reliable estimate of the rutting potential and, hence, can be used to rank mixes according to rut potential. Wheel tracking tests are particularly recommended for the evaluation of rutting performance of stone skeleton mixes, or mixes that include modified binders. Experience has shown that these mix types cannot be properly evaluated by means of conventional tests such as the unconfined uniaxial static or dynamic creep tests [7].

The implementation of a suitable test for assessing resistance to accumulated permanent deformation under repeated loading, which leads to wheel track rutting, is probably the most important requirement for performance-based specifications. This is because a wide range of mixture parameters, not least those associated with the aggregate affects it. By contrast, elastic stiffness and fatigue are principally controlled by binder characteristics and volumetric proportions of the mixture and can be estimated on the basis of past research for conventional materials. It was for these reasons that the uniaxial static creep test was introduced in the 1970s. It is now recognized that repeated loading is a necessary requirement and, hence, the repeated load axial test has been developed. This was done originally very much in the context of mixture design [9].

The dynamic creep test is an interesting alternative to the Wheel-tracking test for measuring the sensibility for permanent deformations, but there is some doubt about the ability of the traditional method to be able to work as a functional method of measurement and to distinguish between different types of mixes. Enlarging the sample to a diameter of 150 mm while the platen is kept at normal size, i.e. 100 mm, accomplishes a limited lateral pressure, which gives more justice to mixes, which get their stability not so much by forces of cohesion but much more so by the inner friction of the aggregate. Trials have shown a much better coefficient of correlation (0.91) with the Wheel-tracking test for the modified model (diameter of sample 150 mm and diameter of platen 100 mm) than for the traditional model (0.36) with the same diameter for sample and platen [10]. 100 mm diameter Marshall Samples were tested in dynamic creep test and obtained controversial results from these two tests for dense mixtures. Unlike this the same diameter was used in earlier study but logical trends were obtained for SMA mixtures [11].

The purpose of this study is to investigate effects of hydrated lime on permanent deformation resistance with repeated creep tests and interrogate Marshall Quotient approach on various sorts of polymer and hydrated lime modified mixtures. Identical many samples were produced and designed damage mechanism was applied on half of samples.