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Laboratory experiment on resilient modulus of BRA modified asphalt mixtures

Muhammad Karami [a,*], Hamid Nikraz [b], Surya Sebayang [a], Laksmi Irianti [a]

[a] Department of Civil Engineering, Lampung University, Bandar Lampung 35145, Indonesia
[b] Department of Civil Engineering, Curtin University, GPO Box U1987, Perth, WA 6845, Australia

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Abstract

The objective of this research is to determine the potential effect on the resilient modulus of asphalt mixtures of using granular Buton Rock Asphalt (BRA) modified binder. The indirect tensile stiffness modulus (ITSM) tests were performed to examine the resilient modulus of unmodified and BRA modified asphalt mixtures for dense graded aggregates of 10 mm (DG10) and 14 mm (DG14) based on standard AS-2891.13.1-1995. In these tests, three percentage of BRA natural binder, including 10%, 20% and 30% by total weight of asphalt binder, were chosen as a substitute for the base asphalt binder in the BRA modified asphalt mixtures, with the purpose of improving the resilient modulus values. According to the test results, the resilient modulus of BRA modified asphalt mixtures was higher as compared to the unmodified asphalt mixtures. A higher percentage of BRA modifier binder content resulted in a higher resilient modulus. Furthermore, the unmodified and BRA modified containing only 20% BRA modified binder of DG10 were tested under different conditions of temperature, rise time, and pulse period. The results indicated that the BRA modified asphalt mixtures containing 20% BRA modified binder were less sensitive to the changes in the temperature, traffic volume and loading frequency. In addition, the substitution of 20% BRA modifier binder reduced the effect of the rest period ratio and loading time on the resilient modulus of the asphalt mixtures.

Keywords: Asphalt mixtures; Granular Buton Rock Asphalt; Resilient modulus

1. Introduction

Resilient modulus is a major input in the flexible pavement design methodology regarding the prediction and understanding of the behaviour of asphalt mixtures. Zoorob and Suparma [1] explain that resilient modulus is a criterion of the asphalt mixture's ability to spread the load and also to control the level of traffic. It is well known that traffic creates a tensile strain on the underside of the asphalt mixture layers which are subjected to fatigue cracking, together with compression strain in the subgrade that can lead to permanent deformation. As Pourtahmasb et al. [2] said, the resilient modulus test can be used to represent conditions in asphalt mixtures subjected to traffic loading and offers the ability of comparing the behaviour of asphalt mixture under various conditions and stress states.

In recent years, the mechanistic approach based on the elastic theory has been used in the philosophy of asphalt pavement design with the aim of changing the previous empirical approach. In this theory, the resilient modulus, as the elastic modulus, is required as input for the elastic

* Corresponding author at: Jurusan Teknik Sipil, Fakultas Teknik Universitas Lampung Jl. Soemantri Brojonegoro No.1 Bandar Lampung 35145, Indonesia.

E-mail address: muhammad.karami@eng.unila.ac.id (M. Karami).

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properties of pavement materials [3,4]. According to studies, obtaining the resilient modulus of asphalt mixtures using the ITSM test is a means of studying the potential elastic properties of asphalt mixtures in the form of stress–strain measurement [5–9]. Lavasani et al. [10] state that the material is considered to be relatively elastic when the material attains a resilient state after a certain critical number of applied loadings.

According to Shafabakhsh and Tanakizadeh [9] and Fakhri and Ghanizadeh [11], the deformation of asphalt mixtures under each load cycle is recoverable and the material is considered to be elastic when a repeated load for a large number of times is small compared to the strength of the materials. Shafabakhsh and Tanakizadeh also state that the resilient modulus is influenced by factors such as test temperature, loading time or loading frequency, rest period and loading pulse waveforms. However, the test temperature has the greatest influence on the resilient modulus [9]. At a typical temperature e.g. 5 °C and high traffic speed e.g. 100 ms rise time, asphalt binder behaves in an almost elastic manner. As a consequence, the resilient modulus is a measure of an asphalt mixture's resistance to bending and hence of its load spreading ability [5]. According to Tayfur et al., the asphalt binder and volumetric proportion of the mixtures influence the stiffness modulus [8].

A number of research studies on resilient modulus have been carried out to investigate the possibility of using Buton asphalt or materials derived from Buton asphalt as a partial material substitute/addition in asphalt mixtures. Subagio et al. [12] reported that the use of asbuton filler in Hot Rolled Asphalt (HRA) improved the resilient modulus and resistance to plastic deformation. The test results of Hot Rolled Asphalt (HRS) with Buton asphalt filler conducted by Subagio et al. [13] revealed that the resilient modulus of HRS modified at a test temperature of 25 °C was lower when compared with unmodified HRS mixtures. By comparison, at a test temperature of 45 °C the resilient modulus of modified HRS was greater than that of the unmodified HRS mixtures. In another experiment, the influence of granular and extracted BRA asphalt binder in asphalt mixtures was investigated by Zamhari et al. [14] They used the ITSM test and dynamic creep test. The results indicated that using granular and extracted asphalt binder in asphalt mixtures increased the stiffness modulus and creep stiffness and decreased the rate of permanent deformation.

Despite the progress of research into the use of Buton asphalt materials [12–14], there are still significant gaps in the research into the resilient modulus properties of BRA modified asphalt mixtures. This is largely due to the complexities of testing magnitude in order to express the response of materials where the temperature and loading time have a significant impact on the behaviour of asphalt mixtures. For example, it is still not known how the rest period, traffic volume, and loading time affect the resilient modulus of BRA modified asphalt mixtures. Furthermore, more sophisticated testing devices and complex parameters are necessary to better understand the response of BRA modified asphalt mixtures. This research, however, considered the use of granular Buton Rock Asphalt (BRA) modifier binder with an aim to improve the resilient modulus of asphalt mixtures.

2. Materials and methods

The determination of the resilient modulus was divided into two stages. The purpose of the first stage was to record the effect on the stiffness modulus of asphalt mixtures of using three percentages (10%, 20% and 30%) of granular BRA modifier binder in two dense aggregate gradations (10 mm and 14 mm), compared to unmodified asphalt mixtures. In this stage, the specimens were tested at under standard conditions. The purpose of the second stage was to find out the effect of temperature, rest period ratio, traffic volume and loading time on the unmodified and BRA modified asphalt mixtures. Hence, the unmodified and BRA modified asphalt mixtures specimens contained only 20% BRA modifier binder were tested under different conditions of temperature, rise time and pulse period.

2.1. Materials

Class-170 (Pen 60/80) base asphalt binder was used for unmodified asphalt mixtures. The binder was classified in accordance with the Australian Standard AS2008 [15]. Three percentages of BRA natural binder, including 10%, 20% and 30% by total weight of asphalt binder, were chosen as a substitute for the base asphalt binder in the BRA modified asphalt mixtures. Specification of the base bitumen and BRA modified bitumen is given in Table 1. The form of the BRA modifier binder (pellets) with a diameter of 7–10 mm used in this study is shown in Fig. 1. Triplicate portions of granular BRA modifier binder were subjected to an extraction process [16]. The test results found that, on average, the granular BRA modifier binders consisted of about 70% mineral and 30% binder by total weight of materials. The particle size distribution of mineral is as follows: 2.36 mm (100%), 1.18 mm (97%), 0.6 mm (92%), 0.3 mm (81%), 0.15 mm (61%) and 0.075 mm (36%).

A crushed granite aggregate from a local quarry in Western Australia was used in all of the mixtures. The unmodified and BRA modified asphalt mixtures used dense graded aggregates of 10 mm and 14 mm based on Specification 504 [17]. In the BRA modified asphalt mixtures, the substitution of the base asphalt binder allowed the proportion of fines passing 2.36 mm to be adjusted as shown in Table 2 with the aim of minimizing the variance in the gradation of aggregates.

2.2. Mix design and specimen preparation

Based on specification 504 [17], dense graded asphalt mixes were assessed in accordance with the standard procedure for the Marshall method of design in order to find out