IOP Conf. Series: Earth and Environmental Science **106** (2018) 012047 doi:10.1088/1755-1315/106/1/012047

Performance of warm mix asphalt with Buton natural asphalt-rubber and zeolite as an additives

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Abstract. The aim of this research is improving of asphalt industry to decrease the fuel consumption by lowering the temperature of mixing and compacting of asphalt mixture. This technology known as Warm Mix Asphalt (WMA). Buton Natural Asphalt Rubber (BNA-R) as a function of the additive has been able to improve the performance of HMA. Zeolit has a function as an additive to lowering the mixing temperature. Aggregate composition using the composition of aggregate grading specifications for airport pavement, with the composition of BNA-R 5% and 10% and Zeolite content of 2%. The mixture have produced Resilient Modulus value by using the Universal Material Testing Apparatus (UMATTA) on optimum bitumen content each of which has been obtained from the Marshall test. Furthermore, the value of permanent deformation of asphalt mixtures tested using Wheel Tracking Machine (WTM). The result shows that BNA-R modified binder for WMA can decrease the rutting potential. The additive of local materials has improved the performance of the WMA for airport pavement with certain restrictions. From this research it is known there have been changes in the characteristics of resilient modulus and permanent deformation due to the addition of BNA-R for type of aggregate composition.
Keywords: aggregate grading, natural asphalt rubber, warm mix asphalt

1. Introduction

The commonly materials used for flexible pavement is Hot Mix Asphalt (HMA) that was produced at high temperature (150 – 190˚C). This temperature will influence the fuel consumption and bad for environment. Warm Mix Asphalt (WMA) is one of innovation in the manufacturing of asphalt mixture that reduce the mixing and compaction temperature about 20-40˚C with involve the organic additives, chemical additives and water-based or water-containing processes [1], [2].

Many advantages of WMA as reported the researcher like reduced emission, lower energy consumption in production of asphalt mixture, better working condition because absence of harmful gasses, longer hauling distances, and extended paving window. Besides, the drawbacks of this mixture still found such are higher costs because there is still a certain reticence to using them, lack of data concerning their long-term performance, greater moisture susceptibility due to lower temperatures and coating and bonding problems [1]. The laboratory evaluation of WMA mixture for use in airport pavement rehabilitation showed that produced or mixed at 30˚C lower than normal can be recommended. This mixture with a coarse gradation exhibited comparable performance compare with the control HMA [3].

Indonesia has many natural deposits such as rock asphalt from Buton Island and zeolite. Some areas in southern Buton Island, Indonesia possess natural rock asphalt resources with deposit of approximately 60,991,554.38 ton (24,352,833.07 barrel oil equivalent). Natural rock asphalt composed of approximately 30% bitumen and 70% mineral [4]. Buton natural asphalt has been applied as an additive or modifier to petroleum asphalt. Because of it has low penetration, the addition of BNA could improve the properties of virgin asphalt [5]. BNA has many forms such like aggregate (raw material), semi extraction and full extraction. BNA-R is a semi extraction of Buton rock asphalt with crumb rubber. The utilization of crumb rubber modified (CRM) bitumen lately more popular because its several benefits such as increasing the stiffness of bitumen, improving the temperature susceptibility, increasing the rutting, decreasing the noisy and maintenance cost [6], [7].

One of WMA types is produced by foaming process. The foaming process is characterized by the injection of small amounts of water directly into the mix chamber or into the hot binder; in fact, when the water is dispersed in hot asphalt, it vaporizes (from contact with the hot asphalt) and it results in a binder expansion with a consequent reduction of the mix viscosity. One of the methodology of this process is water containing technology using synthetic or natural zeolite. Zeolite is one of WMA additives that can be lowering the mixing and compaction temperature because of the foaming processes when heating the mixture [2], [8], [9].

The resilient modulus is the elastic modulus to be used with the elastic theory. It is well known that most of paving materials are not elastic but experience some permanent deformation after load repetition due to traffic. The permanent deformation is one of principal structural distress mode of asphalt mixture. Permanent deformation is an important factor in flexible pavement design. With the increase in traffic load and tire pressure, most of the permanent deformation occurs in the upper layers [10], [11]. The main objective of this research is evaluate the use of additive from local material (BNA-R and Zeolite) on the engineering properties of WMA for airport pavement especially from the point of view of the resilient modulus value and the rate deformation.

2. Research Method

This research use AC WC (Asphalt Concrete Wearing Course) types based on airport pavement standard of Indonesia with the maximum size of aggregate of 19 mm and dense gradation. The BNA-R was use as modifier for virgin asphalt Pen 60/70 from Shell with the content of 5% and 10% of weight of asphalt binder. The virgin asphalt (0% of BNA-R) is still used in this research for comparation.

In warm mix technology where mixing and compaction temperature must lower than hot mix asphalt, the natural zeolite was used in this research. The natural zeolite from Tasikmalaya area West Java that has been activated by chemical process was used in this research because of has the high water content [12]. 2% zeolite of weight of total mixture was used and replace as filler in the aggregate composition. The Marshall test was performed as a standard test for asphalt mixture to obtain the maximum binder content. 5 samples was prepared for every mixture with the content of BNA-R of 0%, 5% and 10%. Based on the optimum binder content, the samples for further test was prepared.

Wheel tracking test (WTT) was used to determine the deformation resistance of mixtures under high temperature. In this method a rubber faced tire moved back and forth in the middle of the 300 x 300 x 50 mm specimen at the speed of 42 passes/min. A high tire-specimen contact pressure of 1.38 MPa was used to fully simulate the aircraft (Boeing 747) loading condition. The specimen was compacted by a rolling compactor, and then held in an environmental chamber for a minimum of 6 h. The test was performed at temperature of 40˚C for an hour.

Resilient Modulus is an important parameter to determine the performance of pavement, to analysis the pavement response to traffic loading. The test was done by measuring the indirect tensile strength in repeated loading using Universal Material Testing Apparatus (UMATTA). Specimens at their optimum bitumen content i.e. mixture with 0%, 5% and 10% BNA-R were made and loaded by diametrical force in pulse loading. This apparatus consists of Control and Data Acquisition System (CDAS), personal computer and related integrated software. The test follows the ASTM Designation D 4123-82. Data inputted were condition pulse count = 5, condition pulse period = 3,000 ms, test pulse period = 2,000 ms, rise time = 50 ms, peak loading force = 1,000 N and estimated poisons ratio = 0.4. The temperature of test was selected as room temperature of 25˚C, 35˚C and 45˚C.

3. Results and Discussion

The optimum binder content which obtained from the Marshall test is 5.9%, 5.5% and 5.4% for warm mix asphalt with content of BNA-R 0%, 5% and 10% respectively. All mixtures have stability over 1,000 kg where this is the minimum value required of AC-WC mixtures for airport pavement. The addition of BNA-R as modifier for warm mix asphalt not give significant enhancement on stability value.

The result of resilient modulus test using UMATTA is concluded as shown in Table 1. With the addition of BNA-R to the WMA, the value of resilient modulus looked increasing in 5% of BNA-R but decrease at 10%. Federal Aviation Association (FAA) stated the minimum value resilient modulus for the surface of flexible pavement at 32˚C of airport viz 1,320 MPa. All mixture (with or without BNA-R) can fulfill the requirement at the temperature of test of 25˚C. While at the test temperature test of 35˚C and 45˚C, all mixture failed to fulfill. The highest value of resilient modulus has shown by WMA mixture with 5% of BNA-R for all test temperature.

Table 1. Characteristics of WMA with BNA-R modifier.

Type of WMA	Optimum Binder Content (%)	Temperature of Test (˚C)	Resilient Modulus (MPa)
0% BNA-R	5.9	25	3,053
		35	853
		45	338
5% BNA-R	5.5	25	4,386
		35	1,016
		45	400
10% BNA-R	5.4	25	3,156
		35	745
		45	363

From the wheel tracking test using wheel tracking machine at the temperature test of 40˚C, the result of WMA with asphalt binder modified by BNA-R shown in Figure 1. In deformation in mm, the addition of BNA-R as asphalt modifier give the significant influence in decreasing deformation value. It means that the rutting potential can be lowered by modify the asphalt binder with BNA-R.

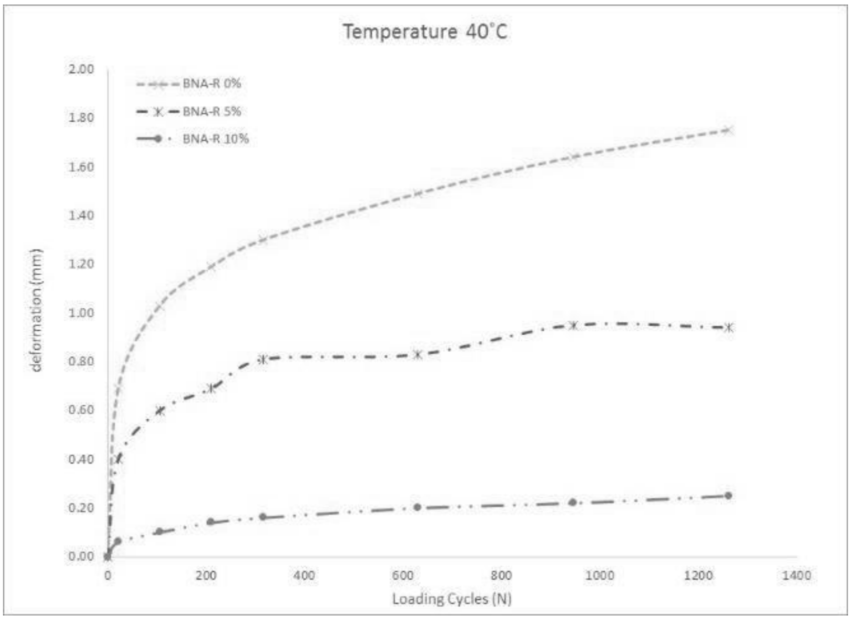

Figure 1. Deformation characteristic of WMA.

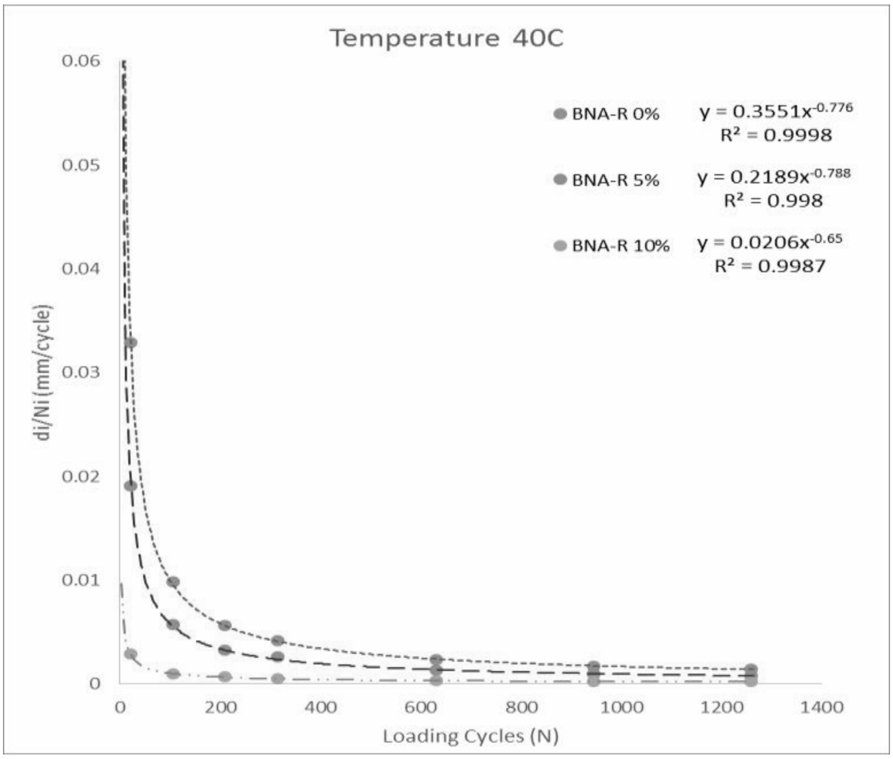

Figure 2. Rate of deformation performance of WMA.

The rate of deformation (di/Ni) versus the cycle Ni for different samples types and temperatures of 40˚ C is shown in Figure 2. At the beginning of the loading time, the value di/Ni is high, and the value decreases rapidly to near zero. Figure 2 show that the relationship between di/Ni and Ni is a power function that can be written as:

$$di/Ni = a.(Ni)^{-b} \quad (1)$$

or

$$di = Ni.a.(Ni)^{-b} \quad (2)$$

The parameter of "$.a$" and "b" can be identified by a series of wheel tracking machine test. The value b is almost same at the same test temperature.

4. Conclusion

The summary and conclusion based on the results of the research presented in this paper are the local material can be used as an additive or modifier on the asphalt mixture. BNA-R modifier can enhance the ability of asphalt mixture to withstand the loading that presented in stability value at the certain content. And zeolite powder can use as filler to help reducing the temperature of mixing and compaction. The warm mix asphalt (WMA) with local materials (BNA-R and Zeolite) still can used as pavement material at airport with certain restrictions. Further research is needed to evaluate the potential of warm mix asphalt as the pavement material.

Acknowledgment
The authors wish to thank Directorate of Research and Community Service at the Universitas Indonesia for their funding towards this research through Hibah PITTA. The experimental work was completed at

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the laboratory of Structure and Material of Universitas Indonesia and the laboratory of Research Centre and Development for Road and Bridge – Ministry of Public Works Republic of Indonesia.

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