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Characterization of an Asphalt Concrete Binder Course Mixture Using Asbuton Granular Asphalt

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Abstract: Indonesia has natural asphalt known as asbuton. Bitumen content in asbuton varies from 10-40% and even reaches 90% in several areas such as Kabungka and Lawele. Asbuton has a sufficient deposit of approximately 677 million metric tons which is equivalent to 24 million tons of oil asphalt. This study used Scanning Electron Microscopy (SEM) and Electron Dispersive X-ray spectroscopy (EDX) to determine the chemical composition of Buton Granular Asphalt (BGA). A compressive strength test was performed to investigate the effect of using BGA in the asphalt mixture on strain. The EDX analysis results showed that BGA consists of Carbon (C), Oxygen (O), Calcium (Ca), Silicon (Si), Sulfur (S), Fluorine (F) and Aluminum (Al). Carbon which has a content of 43.1% is the most dominant element in BGA, followed by oxygen 38.3% and sulfur 1.5%. The asphalt mixture with 5% BGA showed a 25% increase in compressive strength and a maximum of stress of 3.54 MPa.

Key words: Buton granular asphalt, SEM, EDX, asphalt concrete, asphalt mixture, dominant element

INTRODUCTION

In recent years, asphalt production industry has changed a lot due to many changes resulting from the use of waste materials in the mixture. Per day, numerous waste material of factory activity, industrial, service sector and domestic waste water plant is produced in the world (Gaus *et al*., 2014). Currently, Indonesia still imports petroleum asphalt to satisfy the domestic need for asphalt in rehabilitation and new road construction even if the use of local materials has been promoted to reduce the importation of petroleum asphalt 60/70. However, Indonesia has local asphalt that has yet to be fully utilized. It is found on the island of Buton in Southeast Sulawesi (Kurniadji, 2006).

Deposits of asbuton total approximately 677 million metric tons and their mineral content is approximately 20-80% (Furgon, 2006). Using asbuton in Hot-Mix Asphalt (HMA) can affect the binder properties and the Marshall stability of the asphalt mixture (Gaus *et al*., 2014, 2015). Granular asbuton is divided into two types: Buton Granular Asphalt (BGA) and Lawele Granular Asphalt (LGA).

Asphalt concrete modified with various polymer additives is highly resistant to cracking (Tayfur *et al*., 2007). The stress-strain relationship for asphalt concrete in compression is used to describe the limit of elasticity (Karami and Nikraz, 2015). Compared with compression, lateral movement more strongly contributes to permanent deformation (Long, 2001). In a previous study (Karami and Nikraz, 2015), the fatigue lives of Buton rock asphalt-modified asphalt mixtures were found to be higher than those of unmodified asphalt mixtures at the test temperature and under tensile strain. In another study, another type of paving material, stone matrix asphalt was developed to be more resistant to permanent deformation (Suaryana, 2016). These studies show that binder type influences the compressive strength of an asphalt mixture and that the compressive strength of modified asphalt is higher than that of HMA. Notably, the compressive strength of HMA compacted horizontally was found to be lower than that of the HMA compacted vertically, indicating anisotropy in the compressive strength of HMA (Kongkitkul *et al*., 2014).

MATERIALS AND METHODS

The asphalt mixture consists of natural crushed stone aggregate, petroleum asphalt 60/70 as the asphalt binder and BGA from mechanically crushed asbuton (Anonymous, 2006).

Buton granular asphalt: BGA has a relatively uniform grain size with the maximum being 1.18 mm. Table 1

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Table 1: Properties of BGA

Parameters	Values
Bitumen content of BGA (%)	23.00
Asphalt mineral levels (%)	77.00
Water content (%)	1.700
Penetration of bitumen (dmm)	16.00
Melting point of bitumen (°C)	86.00
Flash point before extract (°C)	168.0

Fig. 1: Grain of BGA

shows the properties of BGA. The mineral content of BGA is 77%. The mineral extracted from BGA forms a filler with a maximum size of 0.127 mm and serves as fine aggregate in the Asphalt Concrete Binder Course (AC-BC) mixture.

The 23% bitumen content of BGA was used as a substitute for petroleum asphalt bitumen in the asphalt mixture (Fig. 1).

Petroleum asphalt: Asphalt concrete mixtures in Indonesia generally use petroleum bitumen 60/70. The standard properties of this asphalt are shown in Table 2. Asphalt is a chemical compound consisting of hydrocarbons, nitrogen and other chemical compounds. Table 3 shows the Electron Dispersive X-ray spectroscopy (EDX) analysis results of petroleum asphalt.

Figure 2 shows the Scanning Electron Microscopy (SEM) image of petroleum asphalt 60/70. Carbon which is the main constituent of petroleum asphalt, accounts for 93.5% of the asphalt weight.

Aggregates: Crushed stone and river sand were used as coarse aggregate and fine aggregate, respectively. Both aggregates were sourced from the Jeneberang River in Gowa, Indonesia. The physical properties of the coarse aggregate and fine aggregate are shown in Table 4.

Table 2: Properties of petroleum asphalt

Parameters	Values
Penetration (25°C)	65.0
Softening Point (°C)	52.0
Flashpoint (°C)	310
Ductility (25°C)	110
Specific gravity	1.01
Weight (with TFOT)	0.20
Penetration after TFOT	54.0
Ductility after TFOT	25.0

Table 3: Chemical composition of petroleum asphalt

Elements	Percentage
Carbon	93.50
Oxygen	4.800
Sulfur	1.700

Table 4: Properties of the course aggregate and fine aggregate

Parameters	Values
Coarse aggregate	
Abrasion (%))	22.64
Affinity to asphalt (%)	96.00
Particle flat and oval	8.21
Material through sieve No. 200	0.00
Absorption (%)	2.37
Bulk density	2.55
SSD density	2.61
Apparent density	2.72
Fine aggregate	
Sand equivalent value	83.40
Material through sieve No. 200	7.00
Angularity	90.00
Absorption (%)	2.29
Bulk density	2.55
SSD density	2.61
Apparent density	2.71

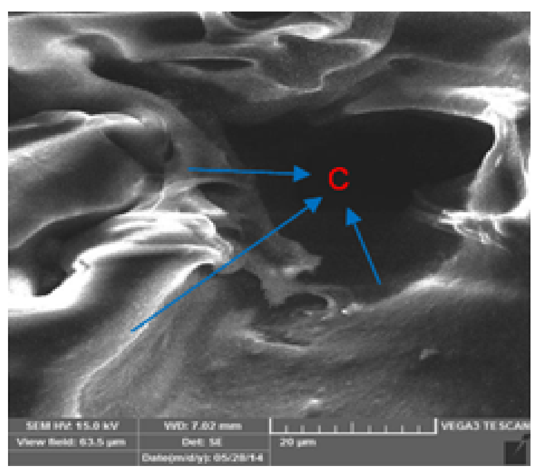

Fig. 2: Scanning electron microscopy image of petroleum asphalt

Asphalt concrete mixtures: In this study, three asphalt concrete mixtures were examined: the AC-BC mixture without BGA, the AC-BC mixture with 5% BGA and the AC-BC mixture with 8% BGA. All mixtures used the

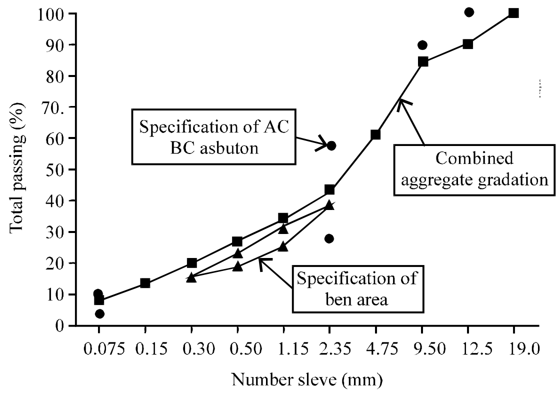

Fig. 3: Combined aggregate gradation

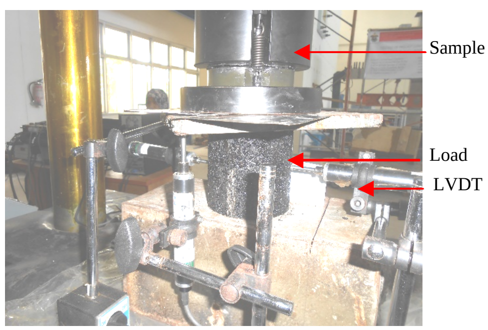

Fig. 4: Setup for the compressive strength test

aggregate combination shown in Fig. 3. The aggregate combination satisfied the requirement for AC-BC mixtures with BGA.

The asphalt bitumen and aggregates of each AC-BC mixture were mixed at a temperature of 150°C and compacted into a cylindrical mold with a capacity of 1,200 g and a diameter of 101.6 mm. The samples were compacted with 0.75 on each face.

Scanning electron microscopy: SEM imaging was performed to generate 2D and 3D images to examine the microstructures and chemical compositions of petroleum asphalt and BGA.

Compressive strength test: A compressive strength test was conducted to measure the stress values and the horizontal and vertical deformations of the samples during failure. The samples were tested using a universal testing machine and the deformations were measured using a linear variable differential transducer and recorded by a data logger. Figure 4 shows the setup for the compressive strength test. The samples were shaped into cylinders with a diameter of 101.6 mm and a height of 100 mm. Triplicate samples were prepared for each AC-BC mixture.

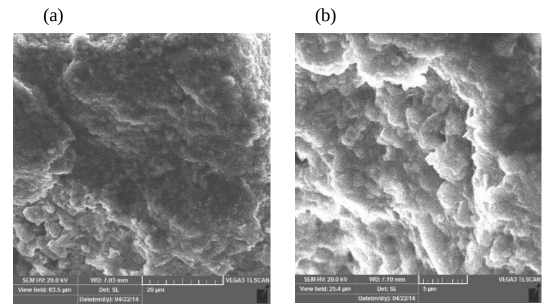

Fig. 5: SEM image of AC-BC mixture without BGA

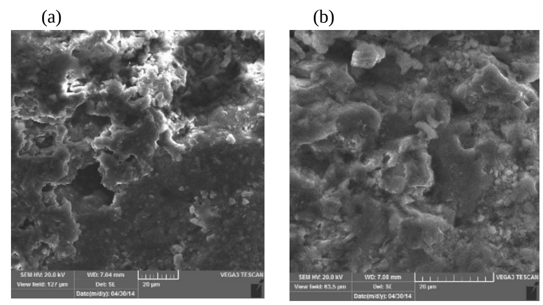

Fig. 6: SEM image of AC-BC mixture with 5% BGA

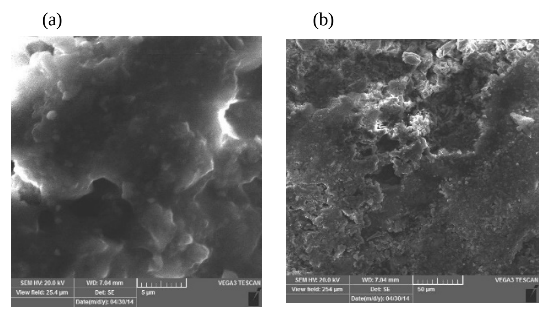

Fig. 7: SEM image of AC-BC mixture with 8% BGA

RESULTS AND DISCUSSION

EDX and SEM analysis results of the AC-BC mixture: The EDX analysis results showed that the BGA consists of Carbon (C), Oxygen (O), Calcium (Ca), Silicon (Si), Sulfur (S), Fluorine (F) and Aluminum (Al). Carbon which has a content of 43.1% is the most dominant element in BGA whereas sulfur has a content of 1.5%. Sulfur may replace carbon in terms of function, however, the former is more reactive and reacts quickly with oxygen. Thus, the sulfur content in asphalt should be minimized so as not to degrade the properties of the HMA.

Figure 5-7 show the 2D SEM images of the AC-BC mixture with and without BGA. The SEM analysis results showed that the chemical compounds in the asphalt concrete mixture with 5% BGA included SiO_2, Al_2O_3, Na_2O,

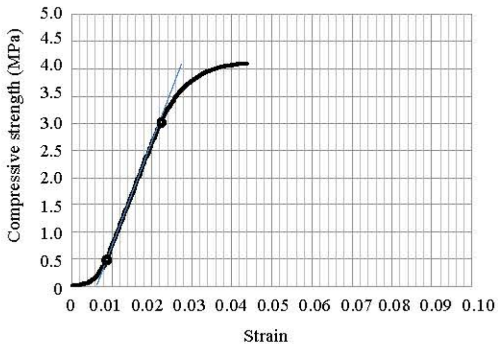

Fig. 8: Stress-strain curve of AC-BC mixture without BGA

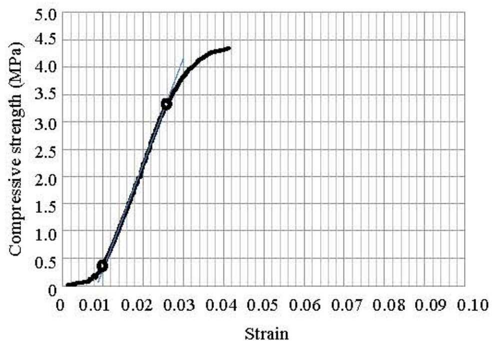

Fig. 9: Stress-strain curve of AC-BC mixture with 5% BGA

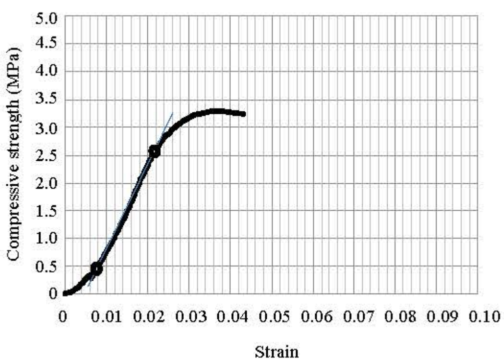

Fig. 10: Stress-strain AC-BC mixture with 8% BGA

SO_3 and MgO whose contents were 0.29, 0.57, 0.72, 95.36 and 1.06%, respectively. Chemical compounds with minimal contents included CaO, TiO_2, P_2O_5, FeO, chlorine and fluorine.

Compressive strength: The compressive strength test results for the AC-BC mixture with BGA are shown in Fig. 8.

The stress-strain curves in Fig. 9 and 10 which indicate the crack formation in the samples of the AC-BC mixtures with BGA can be divided into three stages: an initial non-linear curve, a subsequent linear curve and a final non-linear curve. Figure 9 shows that a strain of 0.008 mm by 0.022 mm forms a linear curve with a maximum stress of 0.5 MPa. Figure 10 shows a linear curve. Figure 9 shows the effect of the strain on the compressive strength of AC-BC mixture with 5% BGA. The linear curve shows a strain of 0.01-0.026 with a stress higher than the asphalt mixture without BGA. Figure 10 shows the compressive strength-strain relationship of the AC-BC mixture with 8% BGA. The strain curve is linear from 0.01-0.24 and similar to the strain curve of the AC-BC asphalt with 5% BGA.

The use of 5% BGA in HMA increased compressive strength by 25% and allowed for a maximum of stress of 3.54 MPa. The presence of sulfur, calcium and iron compounds as well as other metal compounds in the BGA had a positive effect on HMA. However, the HMA with 8% BGA exhibited decreased compressive strength, thus BGA should be added sparingly.

Natural BGA contains lime and sulfur which have a destructive nature in excessive amounts. For example, certain amounts of sulfur in asphalt will have a positive effect as it can replace the function of carbon. However, excessive additions of sulfur will increase the fragility of HMA.

The large grains of asbuton may also contain a large amount of water, consequently, the strength of the HMA may decrease when large grains of asbuton are used. The drawback of asbuton was reduced when the moisture content of BGA was less than or equal to 2%. Likewise, calcium had a negative effect on HMA. However, the calcium in BGA could not be eliminated because bitumen blended with the BGA grains. BGA containing calcium is sensitive to water or temperature changes. Thus, the calcium content must be reduced because it cannot be separated from the grain.

In the HMA samples, BGA was used as a substitute mineral filler. Thus, the BGA used as an HMA filler can be increased, albeit not significantly, nevertheless, differences in the nature of the filler of the aggregate and BGA affected the characteristics of the HMA.

All samples were likely to experience failure when the strain reached 0.04. The AC-BC mixtures with BGA had higher stress values than the mixture without BGA. This result indicates that the AC-BC mixtures with BGA are more resistant to deformation caused by a static load. This outcome can be attributed to the following:

- The filler found in BGA can fill the voids in asphalt mixtures and consequently increase stability
- The filler adds rigidity to the mixture as a result, the mixture becomes more resistant to loads

- The magnesium, aluminum and iron content in BGA can increase the rigidity of the mixture

CONCLUSION

The chemical compounds in BGA include SiO_2, Al_2O_3, MgO, K_2O, CaO, TiO_2, P_2O_5, SO_3, FeO, chlorine and fluorine with CaO, SiO_2 and FeO being dominant with a weight percentage of 80%. The chemical compounds in asphalt concrete mixtures with 5% BGA are SiO_2, Al_2O_3, Na_2O, SO_3 and MgO with SO_3 they had a weight percentage of more than 95% in the asphalt mixture. AC-BC mixtures with BGA can bear a greater load than the mixture without BGA, indicating that the asphalt concrete mixture with BGA is more resistant to cracking because of permanent deformation.

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REFERENCES

Anonymous, 2006. Specification hot mix asphalt with processing as Buton. Ministry of Public works, Directorate General of Highways, Jakarta, Indonesia.

Furgon, A., 2006. Characteristics of bituminous granular as Buton for hot mixture asphalt. Ministry Publ. Works Agency Res. Dev. Inst. Road Eng. Bridge J., 25: 350-368.

Gaus, A., M.W. Tjaronge, N. Ali and R. Djamaluddin, 2014. Experimental study on characteristics of Asphalt Concrete Bearing Coarse (ACBC) mixture using Buton Granular Asphalt (BGA). Intl. J. Appl. Eng. Res., 9: 18037-18045.

Gaus, A., M.W. Tjaronge, N. Ali and R. Djamaluddin, 2015. Compressive strength of Asphalt Concrete Binder Course (AC-BC) mixture using Buton Granular Asphalt (BGA). Procedia Eng., 125: 657-662.

Karami, M. and H. Nikraz, 2015. Using advanced materials of granular BRA modifier binder to improve the flexural fatigue performance of asphalt mixtures. Procedia Eng., 125: 452-460.

Kongkitkul, W., N. Musika, C. Tongnuapad, P. Jongpradist and S. Youwai, 2014. Anisotropy in compressive strength and elastic stiffness of normal and polymer-modified asphalts. Soils Found., 54: 94-108.

Kurniadji, N., 2006. Overview on as Buton addition in hot mix asphalt in terms of technical and financial. Road Bridge J., 23: 327-349.

Long, F.M., 2001. Permanent deformation of asphalt concrete pavement: A nonlinear viscoelastic approach to mix analysis and design. Ph.D Thesis, University of California, Berkeley, California.

Suaryana, N., 2016. Performance evaluation of stone matrix asphalt using Indonesian natural rock asphalt as stabilizer. Intl. J. Pavement Res. Technol., 9: 387-392.

Tayfur, S., H. Ozen and A. Aksoy, 2007. Investigation of rutting performance of asphalt mixtures containing polymer modifiers. Constr. Build. Mater., 21: 328-337.