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Compressive strength of asphalt concrete binder course (AC-BC) mixture using buton granular asphalt (BGA)

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Abstract

This study aims to evaluate the compressive stress-strain relationship of asphalt concrete mixtures using Buton granular asphalt (BGA) as partial replacement for petroleum asphalt in asphalt concrete bearing course (AC-BC) mixture production. The experimental tests show that the stress-vertical strains curve and stress-horizontal strains curve pattern were similar for all mixtures. The application of BGA as partially replaced petroleum asphalt in the AC-BC mixture improved the compressive strength and elastic modulus in comparison to AC-BC mixture without BGA. No significant difference in the Poisson ratio for all mixtures was observed.

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Keywords: Buton Granular Asphalt; Compressive Strength; Strain; Stress

1. Introduction

Annually, Indonesia imports approximately 600.000 tonnes of petroleum asphalt that arises on the national consumption of bitumen asphalt to construct and maintain new flexible pavements. It is therefore needed to explore national bitumen resources to decrease the amount of imported petroleum asphalt [1,2].

Lawele region in south Buton area, possess natural rock asphalt reserve with amount approximately 60 million tons (24 million barrel oil equipment) [6]. Buton granural asphalt (BGA) is produced by crushing the natural rock asphalt to the maximum size of 1.16 mm which is homogenized. The utilization of BGA, in addition to supporting road infrastructure development contributes directly to national economic growth. During the last decades, buton rock

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asphalt produced with granular shape has been investigated in order to use it in the road construction as asphalt wearing course (AC-WC) [1, 2]. Gaus et al. (2014) investigated characteristics of asphalt concrete bearing coarse (AC-BC) mixture using buton granular asphalt (BGA) [3].

The traffic loads induce short term compressive stress at the road pavement surface. The bearing course layer, base-sub base layer and sub grade will bear the load. Asphalt concrete bearing course (AS BC) is designed for a layer that can bear the traffic load. BGA alone is not enough for the purpose of mixing to have proper asphalt mixture therefore BGA have to be used with petroleum bitumen. This research use BGA as partial replacement for petroleum bitumen in order to produce AC-BC mixture. The objectives of this paper were (1) to investigate the stress strain relationship of AC-BC mixture without BGA (only use petroleum bitumen) and AC-BC mixture with BGA under short term monotonic compressive load; and (2) to compare Elastic modulus and Poison ratio as regard to the mixture without BGA and with BGA.

2. Materials and Methods

2.1. Buton Granular Asphalt (BGA)

BGA has a relatively uniform grain size with a maximum grain size of 1.18 mm. Table 1 shows the properties of the BGA. Fig.1 shows the dimensions of BGA.

Table 1. Some Properties of BGA

Parameter	Value
Bitumen Content of BGA (%)	23.00
Asphalt Mineral Levels (%)	77.00
Water Content (%)	1.70
Flash Point Before Extract (ºC)	168
Penetration of Bitumen BGA Extract (dmm)	16
Melting Point of Bitumen BGA Extract (ºC)	86

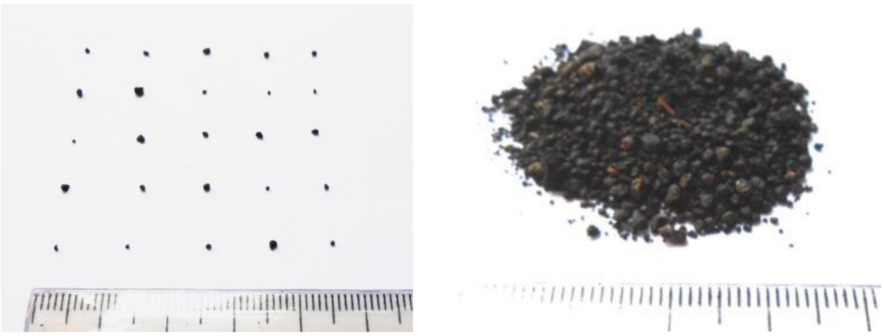


Fig. 1. Buton Granular Asphalt, BGA (dimension in mm)

2.2. Petroleum Asphalt

Asphalt concrete mixtures in Indonesia generally use petroleum bitumen grade 60/70. Standard properties of the petroleum bitumen grade 60/70 are shown in Table 2.

2.3. Aggregates

Crushed river stone and river sand were used as coarse aggregate and fine aggregate, respectively. These aggregates were from Jeneberang River, Gowa Indonesia. The physical properties of coarse aggregate and fine aggregate are showed in Table 3.

Table 2. Some Properties of petroleum bitumen grade 60/70

Parameter	Value
Penetration (25ºC)	65
Softening Point (ºC)	52
Flashpoint (ºC)	310
Parameter	Value
Ductility (25ºC)	110
Specific Gravity	1.01
Weight (with TFOT) (%)	0.2
Penetration After TFOT (25ºC)	54
Ductility After TFOT (25ºC)	25
Penetration (25ºC)	65
Softening Point (ºC)	52

Table 3. Some Properties Of Petroleum Asphalt

Parameter	Value
Coarse Aggregate	65
Abrasion (%))	22.64
Affinity to Asphalt (%)	96
Particle flat and oval (%)	8.21
Material through sieve No. 200 (%)	0
Absorption (%)	2.37
Bulk Density	2.55
SSD Density	2.61
Apparent Density	2.72
Fine aggregate	
Sand equivalent value (%)	83.4
Material through sieve No. 200 (%)	7
Angularity (%)	90
Absorption (%)	2.29
Bulk Density	2.55
SSD Density	2.61
Apparent Density	2.71

2.4. Asphalt Mixtures and aggregates grading combination

The total bitumen content was determined at 5.5% by weight of asphalt mixture. This research prepared AC-BC mixture without BGA, AC-BC mixture with 5% of BGA (contains bitumen from BGA 1.15% and petroleum bitumen 4.35% by mixture weight), and AC-BC mixture with 8% of BGA(contains bitumen from BGA 1.84% and petroleum bitumen 3.66% by mixture weight). All mixtures used aggregates grading combination as shown in Figure 2. The aggregate grading combination met the requirement of mixture AC-BC with BGA [4].

Asphalt bitumen and aggregates of all AC-BC mixtures were mixed at temperature of 150ºC, and compacted into the cylindrical mold with capacity of 1,200 gram and diameter of 101.6 mm. The specimens were compacted with 75 blows each face by using Marshall compactor.

2.5. *Compressive Strength Test*

Starodubsky et. al, (1994) investigated the stress-strain relationship for asphalt concrete in compression to described the limit of elasticity [5]. Compressive strength test was conducted according to ASTM D6931 – 12. Axial strain were derived via two linear variable differential tranducers (LVDTs) measuring platen-to-platen displacement. Two LVDTs are mounted diametercally opposite one another to measure horizontal strain. The recording equipment consists of digital interface unit (data logger) connected to a computer that utilized to monitor and record data from the load actuator and LVDTs.

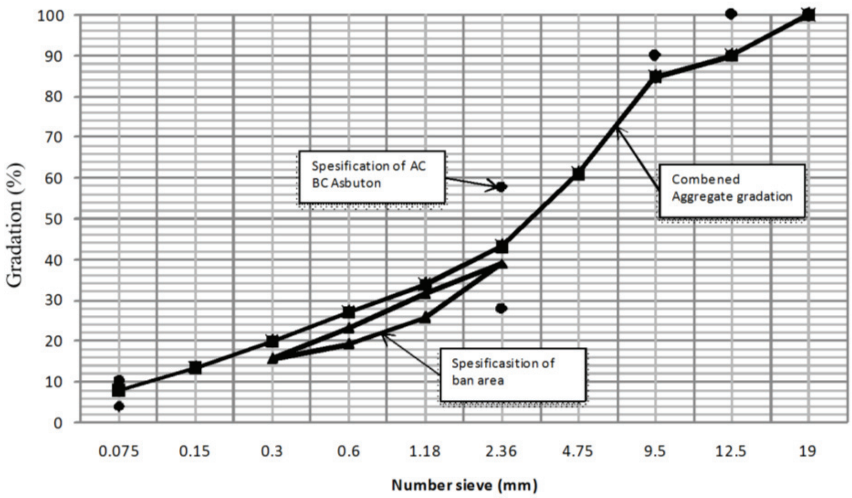
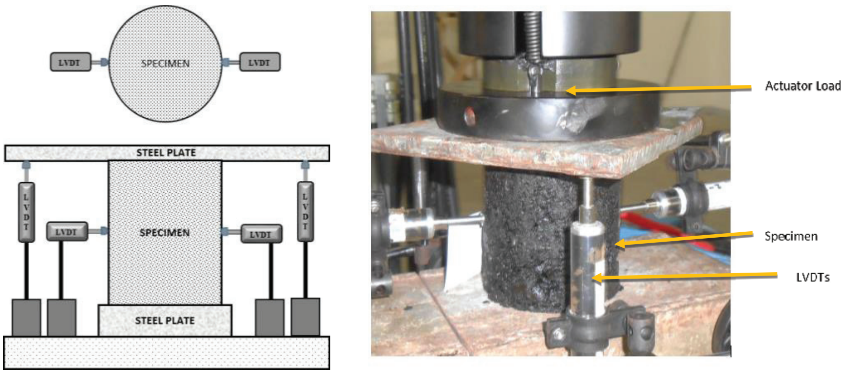


Fig. 2. Combined Aggregate Gradation Using 5% BGA.



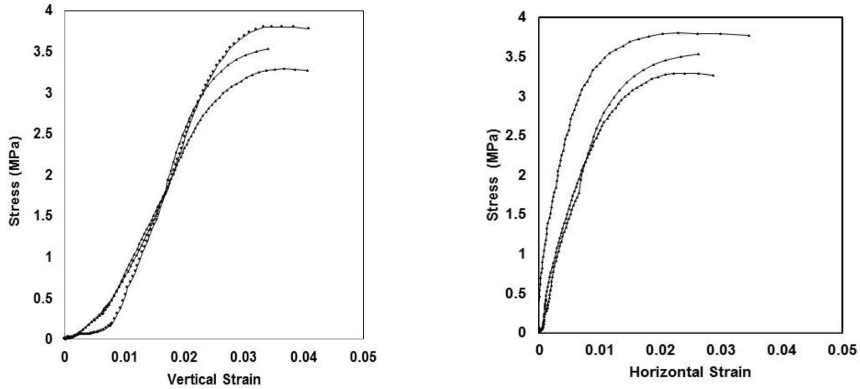
(a) Plan view at mid height side view (b) Specimen and LVDTs

Fig. 3. Equipment of compressive strength test.

3. Results and Discussion

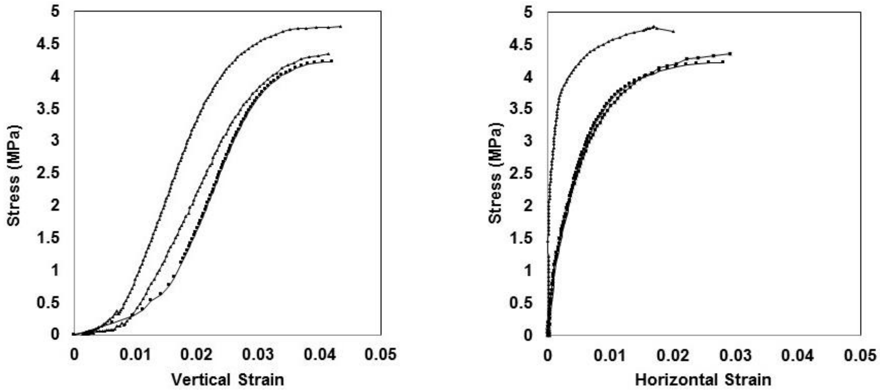
3.1. Stress-strain curve of asphalt concrete

The vertical and horizontal strains were measured up to the peak stress. The stress strain relationship of specimens subjected to short term monotonic compressive load are presented graphically in Fig. 4 to Fig. 6. Figs. 4(a), 5(a) and 6(a) show that the stress- vertical strains curve consists of three parts. The first part shows the initial bottom concave that reflects the settling of specimens arises up to approximately 0.4MPa. The second part shows the linear zone that represents the elasticity arises up to approximately 80% of peak stress. The third part shows the nonlinear zone arise up to peak stress.



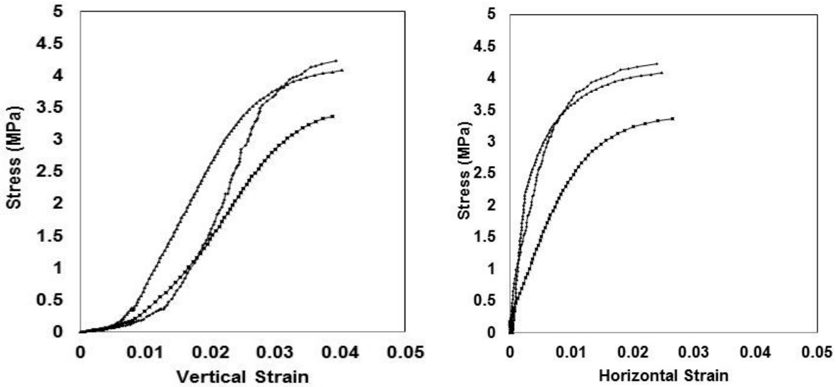
(a) (b)

Fig. 4. Stress-strain curves of AC-BC mixture without BGA.



(a) (b)

Fig. 5. Stress-strain curves of AC-BC mixture using 5% BGA.



(a) (b)

Fig. 6. Stress-strain curves of AC-BC mixture using 8% BGA.

AC-BC mixture without BGA, AC-BC mixture with 5% of BGA and AC-BC mixture with 8% of BGA had compressive strength of 3.53, 4.45, and 3.88 MPa, respectively. All samples that use BGA showed higher strength values than the asphalt mixture without BGA. All samples failed when the vertical strain and horizontal strain reached 0.04 and 0.03, respectively.

Figs. 4(b), 5(b) and 6(b) show that the stress- horizontal strains curve consist of two parts. The first part shows the initial bottom concave that reflects the settling of specimens arises up to approximately 0.4MPa. The first part shows the linear zone that represents the elasticity arises up to approximately 50% of peak stress. The second part shows the nonlinear zone arises up to peak stress.

Asphalt mixture using BGA obtain the stress value is higher than the mixture without BGA. This indicates that the asphalt mixture with BGA is more resistant to deformation caused by the short term monotonic compressive load. The reason that makes the asphalt mixture AC-BC with BGA can withstand higher stress is the filler within BGA can fill the voids in asphalt mixtures that contribute to the higher stability.

3.2. *Elastic Modulus and Poisson Ratio*

Table 4 shows the Elastic modulus (E) and Poisson ratio that measured under short term monotonic compression load. The Elastic modulus and Poisson ratio were corresponded to the 80% of peak load. The elastic modulus of AC-BC contains BGA is higher than the elastic modulus of AC-BC without BGA. The result tests show no significant difference in the Poisson ratio for all mixtures.

Table 4. Elastic modulus and Stress of AC-BC mixture

Type Asphalt	Elasticity (MPa)	σ_{max} (MPa)	Poisson ratio (v) at 80% of ultimate stress
Without BGA	327.95	3.53	0.37
With 5% BGA	410.82	4.45	0.33
With 8% BGA	415.00	3.88	0.31

4. Conclusions

1. Stress-vertical strains curve and stress-horizontal strains curve pattern were similar for specimens irrespective of BGA content.
2. The application of BGA as partially replacement petroleum asphalt in the AC-BC mixture resulted in an improvement of compressive stress and elasticity modulus in comparison to AC-BC mixture without BGA.
3. No significant difference in the Poisson ratio for all mixtures.

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