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Effect of portland composite cement and buton granular asphalt on indirect tensile strength of emulsified asphalt cold mix using limestone aggregate

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Abstract. The research is laboratory experimental purposing to analyze effects of Portland Composite Cement (PCC) and Buton Granular Asphalt (BGA) on Indirect Tensile Strength (ITS) of Emulsified Asphalt Cold Mix (EACM) using limestone aggregate. The EACM is designed as Asphalt Concrete-Wearing Course (AC-WC). The material of EACM contains emulsified asphalt CSS-1h, BGA 50/30, PCC, and Limestone Aggregate. The specimen consisted of Bitumen 8% of total weight, BGA 8% of total weight, and PCC 0%, 1.5%, and 2% of total weight. The specimen is classified into 5 groups, namely P0B0, P0B8, P1.5B8, P2B0, and P2B8. PCC is used as partial substitutions of limestones filler. BGA is used as partial substitutions of bitumen emulsion and partially substitutions of filler or and fine aggregate. The specimens of EACM having 101 mm in diameter and 63.5 mm in height ware tested by UTM apparatus with Horizontal Linear Variable Displacement Transducer (LVDT) 10 mm and vertical LVDT 25 mm according to ASTM D 6931 – 12. The result of this study concludes that the use of PCC and BGA increased ITS of EACM. Both P1.5B8 and P2B8 Specimens met maximal performance, where Indirect Tensile Strength of them 2.8 times ITS of P0B0.

1. Introduction

Nowadays, the utilization of Cold Asphalt technology has dramatically grown in worldwide. The cold mixed asphalt has environmental and economic advantages compared to hot asphalt mixtures. However, the emulsion asphalt mixture has inadequate performance, and it is susceptible to early service damage due to precipitation [1]. To improve the mechanical properties of the cold mixed asphalt, it has been done with the addition of cement. EACM using cement increased Marshall Stability and Stiffness Modulus. Modulus stiffness of EACM was lower than that of Hot Mix Asphalt [2]. In the long term, characteristic of EACM would be better caused by increasing of dynamical modulus [3, 4]. In dry conditions and wet conditions, the used cement in EACM increased Indirect Tensile Strength. Cement used less than 0.5%, Performance of EACM is not good on water damage and early aging. The use of cement being more than 1.5%, the performance of EACM on rutting resistance does not change. The optimum cement content is 1.5 [4, 5].

Some studies of the use of BGA in hot mixed asphalt show that the use of BGA can increase the modulus of elasticity, increase unconfined compressive strength, good rutting resistance (increased dynamic stability), reduce bleeding problems, and give sufficient flexibility. While the weakness of the use of BGA is the release of higher granules but still in the requirements, and tend to be more fragile [6-8]. Meanwhile, the study showed that the Stability of AECM using BGA and Limestone Aggregate is lower than the Stability of EACM using BGA and Standard Aggregate [9].

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In Indonesia, the potential of local materials for road construction needs has not been optimally utilized, including natural asphalt and limestone aggregate. The natural asphalt located in Buton Island-Southeast Sulawesi Province has a potential of 677 million tons [10]. It is estimated to be equivalent to 150 million tonnes of Petroleum Asphalt. Meanwhile, the potential of limestone is about 639.36 billion tonnes spread throughout Indonesia [11].

To optimize the utilization of local material: BGA, limestone, and cement containing fly ash waste/PCC, it is necessary to use the local material for road construction. This study purposes of analyzing the effects of PCC and BGA on Indirect Tensile Strength of EACM cold mixed asphalt using limestone aggregates.

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2. Materials and methods

2.1. Materials

2.1.1. Aggregates

The source of limestone aggregate is taken in Muna Regency, Southeast Sulawesi Province. The aggregate consisting of Coarse Aggregate, Fine Aggregate, and Filler met Indonesia National Standard for Road Pavement Development. The physical characteristics of coarse aggregates have a Los Angeles abrasion value of 27.5%, pH of 9.4, Bulk Specific Gravity of 2.53 gr/cc, and Water Absorption of 2.03%. The physical characteristics of fine aggregate have Bulk Specific Gravity of 2.5 gr/cc and Water Absorption of 3.94%. The aggregate gradation was designed for the Asphalt Concrete Wearing Course (AC-WC). The ideal gradation is shown in figure 1.

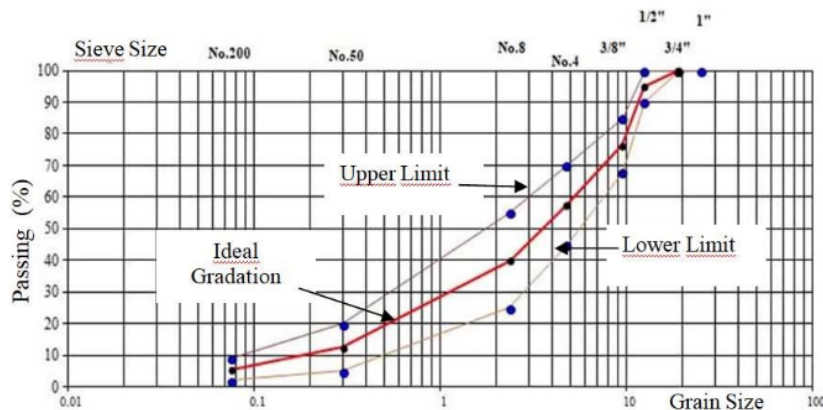


Figure 1. Aggregate Gradation Design of EACM

2.1.2. Portland composite cement

PCC used was one of the cement factories in Indonesian. The result of laboratory was carried out in 2016 showing that mineralogical characteristics of PCC contain 61.79% CaO, 18.39% SiO₂, 5.15% Al₂O₃, 3.41% Fe₂O₃, 1.81% SiO₃, 0.99% MgO, 4.61% Loss Ignition, and 2.78% Insoluble Residue. The PCC used has grain size passed No. 200 sieve. It contributes to an active filler.

2.1.3. Emulsified asphalt

Based on Laboratory Test carried out by Balai Besar Pelaksanaan Jalan Nasional XIII Makassar in 2016, Characteristics of Emulsified asphalt type CSS-1h used in the study are: a penetration value of 101, bitumen residues content of 64.35 %, and water content of 35.65%.

2.1.4. Buton Granular Asphalt (BGA)

BGA-50/30 used acts as a partial substitution of emulsified asphalt residues. In addition, the minerals contained in BGA are also used to replace limestone fillers or fine aggregates. Residual bitumen and mineral of BGA was tested according to SNI 03 – 3640, which obtained Residual bitumen content of 32,10%, and Mineral content of 66.36%. Meanwhile, the water content of BGA was tested according to SNI 06-2490-1991, which obtained water content of 1.54%. Grain and Mineral Size of BGA were tested according to SNI 03 – 4142. The testing result of grain and mineral size are shown in table 1.

Table 1. Grain and Mineral Size of BGA-50/30

Sieve Size	Grain of BGA	Mineral of BGA
	Passing (%)	Passing (%)
No. 8	100	100.00
No. 16	59.86	98.13
No. 30	32.91	93.85
No. 50	12.66	87.73
No. 100	3.28	58.35
No. 200	0.82	39.42

2.2. Preparation of specimen and methodology

2.2.1. Preparation of specimen

Indirect Tensile Test uses cylindrical specimens of Marshall having dimensions of 101 mm in diameter and 63.5 mm in height. The specimens is classified into 5 groups: POB0, POB8, P2B0, P1.5B8, and P2B8. All specimens were made with 8% optimum bitumen content of the total weight. Specimens using BGA were made with 8% BGA content of the total weight which determined based on volumetric parameters, especially the VIM parameter, to meet 3-12%. Meanwhile, the PCC used was 1.5% and 2% of the total weight. Each variation of the mixture is made as many as 3 specimens. The proportion of PCC, BGA 50/30, and emulsified asphalt CSS-1h based on variations of specimens is shown in table 2.

Table 2. The proportion of PCC, BGA 50/30, and Emulsified Asphalt CSS-1h in EACM

No	Group	PCC Content (%)	BGA Content (%)	Bitumen Content of BGA (%)	Bitumen Content of Emulsified Asphalt (%)	Emulsified Asphalt Content (%)
1	POB0	0	0	0	8	12.43
2	P2B0	2.0	0	0	8	12.43
3	POB8	0	8	2.57	5.43	8.44
4	P1.5B8	1.5	8	2.57	5.43	8.44
5	P2 B8	2.0	8	2.57	5.43	8.44

2.2.2. Testing methodology

ITS testing used UTM Apparatus attached data logger. Testing Procedure according to on [12]. The testing uses a static load of 80 KPa and a speed of 50.8 mm/min. The width of the line load is 1/2 inch. Linear Variable Displacement Transducer (LVDT) is used to measure changes in test objects in the horizontal direction and vertical direction. ITS testing is carried out at a temperature of 25°C. The ITS testing scheme is shown in figure 2.



Figure 2. Scheme of ITS Testing

2.2.3. Data analysis

The result of ITS test was analyzed using Equation 1.

$$ITS = \frac{2P}{\pi D t} \dots\dots\dots (1)$$

where :

- ITS = Indirect Tensile Strength on the center of the specimen (MPa)
- P = Maximum Compressive Load (N)
- t = Thickness of specimen (mm)
- D = Diameter of specimen (mm)

A comparison between the control specimen (POB0) and other specimens is stated in ITS Index calculated using equation 2.

$$ITS Indeks = \frac{ITS_i}{ITS_o} \dots\dots\dots (2)$$

Where:

- ITS_i = ITS of specimen-i (MPa)
- ITS_o = ITS of control specimen (MPa)

The slope of the elastic stiffness modulus indicating ratio of load and vertical or horizontal displacement in elastic condition analyzed use equation 3.

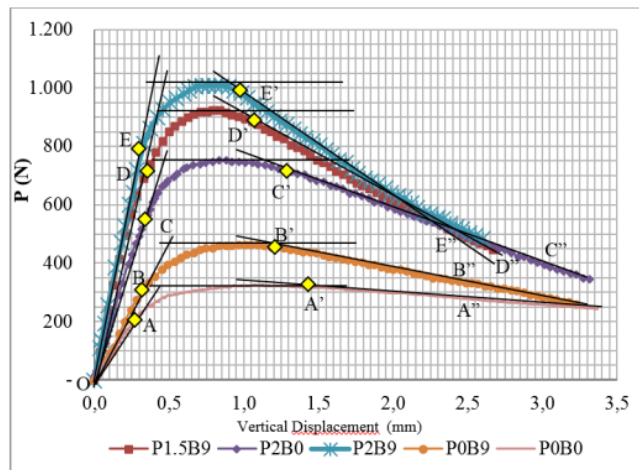
$$SM = \frac{P}{\Delta} \dots\dots\dots (3)$$

Where:

- SM = slope of the elastic stiffness modulus (N/mm)
- P = Maximum Load (N)
- Δ = Displacement (mm)

3 Results and discussion

Relationship between Load and Vertical Displacement during the loading process can be divided into 3 segments, namely segments forming positive linear lines (OA, OB, OC, OD, and O7), parabolic curve segments (AA', BB', C6, DD', and EE'), and segments forming negative linear lines (A'A", B'B", C'C", D'D", and E'E"). The relationship between the Load and the Vertical Displacement of the EACM specimen is shown in figure 3.



13 **Figure 3.** Relationship between Load and Vertical Displacement of AECM specimens

Positive linear lines illustrate the slope of the elastic stiffness modulus. Parabolic curve segments describe specimens undergoing hardening and gradually failing to exceed the maximum load. The negative linear segment describes the test object having failed until it collapses. In figure 3, it can be seen that the specimens P2B8, P1.5B8, P2B0, P0B9, and P0B0 have the slope of the elastic stiffness modulus 2.4 KN/mm, 2.3 KN/mm, 2.1 KN/mm, 1.0 KN/mm, and 0.8 KN/mm respectively. Increasing the elastic stiffness modulus of AECM is followed by increasing the maximum load of the AECM specimen.

The relationship between Load and horizontal displacement of AECM specimen is shown in figure 4. The slope of the elastic modulus stiffness of the specimens P2B8, P1.5B8, P2B0, P0B9, and P0B0 specimen are 50.4 KN/mm, 23.0 KN/mm, 13.2 KN/mm, 7.7 KN/mm, and 3.2 KN/mm respectively.

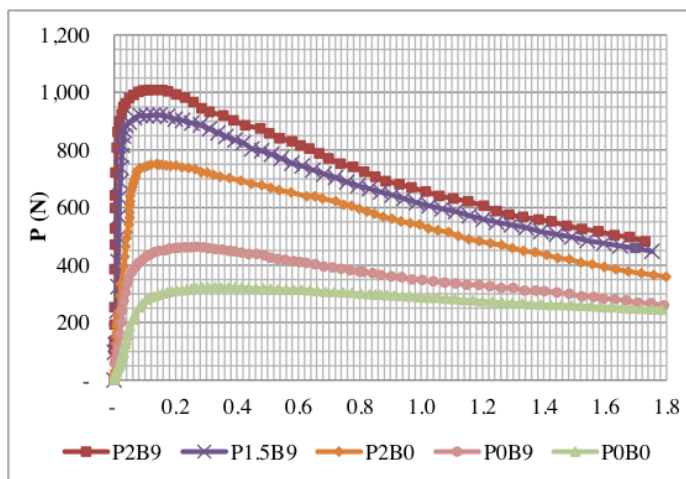


Figure 4. Relationship between K TTL and Horizontal strain of CAED specimen

The crack pattern of the results of ITS Testing forms a vertical line parallel in the direction of loading. The crack pattern of the AAECM specimen after ITS testing is shown in figure 5.

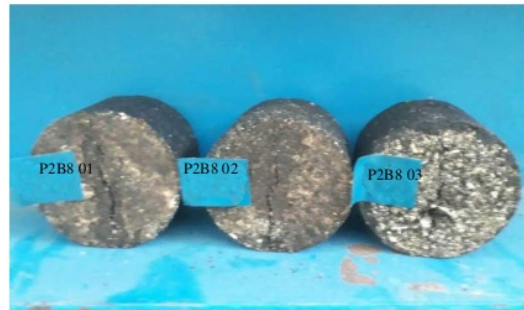


Figure 5. The crack pattern of the ITS Specimen

The synergy of using PCC and BGA is very effective in increasing ITS of EACM specimens. This shows that the water contained in Emulsified Asphalt and PCC can form a hydration process that goes well in EACM using Limestone Aggregates. Besides, BGA substituting bitumen of emulsified asphalt also effectively increases the ITS of EACM specimens in dry conditions.

The use of PCC as a substitute for limestone filler as much as 2% of the total weight (P2B0 specimen) resulted in ITS of 75.79 KPa or an increase of 134% compared to the P0B0 Control specimen. The use of 8% of BGA substituting residual bitumen of emulsified asphalt and limestone fillers (P0B8 specimen) resulted from ITS of 44.28 KPa or increased by 37% compared to the Control specimen (P0B0). The use of 1.5% PCC and 8% BGA (P1.5B8) resulted in ITS of 89.42 KPa or an increase ITS of 176%. Furthermore, the ITS of EACM specimens used 2% PCC, and 8% BGA (P2B8) was relatively similar to the ITS of P1.5B8 specimens, ie 89.91 KPa or increased ITS by 177% compared to the control specimens. Accordingly, the ITS Index of P2B8, P15B8, P2B0, P0B8, and P0B0 are 2.8; 2.8; 2.3; 1.8; and 1 respectively. The analysis of ITS on each variation of EACM specimens and the ITS Index on the Maximum load is shown in Table 8.

Table 3. ITS and ITS Index of EACM specimens using PCC, BGA 50/30, and Limestone Aggregate

Group of Specimen	P0B0	P0B8	P1.5B8	P2B0	P2B8
P max (KN)	0.32	0.462	0.990	0.758	1.035
ITS (KPa)	32.42	44.28	89.42	75.79	89.91
ITS Index	1.00	1.4	2.8	2.3	2.8

4. Conclusions

The result of this study concludes that the use of PCC and BGA increased ITS of EACM. Both P1.5B8 and P2B8 specimens met maximal performance, where Indirect Tensile Strength of them 2.8 times ITS of P0B0.

4. Acknowledgments

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