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Influence of Water Immersion on Physical Properties of Porous Asphalt Containing Liquid Asbuton as Bituminous Asphalt Binder

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ABSTRACT

The connected voids of the porous asphalt allow water to flow within the surface road. The natural rock asphalt from the Buton Island, Indonesia, can be refined without addition of petroleum asphalt to reduce the mineral content in the production of the liquid Asbuton. The present research is part of ongoing project that intends to study the potential use of liquid Asbuton as bituminous asphalt binder of porous asphalt. This paper provides the informations concerning the chemical compounds, microstructure and the rheological properties of liquid Asbuton. The specimens of porous asphalt that prepared by utilizing the liquid Asbuton have the average porosity of 16.6% and permeability of 0.25 cm/sec. After immersed into the water with temperature of 25 or 60^{o} Celsius and the immersion time was up to 2 hours, the specimens were tested to study the influence of water immersion on the raveling resistance and the indirect tensile strength.

Keywords. liquid Asbuton, water immersion, raveling resistance, indirect tensile strength,

INTRODUCTION

The service life of infrastructures made of asphalt are largely reduced by the climate and weather actions such as rainy condition. The flood or aquaplaning that are generated by the rainy condition are one of the primary factor of the performance degradation and rapid aging of asphalt pavement. The utilization of material that durable to the climate and weather actions will reduce the use of new material for repair and maintenance, thus can improve service life and sustain the development of infrastructures made of asphalt. The sedimentary rock containing of high hydrocarbon substances naturally occurs in the southern area of Buton Island Indonesia. The deposit of solid bitumen resources are approximately 60,991,554.38 tons (24,352,833.07 barrel oil equivalent). The solid bitumen resources are deposited in the lime-sandstone of the Tondo Formation and in the sandy-limestone rock of Sampolakosa Formations. The both formations sources likely come from Winto Formation (Triassic) and considered as the solid bitumen-bearing formation (Suryana. A, 2003).

The solid bitumen or natural rock asphalt is namely Buton asphalt or Asbuton that basically consists of approximately 30% of bitumen and 70% of minerals such as limestone or sandstone. A refining process without addition of the petroleum asphalt can reduce the mineral content to produce another form of Buton asphalt product that called liquid Asbuton.

Annually 1.2 million tons of bitumen are requisited to maintenance and construct the asphalt pavements in Indonesia. The national refineries can supply about 600.000 tons of bitumen that consist of 500,000 tons of petroleum bitumen and 100,000 tons of Buton asphalt, therefore approximately 600,000 tons of the petroleum bitumen must be imported to fulfill the national consumption (F. Affandi, 2009). By empowering the utilization of Buton asphalt product such as the liquid Asbuton can reduce the consumption of petroleum bitumen, thus can improve the national and regional infrastructure sustainabilty development.

In Indonesia, the heavy precipitation of high intensity rainfall always creates temporary flood on the surface road in the low land area up to several tens of minutes before flows into the drainage. The utilization of porous asphalt as a wearing course of pavement can overcome the temporary flood problem that occurred from rainfall.

Porous asphalt consists mainly of open graded coarse aggregate with small amounts of fine aggregate and filler. Porosity and permeability within the porous asphalts are formed by the skeleton of the open graded aggregate. In rainy conditions, its porosity absorbs rainfall, allows water to drain freely through it, reduces aquaplaning, provides less splash-spray, and keeps its high skid resistance. Thus, it can improve safety and reduce traffic accident (B. K. Ferguson, 2005). Porous asphalt is widely used in many countries such as Netherland (M.Miradi et.al, 2009), Japan (K. Nishijima et.al, 2009), and Malaysia (F. Hanim et.al, 2009).

The present research is part of ongoing project that intends to study the suitability of liquid Asbuton as bituminous asphalt binder in production of porous asphalt. This paper reported the test results those are carried out to study the effect of the rain water and hot temperature on the ravelling resistance and the indirect strength of the porous asphalt utilizing liquid Asbuton as bituminous asphalt binder.

MATERIALS AND EXPERIMENTAL METHODS

Rheological Properties, Chemical Compounds and Microstructure of Liquid Asbuton. Rheological properties, chemical composition and microstructure of liquid Asbuton are shown in Table, Table 2 and Figure 1, respectively. Penetration value of 47.3 (unit: 0.1 mm) in Table 1 shows that liquid Asbuton is harder than the petroleum bitumen with 60/70 penetration grade. Density value of liquid Asbuton is 1.26. Test of solubility in C_2HCL_3 points that the liquid Asbuton consists approximately 30% of mineral and 70% of bitumen, respectively. Approximately 30% of mineral are within the liquid Asbuton as shown in Figure 1. The higher penetration value and density of liquid Asbuton than the pure petroleum bitumen are attributed to the mineral content within the liquid Asbuton.

Table 1. Rheological Properties of Liquid Asbuton

No.	Properties	Value	Unit
1.	Penetration at 25°C	47.3	0.1 mm
2.	Softening Point	57.25	°C
3.	Ductility	67.45	cm
4.	Solubility in C_2 HCL_3	72.9	% wt
5.	Flash Point	201.4	°C
6.	Density	1.26	
7.	Loss on Heating TFOT	1.41	% wt
8.	Penetration after loss on heating	76.33	%
9.	Viscosity 170 Cst (Temp. mixing)	169	°C
10.	Viscosity 280 Cst (Temp. compaction)	152	°C

Table 2. Chemical Compositions of Liquid Asbuton

Element	Mass (%)	Compound	Mass (%)
C	65.93	C	65.93
Al	1.74	Al_2O_3	3.30
Si	3.12	SiO_2	6.68
S	6.76	SO_3	16.888
Ca	5.15	CaO	7.21
Total	100	Total	100

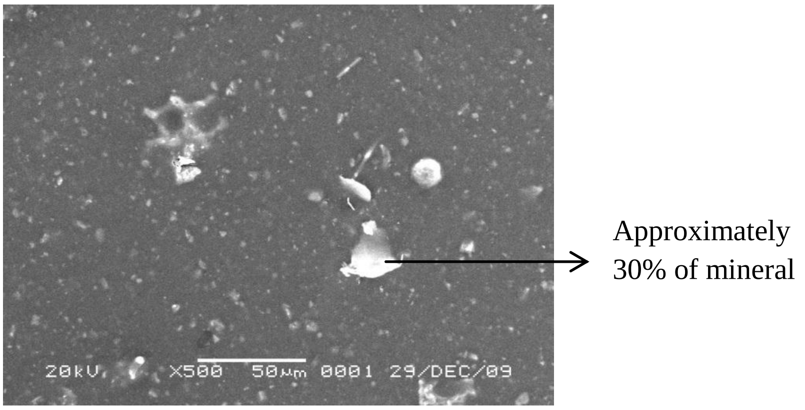

Figure 1. Microstructures of liquid Asbuton

Physical Properties of Aggregates. The physical properties of aggregates are shown in Table 3. This research utilized the open graded crushed stone and the river sand as coarse aggregate and as fine aggregate, respectively. A small amount of sand was added to form a matrix that controls the cohesiveness and flow of mixture.

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Table 3. Physical Properties of Aggregates

No.	Properties	Crushed stone	Sand
1	Specific Gravity		
	a. Bulk / Dry	2.60	2.55
	b. Surface Saturated Dry	2.65	2.61
	c. Apparent	2.74	2.71
2	Abrasion (%)	25.72	-
3	Unit Weight (kg/m^3)		
	a. Loss	1.30	1.08
	b. Compact	1.49	1.32
4	Flanknes (%)	10.23	-
5	Sand Equivalent (%)	-	85.71
6	Absorption (%)	1.89	2.35

Mixture of Porous Asphalt. There were some trial mixes and the preliminary tests were conducted to gain the composition of porous asphalt. Porous asphalt was designed with porosity of 15±2.5%. The porosity is the volume of the air voids as percentage of total volume of a specimen. Contain of liquid Asbuton was 9% (with approximately 6% of bitumen equivalent). The composition of the coarse aggregate and fine aggregate are 90% and 10%, respectively. Where coarse aggregate consisting of crushed stone with diameter of 3/8 " and 1/2" are 50% and 50%, respectively.

Immersion Time and Temperature. The standard Marshall mold with capacity of the 1,200 g sample was used to prepare the specimens. All specimens were compacted with a Marshall compactor using 2x50 blows. In this research, the specimens of porous asphalt were immersed in the tap water for 30 minutes, 6, 12, 18 and 24 hours with two immersion temperatures of 25 and 60ºC.

Evaluation of Raveling Resistance (Cantabro Test). The abrasive action of vehicle wheels on pavement surfacing leads to a material loss which known as raveling. The Cantabro test was conducted to evaluate the raveling resistance or material loss of porous asphalt mixture. Some recommendations of doing Cantabro test are describe in Table 4.

Table 4. Some recommendations for Cantabro Test

No	Institution	Material loss
1	NAPA IS 115 (National Asphalt Pavement Association)	At a temperature of 25^{0}C, it shall not exceed 30%.
2	PIARC Technical Committee (Permanent International Association of Road Congress)	It must be less than 30% for a test temperature of 18%, and 25% (sometimes even 20%) for a test temperature of 25^{0}C.
3	NCAT Report No. 2000-01 (National Center for Asphalt Technology)	At a temperature of 25^{0}C, the recommended maximum permitted material loss value for freshly compacted specimens is 20%

Indirect Tensile Strength Test. The vehicles wheels generate the tensile stress within the wearing course made of porous asphalt. Indirect tensile strength test was carried out to evaluate the tensile stress resistance of specimens. In the test, the Marshall stabilty equipment was used to give compression loading along the vertical diameter of the specimens.

RESULTS AND DISCUSSIONS

Mechanical Properties of Specimen. The porosity and permeability of all specimens were measured before the stability tests, Cantabro test and indirect tensile strength test were carried out. The stability and flow of specimens was tested in accordance with ASTM D6937-06. Table 5 shows some mechanical properties of specimens. The porosity of 16.6% and permeability of 0.25 cm/sec show that all of the materials form the interconnected voids properly within the porous asphalt thus water drain freely. The flow of 30 mm and stability of 8.8 kN show that the porous asphalt made of liquid Asbuton can be used as a wearing course for the normal traffic load with sufficient flexibility.

Table 5. Some Mechanical Properties of Specimens

No.	Property	Value
1	Porosity (%)	16.6
2	Permeability (cm/sec)	0.25
3	Flow (mm)	3
4	Stability (kN)	8.8

Influence of Immersion Time and Temperature on Raveling Resistance and Tensile Strength. The asphalt mixture should be compacted to create the bonding between bituminous asphalt binder and aggregates. The adhesive and cohesive of bituminous asphalt binder govern the resistance of asphalt pavement from raveling. Figure 2 shows the cantabro test result on the specimens those have been immersed in water. By adding the immersion time and temperature, it will weaken the cohesion of liquid Asbuton, furthermore decrease the adhesive force between liquid Asbuton and aggregates. The failure of cohesion and adhesive force generate progressive material loss or raveling. For all immersion times and temperatures, the porous asphalt can maintain material loss below than 25%, it pointed that for all immersion time and temperature, the asphalt porous made of liquid Asbuton met the recommendations of NAPA, and PIARC. Only at immersion time of 24 hours and temperature of 60ºC, the material loss did not satisfy the recommendations of NCAT.

Figure 3 illustrates that increasing in immersion time and temperature have influence on decreasing in tensile strength of porous asphalt. Explaination of this result was when the asphalt porous undergone tensile stress, coupled with the water immersion and hot temperaure that make decreasing in cohesive and adhesive force, thus weaken the tensile strength of porous asphalt.

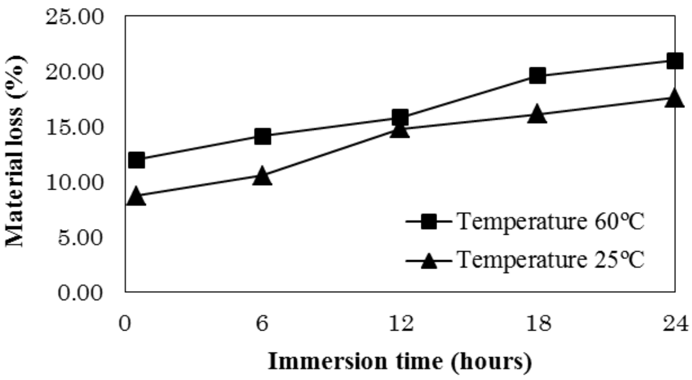

Figure 2. Influence of immersion time and temperature on material loss

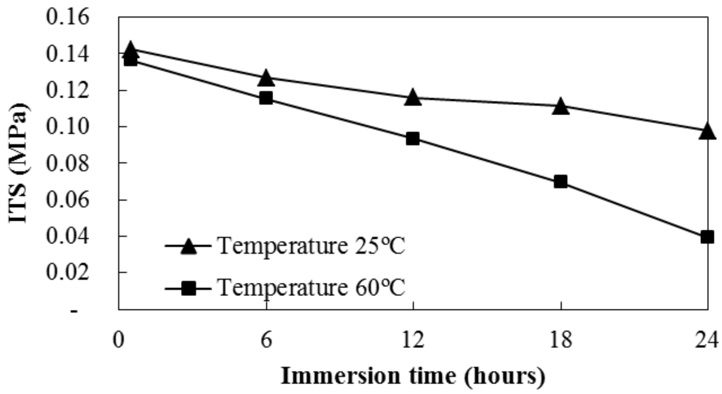

Figure 3. Influence of immersion time and temperature on tensile strength

CONCLUDING REMARKS

For all immersion times and temperatures, the value of material loss was lower than 25%. It can be concluded that the use of of liquid Asbuton as bitumious binder could improve its susceptibility of materrial loss. However, tensile strength will decrease as increasing in immersion time and temperature.

Porous asphalt have been extensively utilized as wearing course of road pavement in developed countries for many years but its application within Indonesia is few in numbers. More over, the utilization of liquid Asbuton as bituminious binder of road pavement is only recent. Therefore, it needs many researchs to improve the durability of porous asphalt made of liquid Asbuton with incorporation other materials to address the climate and weather actions.

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