Characterization of Physical Properties and Morphological Ruberized Asphalt Paving Blocks based on Bituminous Coal and Concentrated Natural Rubber Latex

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Abstract: This research about the characterization physical properties and morphological ruberized asphalt paving block using asphalt as a binder replacement and utilization of natural resources such as bituminous coal and natural rubber latex concentrate (NRLC). This research aims to determine the optimum value of physical properties and learn the effect of morphological control on the paving block that have been prepared. Morphological control with varied the composition asphalt, bituminous coal, and natural rubber latex concentrate that mixed using by an internal mixer with addition of aggregates and additive agents such as dicumyl peroxide as an initiator and divinylbenzene as a crosslinker. After the mixing process, then the mixture on shaping/forming process. The result of physical properties obtained optimum value at the variation of composition asphalt : bituminous coal : natural rubber latex concentrate (70:25:5)(Paving Block E). The percentage of water absorption is 0.85 % and compressive strenght is 154.23 Kgf (0.605 Mpa). At this optimum variation of composition has been characterized the morphological using by Scanning Electron Microscopy (SEM) which is the result of surface morphology showed the mixture compactly and most effective homogenity of the mixture.

1 INTRODUCTION

Infrastructure is a benchmark for developing a country. Infrastructure development in developing countries like Indonesia is urgently needed. One of them is infrastructure in the field of road pavement. The road pavement material used is paving block.

Interest in the use of paving blocks because it can be applied to many areas such as parking lots, residential streets, home yards, parks, industrial areas, and other open spaces. Increased use of paving blocks due to paving blocks including environmentally friendly construction, good water absorption ability, faster installation, lower cost, diverse shades and colors so as to increase aesthetic value (Hastuty et al., 2018). Based on ([Standar Nasional Indonesia] SNI-03-0691-1996, n.d.), the constituent components of paving blocks are made from a mixture of portland cement or other adhesives with aggregates using or without the addition of other materials which do not reduce the quality of paving blocks.

Research on paving blocks has been carried out by adding or replacing components in paving blocks. The use of rice husk ash and lime as a partial substitution of cement, addition of coconut shell, use of spent catalyst waste. However, the physical properties produced on the ability of water absorption do not meet the water absorption standards on paving blocks. The chemical composition of the constituent of paving blocks also influences the characteristics of paving blocks, such as physical, mechanical, and morphological characteristics. One of the efforts made to improve these characteristics is polymer modification.

Asphalt can also be used as a substitute for cement. Asphalt contains a long hydrocarbon chain, where the longer the hydrocarbon chain content will affect its polarity, so that the paving block produced physical properties on good water absorption ability, the use of cold mild catalyst waste results in better water absorption. The characteristics of binder substitutes such as asphalt can be modified with other polymer materials. Asphalt modification can also be

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done by using natural binders (natural binders) such as pine resin (Yuniarti, 2015).

Rubber plants have been supporting the Indonesian economy, since a few decades ago, but the performance of rubber is less than optimal. Indonesia is one of the countries with the largest rubber plantations in the world, but its productivity is still far behind that of other natural rubber producing countries. Natural rubber is an efficient polymer added to asphalt. Asphalt modification has been done by Kartika (2017) using fresh natural latex rubber.

Modification of asphalt has been carried out with commercial liquid bitumen and (Kartika, 2017). Bitumen can be classified into liquid bitumen and solid bitumen. The source of solid bitumen is coal.

Coal is an option that needs to be developed as much as possible, because coal is a natural resource whose availability and distribution is very abundant in Indonesia. One rank of coal is bitumen coal. The rank of coal which is widely spread in Indonesia is bitumen coal. Bitumen coal is an organic and inorganic macromolecule. The chemical composition of bitumen coal contains the main elements namely C, H, O, N, S, P. Based on ([WCI] World Coal Institute, 2005) data, coal quality depends on the hydrocarbon group (Rajan et al., 2017). Bitumen has been applied as adhesives, sealants, waterproof agents, and binders on road pavement construction materials (Zhu et al., 2014).

Modification of bitumen with other polymers is the incorporation of polymers in bitumen by mechanical mixing or chemical reaction. Fresh natural latex with a combination of liquid bitumen (Kartika, 2017) has an effect on increasing the characteristics of asphalt. Fresh natural latex contains 60% water and 40% rubber (Suksup et al., 2017). The water content also influences the characteristics of paving blocks. To optimize the performance of natural rubber can be done with concentration and centrifugation to produce concentrated latex with more rubber content that is 60% and reduce water content to 40% (Suksup et al., 2017). In addition, the performance of natural rubber can be improved by chemical modification by grafting techniques using a compatible agent such as a crosslinker such as divinyl benzene (Ritonga et al., 2018). Thus, it can increase the stability and density of asphalt mixes (NorFazira et al., 2016).

In the mixture of asphalt with aggregate, bitumen, concentrated latex will only occur physical bonds. The use of dicumil peroxide (DCP) as an initiator and divinyl benzene (DVB) as a crosslinker in the mixture, the polymers used in asphalt, concentrated latex or bitumen will be radical. This radicalism encourages chemical bonds between concentrated latex, asphalt, bitumen ie covalent bonds.

Based on the description, researcher interest in research about the Characterization of Physical Properties and Morphological Ruberized Asphalt Paving Block Based on Bituminous Coal and Concentrated Natural Rubber Latex (CNRL) with the addition of dicumyl peroxide (DCP) initiators and divinyl benzene crosslinker (DVB).

2 MATERIALS AND METHODS

2.1 Materials

Bituminous coal from PT. Amber and Coal Sumatra, Asphalt from Iran Type Grade 60/70, Concentrated latex from PT. Bridgestone Sumatera Rubber Estate, Divinyl benzene (DVB) from Sigma-Aldrich, Dikumil Peroxide (DCP) from Sigma-Aldrich, Aggregate from Pebble Stone from CV. Setia Jaya, Fine Sand Aggregate from CV. Setia Jaya

2.2 Preparation of Paving Blocks

5 ml of concentrated latex was put into a 50 ml glass beaker and heated at 70 °C. Then put 70 ml of asphalt into the beaker while heated. Then both of them were mixed while being heated at 140 °C for 15 minutes, then added 25 grams of solid bitumen while stirring. The mixture was added 0.9 ml DVB and stirred for 10 minutes. 300 grams of sand and 50 grams of gravel were added to the mixture while still stirring, then added 0.9 grams of DCP while still stirring for 10 minutes under the same heating. The mixture is then put into a cube mold. Then the molds are put into a hydrolyc press which has been set at 140 °C for 30 minutes, then cooled to room temperature.

Table 1: Variation Asphalt, Bituminous Coal, and CNRL.

Paving block	Asphalt (mL)	Bituminous Coal (gram)	CNRL (mL)
A	70	5	25
B	70	10	20
C	70	15	15
D	70	20	10
E	70	25	5
F	80	0	20
G	80	20	0

2.3 Characterization

2.3.1 Water Absorption Test

Water absorption test to find out the amount of water absorption by polymer asphalt that has been made refer to ASTM C C140 / C140M-15 by weighing and recording it as a dry mass (Mk). Then soak the sample in water for 24 hours then lift the sample and the surface is dried with a tissue, then weigh the sample weight after soaking and recorded as a saturated mass (Mj) and calculate the value of water absorption test using equation:

$$\% \, WA = \frac{Mj - Mk}{Mk} \, x \, 100 \, \%$$

2.3.2 Compressive Strength Test

Analysis of mechanical properties by compressive strength test The tool used in the compressive test is GOTECH AI - 7000M with a capacity of 2000 Kg.f and refers to ASTM D-790 / C-293, with a sample testing procedure in the form of a cube with a 5 cm side in accordance with ASTM C-348-2002 by placing a sample placed on a compressive testing machine. Loading is given until the test object collapses, ie when the maximum load is working. The maximum load is recorded as P max. Then calculate the compressive strength test value using equation then the value of the compressive strength test of polymer asphalt can be determined by using the equation :

$$P = \frac{Max \, Load}{Ao}$$

2.3.3 Surface Morphology Analysis by using SEM

Scanning Electron Microscope (SEM) is used to analyze the surface of an object (solid) to find out topographic, morphological, and composition information of a sample. The instrument used was SEM Hitachi TM-3000 with SEM specifications including a resolution of 1-10 nm. SEM analysis was conducted at the Integrated Research and Testing Laboratory, Universitas Sumatera Utara.

3 RESULTS AND DISCUSSIONS

3.1 Results and Analysis of Water Absorption Test

Water absorption analysis is carried out to determine the capacity of paving block material produced in absorbing water. This analysis refers to ASTM C140 / C140M-15. The test is done by immersing all samples in water for 24 hours. This test is carried out on samples with different component variations to find out the percentage content of the combination components in an ideal mixture. The relationship between the percentage of water absorption with variations in asphalt components, solid bitumen, and concentrated latex is presented following Table 2 and Figure 1.

Table 2: Percentage water absorbtion paving block.

Paving Block	% WA
A	1.56
B	1.46
C	1.27
D	1.21
E	0.85
F	2.75
G	2.30

In table 2 shows the minimum percentage of water absorption value that is in samples with variations of asphalt components: solid bitumen: concentrated latex (70: 25: 5) which is 0.85%. It can also be seen in the graph that with more levels of addition of solid bitumen tends to reduce the value of water absorption. This is because solid bitumens are resistant to water (McNally, 2011). whereas in samples without the addition of solid bitumen, a higher water absorption value of 2.75% is produced. This explains that the addition of solid bitumen to a mixture of asphalt and concentrated latex can reduce the percentage value of water absorption.

Inversely proportional to the increasing levels of concentrated latex in a mixture of asphalt and solid bitumen. Increased concentrated latex levels tend to increase the ability of water absorption. In this research, the percentage of absorption was 1.56% with the addition of rubber at the most, 25%. The ability of water absorption increases with increasing levels of concentrated latex in the mixture (Kartika, 2017) so that the water content of concentrated latex binds water from the sample marinade. The minimum percentage of water absorption in this study did not differ significantly from the results reported by

Kartika (2017) using liquid bitumen, which is about 0.8%.

Based on this, variations with concentrated latex levels will increase the mixing homogeneity to be less effective. However, water absorption is increasing without the addition of concentrated latex in the material mixture which is 2.30%. This explains that the added rubber content also affects the percentage of water absorption.

The percentage of water absorption from paving blocks produced meets the standards of SNI 03-0691-1996. Based on this value, the resulting paving blocks meet the quality requirements for all areas with a maximum percent of each% WA, namely: 3% of the road, 6% of the parking area, 8% of pedestrians, and 10% of parks and other uses.

3.2 Results and Analysis of Compressive Strength Test

Compressive strength is the main mechanical characteristic of road pavement material. This test aims to determine the maximum compressive strength characteristics that can be accepted by paving block samples. This test refers to ASTM D790 / C293. Compressive strength analysis has been carried out on all samples using GOTECH AI-7000M by giving a load of 20 KN or 2039.4 Kgf (1 KN = 101 Kgf). The results of the test are obtained in the form of graphic output and max load data

Calculation of compressive strength value is obtained from the price of P substituted into equation 3.2, so that the compressive strength value is obtained in units of Kgf / mm2, then converted into units of MPa (1 Kgf / mm2 = 9.81 MPa).

The variation of the ideal composition in the paving block based on the compressive strength test was obtained in the variation of the composition of asphalt: solid bitumen: concentrated latex (70: 25: 5) with a compressive strength value of 0.605 MPa. In the mixture without the presence of solid bitumen, the compressive strength value obtained is 0.085 MPa, while without the addition of rubber the compressive strength value of 0.103 MPa is obtained. Based on the results of the data obtained, the addition of a combination of concentrated latex and bitumen can increase the strength of asphalt. Addition of polymer materials around 2-6% is enough to improve the quality of the asphalt mixture (Polacco & Berlincioni, 2005).

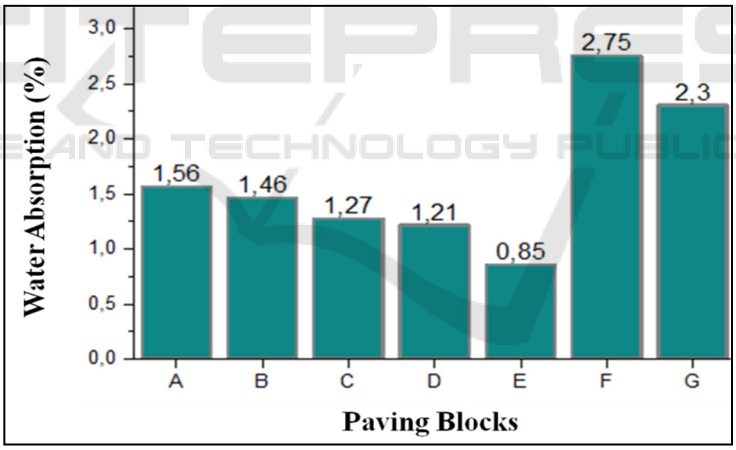


Figure 1: Percentage Value of Water Absorption for Asphalt, Bitumenous coal and Latex Variations.

The relationship between compressive strength values and variations in the composition of asphalt mixes: solid bitumen: concentrated latex is presented in graphical form in the following Table 3 and Figure 2.

Based on the diagram in Figure 2. can be seen an increase in compressive strength after the addition of solid bitumen and concentrated latex. This shows that in the asphalt mixing: solid bitumen: concentrated latex (70: 25: 5), the dispersion of latex in the asphalt and bitumen mixture is more homogeneous. The more addition of solid bitumen, which is as much as

Table 3: Compressive Strenght Value of Paving Block.

Paving Blocks	Compressive Strenght (MPa)
A	0.180
B	0.222
C	0.299
D	0.452
E	0.605
F	0.085
G	0.103

25%, shows an increase in compressive strength. This works as a synergy with the addition of only 5% latex.

This is consistent with Azliandry (2011) reported, where the highest mechanical properties were obtained in asphalt mixtures with the addition of 5% SIR 20 (95:5). This is because the dispersion of rubber in asphalt is more homogeneous and the role of rubber in the mixture slows the rate of permanent deformation. DaSilva et al. (2015) also produced paving blocks with cement binder and crumb rubber obtained data on the addition of crumb rubber with the least amount of content obtained the maximum compressive strength in the resulting paving block. In this variation crumb rubber is sufficient to be distributed evenly throughout the matrix. Loading strength is also distributed evenly, resulting in increased compressive strength, but when there is no addition of crumb rubber, the compressive strength produced also tends to decrease. With increasing levels of natural rubber in the mixture will reduce the mechanical properties of the mixture. This is because the elastomeric phase remains as dispersed particles, also resulting in agglomeration and interaction of the particles of rubber so that the stiffness in the mixture will decrease (Ismail & Suryadiansyah, 2002).

In a mixture, the attachment of a molecule to the rubber chain cannot prevent the rate of fracture quickly against the applied pressure. Conversely, the lower level of rubber tends to increase its mechanical properties, because if a smaller size and more uniform dispersion in the dispersed phase will contribute to improving the mechanical properties of the mixture (Ismail & Suryadiansyah, 2002).

The results obtained in this study are greater when compared to studies conducted (Kartika, 2017), where the mixture of asphalt and fresh latex using liquid bitumen without crosslinkers. In addition to the higher rubber content factor in concentrated latex when compared with fresh latex, the thing that influences this is the presence of a crosslinker will limit the flow and mobility of the mixture which allows the particles to reach higher pressures, when the same will also give mechanical strength to the particles (Ismail & Suryadiansyah, 2002). So that the use of solid bitumen with concentrated latex using crosslinkers is more effective.

Based on the results of the compressive strength values obtained in the material with the optimum combination between asphalt, solid bitumen, and concentrated latex, it shows that the compressive strength of the resulting paving blocks has not been effective with the standard compressive strength values based on SNI 03-0691-1996. When viewed from its polarity, the components used such as bitumen have an excellent combination of compositions that are both adhesives and water resistant (McNally, 2011) and concentrated latex which are nonpolar but still contain 40% water (Suksup et al., 2017) which when mixed will produce a mixture that is misible or can be mixed but the compatibility is less effective so that it will affect the mechanical properties obtained (Ismail & Suryadiansyah, 2002).

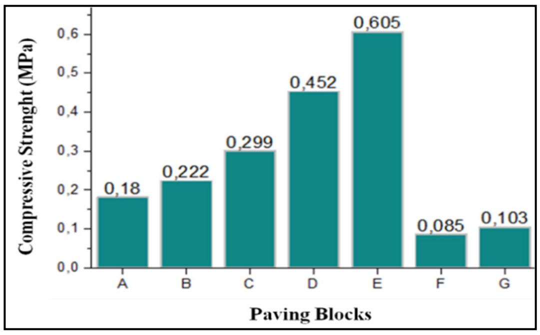


Figure 2: Graph of Compressive Values with Variations in Asphalt, Solid Bitumen and Concentrated Latex Mixture.

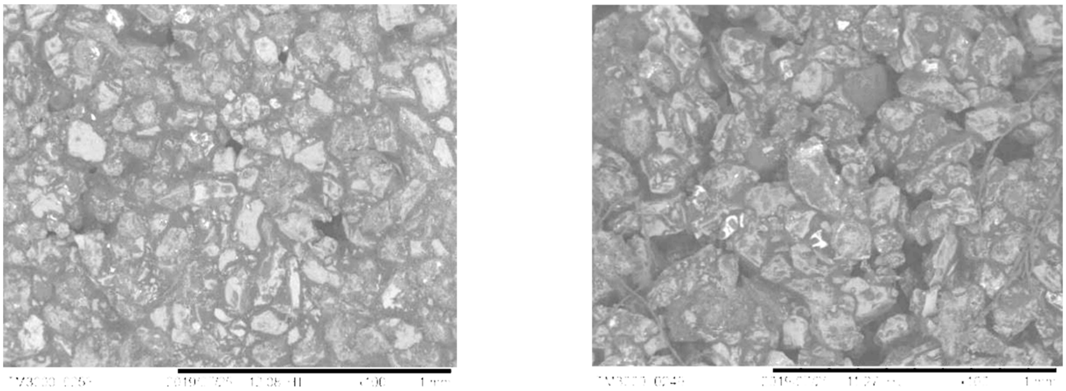
3.3 Results of Surface Morphology by using SEM

In this study, an analysis using SEM was conducted to determine the surface morphology of the resulting paving block sample material. Objects that are characterized are the results of asphalt mixing: solid bitumen: concentrated latex with variations (70: 25: 5), (70: 5: 25), and control samples namely asphalt: concentrated latex (80: 20) without the presence of solid bitumen. SEM analysis is performed after compressive strength testing. The results of the characterization with SEM in the form of micrographs. SEM analysis is carried out at magnification 100 times which can be seen in the figure 3.

The results of SEM micrographs show a significant difference in surface morphology between the mixture composition of the resulting paving block material. Figure 3 a. is a control sample without the addition of solid bitumen with a variation of asphalt: concentrated latex (80: 20). In micrographs, it can be seen that there are large piles which do not bind to one another due to the lack of homogeneity from mixing asphalt and concentrated latex. In all areas are scattered small particles attached, which are small particles which are aggregates of sand. This shows that the sand aggregate is attached to asphalt and concentrated latex.

Figure 3 b. is a SEM micrograph of the sample with the addition of solid bitumen with asphalt variation: solid bitumen: concentrated latex (70: 5: 25). On the micrograph there is a very significant difference with the micrograph in Figure 3 a, where there are large piles that were previously not homogeneous,

SEM micrograph in figure 4. is the result of a sample with variations of asphalt: solid bitumen: concentrated latex (70: 25: 5). Based on SEM micrographs in this variation produce



(a) **(b)**

Figure 3: Micrographs of SEM Analysis Results in Paving Blocks (a) Paving Block F (b) Paving Block A.

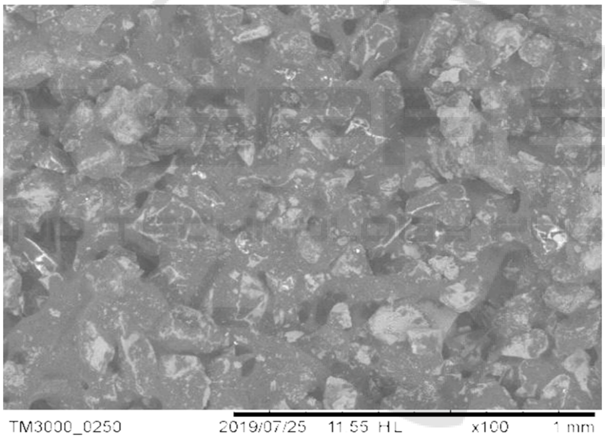


Figure 4: Micrographs of SEM Analysis Results in Paving Block E.

mixing with the most effective homogeneity between one component with another component. Aggregates which previously still look like in Figures 3 a and 3 b, are no longer visible in Figure 4, where aggregates are more bound to all components.

Surface structure density in asphalt variation: solid bitumen: concentrated latex (70: 25: 5) is very good compared to the structure density in Figures 3 a and 3 b. The more even distribution of components in micrographs indicates effective homogeneity (Hardeli et al., 2018). This is due to the influence of the addition of concentrated latex composition. Addition of concentrated latex with less composition results in a better surface structure compared to more addition of concentrated latex composition, because concentrated latex still contains water, so the homogeneity of mixing concentrated latex with bitumen and solid bitumen is less effective. Thus, the dispersion of rubber in asphalt and with solid bitumen is more homogeneous in this optimum variation, binds to each other and plays a role in improving the morphological properties of paving blocks with asphalt as a binding.

4 CONCLUSIONS

Based on the results of the research and discussion, it can be concluded that: Paving blocks based on polymeric materials can be made by mixing asphalt as a substitute for binder and solid bitumen and concentrated latex as an adhesive (adhesive) with the addition of dicumyl peroxide as an initiator and divinyl benzene as a crosslinker using sand and gravel aggregates. Utilization of asphalt, solid bitumen, and concentrated latex can improve the physical and mechanical properties of the resulting paving block with an optimum ratio of asphalt: solid bitumen: concentrated latex (70: 25: 5) (Paving Block E). Physical properties of the water absorbing capacity is 0.85%. The mechanical properties of compressive strength are 0.605 MPa. Morphological characteristics by using SEM show differences in surface structure by comparison of the composition of each component used. At the optimum ratio, mixing is produced with the homogeneity of the most effective surface structures.

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