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Utilization of Used Polystyrene As Adhesive In Polymer Emulsion Asphalt

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Abstract. The utilization of used polystyrene as adhesive material for emulsion polymer asphalt has been carried out. Polystyrene foam was dissolved in toluene at the ratio of 30:70 mL, then the solution was mixed with aquadest at ratios of 90: 10 mL, 70: 30 mL, 50: 50 mL, 30:70 mL, and 10: 90 mL. Then added with 10 mL of Sodium Dodecyl Sulfate solution at concentrations of 10%, 20%, and 30%. The most stable latex polystyrene was mixed with 200 g of sand aggregate at volume ratios of 10 mL, 20 mL, 30 mL, 40 mL, and 50 mL. Then the mixture was pressed into a hotpress at 150ºC for 20 minutes. The mixture obtained was characterized using tensile strength testing, water absorption, and SEM spectroscopy. The results showed that the mixture of sand aggregate with 50 mL latex polystyrene has the best compressive strength and water absorption, at a load of 1606 Kg.f, a stroke of 14.93 mm/minutes, and a water absorption percentage of 18%. The morphology result showed that the surface of sand aggregate with 50 mL of latex polystyrene mixture contains smaller and least holes than the surface of sand aggregate with 10 mL of latex polystyrene mixture.

Keywords: Polystyrene Latex, Emulsion, Sodium Dodecyl Sulfate, Sand Aggregate

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1 Introduction

One of the polystyrenes that are quite popular among producers and consumers is polystyrene foam. Polystyrene foam is widely known as styrofoam which is often used inappropriately by the public (Badan POM, 2008). The utilization of used styrofoam is rarely done because styrofoam is often burned by scavengers. Styrofoam burning causes air pollution. Therefore, it is very important to research how styrofoam can be used again to produce products that are environmentally friendly and have economic value (Yuliani, 2007). The manufacture of latex polymers using emulsion polymerization whose application is to increase the California Bearing Ratio (CBR) of soil on road subgrades has been carried out by K. Moto et al (2004) reported that the FTIR results show that the polymer binder formula can be used for fixed formulas for the manufacture of latex polymers for application in sub-grade hardening of soils. Meanwhile,

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the CBR polymer binder has the best yield at Tg of 15% to 18% compared to soil without polymer. The emulsion polymerization process using a mixture of sodium polystyrene sulfonate (NaPSS) and sodium sodecyl sulfate (SDS) as an emulsifier for styrene emulsion polymerization at 60ºC has been carried out by Chu (2007).

2 Materials and Methods

2.1 Equipments

In this study, the equipments used were a pycnometer, volumetric flask, mixer, optical microscope, hot compressor, a set of compressive strength test, and, SEM-EDX spectroscopy.

2.2 Materials

The materials used were distilled water, polystyrene foam, toluene, fine sand aggregate, and sodium dodecyl sulfate.

2.3 Aggregate Preparation

The aggregate in the form of fine sand was previously washed using distilled water, then dried in an oven at 110ºC. Then all the fine sand aggregate was filtered in a sieve. Each sieve obtained was made into 200 g.

2.4 Preparation of Concentrated Polystyrene Solution

As much as 70 mL of toluene was put into a beaker glass. Then added 30 g of polystyrene foam. Next. stirred until all the polystyrene foam dissolved. The density of the solution formed was measured.

2.5 Preparation of 10%, 20%, and 30% of Sodium Dodecyl Sulfate Solutions

As much as 10.1 g of SDS was put into a beaker glass and dissolved with 50 mL of distilled water. Then put into 100 mL of the volumetric flask, diluted with distilled water to the marked line, and homogenized. The same treatment was carried out by dissolving 20.2 g and 30.3 g of SDS, respectively to obtain 20% and 30% SDS.

2.6 Fabrication of Polystyrene Latex

As much as 90 mL of polystyrene solution was put into a beaker glass and added with 10 mL of distilled water. Then, 10 mL of 10% SDS solution was added drop by drop slowly while stirring. Then let stand for 1 day. The same treatment was carried out for 20% and 30% SDS solutions. The same treatment was also carried out for variations of polystyrene and aquadest solutions with ratios of 70:30, 50:50, 30:70, and 10:90. The results obtained were calculated their density and observed the shape and size of the particles.

2.7 Measurement of The Density of Polystyrene Solution and Polystyrene Latex

A 5 mL pycnometer was prepared and weighed the mass of the empty pycnometer. The polystyrene solution was added to the pycnometer. Then the mass was weighed using an analytical balance. The same treatment was carried out three times and the density was calculated using the formula 1. The same treatment was also carried out for polystyrene latex in each variation.

$$d = \frac{m_{p1} - m_{po}}{v_p} \tag{1}$$

Description :

m_{p1} = mass of the empty pycnometer

m_{po} = mass of the pycnometer contain

v_p = volume of the pycnometer

2.8 Determination of Size and Shape of Polystyrene Latex Particles

This analysis was carried out on the most homogeneous polystyrene latex. One drop of polystyrene latex was placed on a glass slide. The optical microscope was turned on, and the slide was placed under an optical microscope with a magnification of 400x. The particle size distribution was calculated, then the average particle size was calculated.

2.9 Manufacturing of Asphalt Polymer Emulsion

This process was carried out only on the most homogeneous and stable polystyrene latex. As much as 200 g of sand aggregate was put into 500 mL of beaker glass, then 10 mL of polystyrene latex was added little by little while stirring by a mixer at 400 rpm for 15 minutes until the mixture was homogeneous. Next, the mixture was put into a cube mold measuring 5 x 5 x 5 cm and placed into a hot compressor at 150°C for 20 minutes. Then the sample was removed and opened from the mold and then cooled. The same treatment was carried out with the addition of 20 mL, 30 mL, 40 mL, and 50 mL of polystyrene latex, respectively. The sample was then ready to be tested for its mechanical properties, namely the water absorption and compressive strength tests.

2.10 Water Absorption Test

The mass of the printed sample was weighed and recorded as dry mass (M k). Then, the sample was immersed in water for 24 hours. Next, the sample was removed and the surface was dried using the tissue. Then the sample was weighed again after immersion and recorded as saturated mass (Mj). The water absorption test value was calculated using formula 2:

$$WA = \frac{(M_j - M_k)}{M_k} x100 \tag{2}$$

Description:

WA = Water absorption

M k = Mass of dry sample

Mj = Saturated mass of water

2.11 Compressive Strength Testing

The equipment used in the compression test was Tokyo Testing Machine Type SC 2DE with a capacity of 2000 kg.f and refers to ASTM D 1559-76.

The sample was placed on a compression test machine and given a load until the test object fell, at the maximum load (P_{max}) was working. The compressive strength test value was calculated using the equation presented in formula 3.

$$P = \frac{F}{A} \tag{3}$$

Where :

P = Compressive strength (mm/min)

F = Maximum force of press machine (N)

A = The cross-sectional area of which pressurized (m^2)

2.12 SEM (Scanning Electron Microscopy) Analysis

The test was carried out on the fracture surface of the sample. Firstly, the sample was attached to the specimen holder that has been smeared with silver paste in a pressure chamber (vacuum gauge) of 0.2 torrs. Furthermore, the sample was irradiated with an electron beam of ± 1.2 kV in a special room so that the sample emits secondary electrons and bounced electrons which can be detected by a scientor detector which was amplified by an electrical circuit that causes a cathode ray tube (CRT) image to appear. A coating with a thickness of 400 Armstrong was inserted into the specimen chamber on the SEM machine (JSM-6360 LA). The results of the shoot were conducted after selecting a certain part of the object (sample) and the desired magnification so a good and clear photo was obtained.

3 RESULT AND DISCUSSION

3.1 Polystyrene Latex Stability Testing

Stability testing has been carried out on all variations of the most homogeneous polystyrene latex in this study. The test results obtained were the density value and the size distribution value and the shape of the polystyrene latex particles. This stability test was based on the relationship between the density of the dispersed phase, the density of the dispersing phase, the density of the emulsion, and the volume of the fraction that determines the concentration of oil particles (Weiss, 2002).

Based on the results of the polystyrene latex photography shown in figure 1, 2, and 3 show that the most homogeneous polystyrene latex was obtained at a ratio of 90 mL of concentrated polystyrene solution and 10 mL of distilled water at each concentration of SDS. This has also been proven by previous researchers by keeping the polystyrene latex produced in ratios of 90: 10 mL, 70: 30 mL, 50: 50 mL, 30: 70 mL, and 10: 90 mL for 1, 3, 5, and 7 days. The density of polystyrene latex with SDS results obtained was indicated in Table.1.

Tabel 1. Density of Polystyrene Latex with SDS at a ratio of 90: 10 mL

Concentrated Polystyrene Solution (mL)	Aquadest (mL)	SDS Concentration (% v/v)	Density (g/mL)
90	10	10	1.044
		20	1
		30	0.998

Furthermore, the most homogeneous polystyrene latex was tested for particle size and shape observations to obtain the most stable polystyrene latex. This was done by observing polystyrene latex under an optical microscope with a magnification of 400 times. From these observations, the data on the particle size distribution of polystyrene latex was obtained at each SDS concentration as shown in Table 2.

Tabel 2. Distribution of particle size distribution of polystyrene latex (90 mL of concentrated polystyrene solution: 10 mL of aquadest) at each SDS concentration

Concentrated Polystyrene Solution (mL)	Frequency Distribution of Polystyrene Latex (%)		
	SDS 10%	SDS 20%	SDS 30%
1	31.6	56.7	56.9
2	21.4	14.2	21.6
3	14.5	4.7	9.2
4	10.3	4.7	3.9

5	8.6	3.8	2.5
6	6.0	3.8	1.7
7	2.6	1.9	1.1
8	1.7	1.9	0.8
9	0.9	-	0.6
10	1.7	0.9	0.3
11	0.9	0.9	0.8
12	-	0.9	-
13	-	-	0.3
14	-	0.9	0.3
15	-	1.9	-

The average diameter of the particles was calculated using the formula 4.

$$(\overline{D}_n) = \frac{\sum n_i D_i}{\sum n_i} = \sum f_i D_i \tag{4}$$

3.2 Sample Characteristics and Mechanical Properties Testing of Emulsion Polymer Asphalt

Mechanical properties testing has been carried out on all mixtures of sand aggregates on the most stable polystyrene latex from each variation so the average results were obtained. The data were the initial average data for each sample that has been made in the form of a graph. A compressive strength test was conducted on Torsces Electronic System (Universal System Machine). The tester has been applied and transmitted in graphical form. The test results were obtained from the measurement of the Load and Stroke value. The results obtained were interpreted to obtain strain and stress data. The compressive strength test data obtained shown in Table 3.

Tabel 3. The compressive strength test of the emulsion polymer asphalt

Sample			Load		Strokes (mm/min) (N/m^2)
Fine Sand Aggregate (g)	Polystyrene Latex (mL)	Area (mm^2)	(Kg.f)	(N/m^2)	
200	10	2500	170,2	0.667×10^6	7.21
	20		500.9	1.962×10^6	7.81
	30		687.2	2.697×10^6	8.16
	40		936.7	3.676×10^6	9.52
	50		1606	6.302×10^6	14.93

3.3 Water Absorption Test

The sample was immersed in the water for 24 hours, and from various percentages of the mixture were obtained the samples containing more polystyrene latex absorb less water, where this difference was used as a percent by weight of absorbed water. The difference in the weight of the samples that have been soaked was obtained and presented in Table 4.

Tabel 4. The water absorption capacity of asphalt polymer emulsion

Sample		Initial Weight (g)	Final Weight (g)	Difference	Water Absorption (%)
Sand (g)	Polystyrene Latex (mL)				
200	10	175.56	221.12	45.56	25.95
	20	198.39	244.57	46.18	23.28
	30	197.54	234.50	36.96	18.71
	40	199.68	236.51	36.83	18.45
	50	195.8	231.04	35.24	18

Sand in general has a high water absorption capacity, this is because sand has a high porosity. The addition of polystyrene latex can coat the pores between the sand particles and can cause physical interactions with the sand particles.

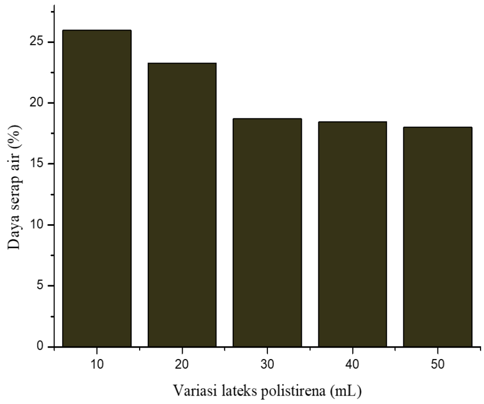


Figure 1. The graph of water absorption of polystyrene latex with sand

Figure 1 showed that there was a very sharp decrease between the samples with the addition of 20 mL of polystyrene latex to the sample with the addition of 30 mL of polystyrene latex. This was due to the addition of 20 mL of polystyrene latex, the sand particles cannot be completely mixed with polystyrene latex, so the water was more easily absorbed into the sand particles. Meanwhile, with the addition of 30 mL of polystyrene latex, the amount of latex added can coat almost the entire surface of the sand particles so their absorption capacity for water was lower. In addition, decreasing indicated that with the increase in the volume of polystyrene latex, the absorption capacity of the sample to water will decrease, where this polystyrene latex functions as an adhesive in the sand aggregate sample. This was due to the sand particles being very porous and having a great affinity for water (Sukat, 2012). The initial weighing with a mixture of 10 mL of polystyrene latex was 175.56 g, but after soaking for 24 hours the weight obtained was 221.12 g. There was a difference of 45.56 g or about 25.95%. And in the 50 mL of polystyrene latex mixture, the initial weight was 195.8 g, and the weight after soaking was 231.04 g, or 18%. This was because polystyrene latex coats the pores of the sand aggregate, while polystyrene latex is a waterproof material so an increase in the volume of polystyrene latex can reduce the water absorption of the sample.

However, according to SNI 03-1969-1990, the standard maximum water absorption sand aggregate was 3%. This shows that all samples tested with water absorption have not met the Indonesian National Standard.

3.4 Polystyrene Latex Stability Test Analysis

The density measurement results obtained was shown in figure 1.

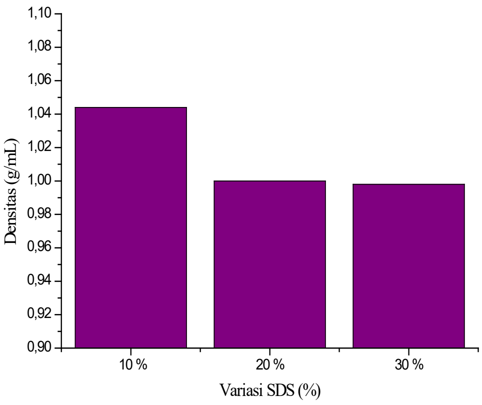


Figure 2. The graph of polystyrene latex density at a ratio of 90: 10 mL

Figure 2 indicates that increasing the concentration of SDS can reduce the density value of polystyrene latex. In polystyrene latex manufacturing at a ratio of 90: 10 concentrated polystyrene and aquadest solution were obtained the result was a homogeneous emulsion with a milky white color, but at a ratio of 70: 30 concentrated polystyrene and aquadest solution clumping began to occur. Likewise, at a ratio of 50: 50, there was more clumping. So a decrease in the amount of polystyrene latex and an increase in the amount of aquadest causes an inhomogeneous emulsion to form any clumping occurs. This was due to the presence of aquadest volume as a high dispersion fraction, which caused the phenomenon of flocculation, particle electric charge, partial crystallization of the dispersed phase molecules, and the presence of an absorbent layer resulting in agglomeration and precipitation processes (Weiss, 2002).

3.5 Analysis of the Size and Shape of Polystyrene Latex Particles

Analysis of the particle size distribution of polystyrene latex was carried out using a manual method, namely by counting the number of polystyrene latex particles that appeared in the results of observational photography of polystyrene latex particles using an optical microscope. The graph of the particle size distribution of polystyrene latex was shown in the following figure 2.

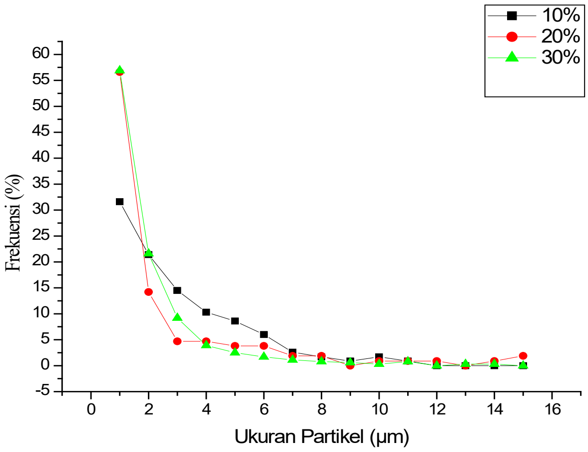


Figure 3. The graph of the particle size distribution of polystyrene latex at various SDS concentrations.

Figure 3 showed that the average diameter (Dn) of polystyrene latex particles with SDS concentrations of 10%, 20%, and 30% respectively were 3.049 m, 2.59 m, and 2.054 m. It was according to the general emulsion particle size in the range of 1 to 10 µm (Goodwin, 2004).

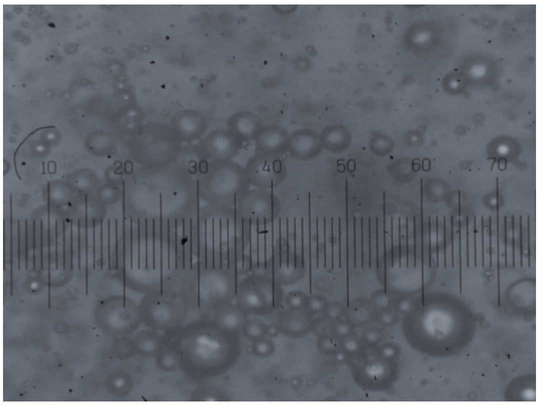


Figure 4. The micrograph of polystyrene latex with 10% of SDS using an optic microscope (400x magnification)

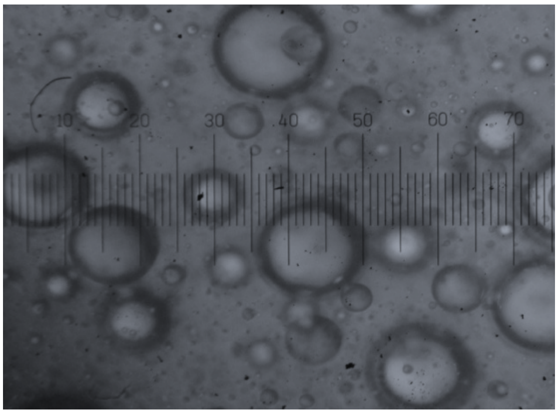
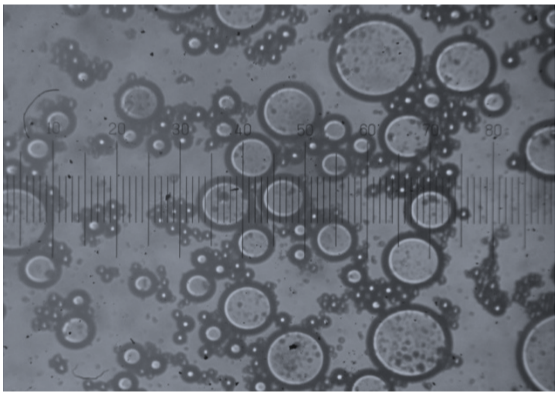


Figure 5. The micrograph of polystyrene latex with 20% of SDS using an optic microscope



(400x magnification) (400x Magnification)

Figure 6. The micrograph of polystyrene latex with 30% of SDS using an optic microscope (400x magnification)

The results of the photography of polystyrene particles using an optical microscope as shown in figures 3, 4., and 5 show that 30% of SDS has a more uniform shape and size compared to 10% and 20% of SDS polystyrene latex. This shows that the greater the concentration of the emulsifier, so the smaller the particle size of the polystyrene latex formed. Because surface tension was an important parameter in controlling the particle size of the emulsion. The surface tension was lowered to a very low level, the particle size can be reduced even further (Goodwin, 2004).

3.6 Asphalt Polymer Emulsion Mechanical Properties Analysis

The results of the strength and strain measurement of the emulsified polymer asphalt were shown in figures 7 and 8 showed that with the increase in the volume of polystyrene latex, the tensile strength tends to increase, until the composition of the addition of 50 mL polystyrene latex was about 14.93 mm/minute, the stress was 1606 Kg.f so the hardness was good for emulsion polymer asphalt. The mechanical properties increase because the pores between the fine sand aggregates have been coated with polystyrene latex and due to the adhesion force between the sand aggregate particles and the polystyrene latex. By the percentage of sample concentration was obtained the optimum combination of materials in the polymer emulsion asphalt. Polystyrene latex is effective in coating sand aggregate particles to increase the compressive strength of the specimen. This was due to the physical interaction between the sand particles and the polar ends of the polystyrene latex (Vyes, 2011).

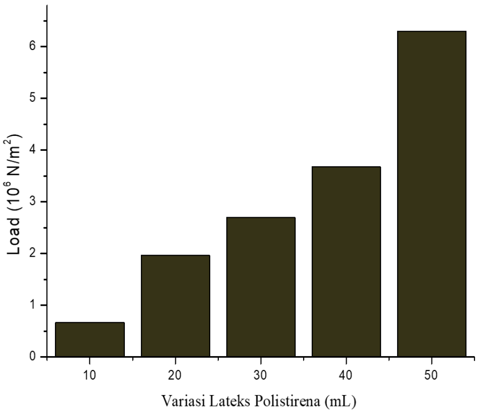


Figure 7. The bar chart of the stress of polystyrene latex and sand mixture

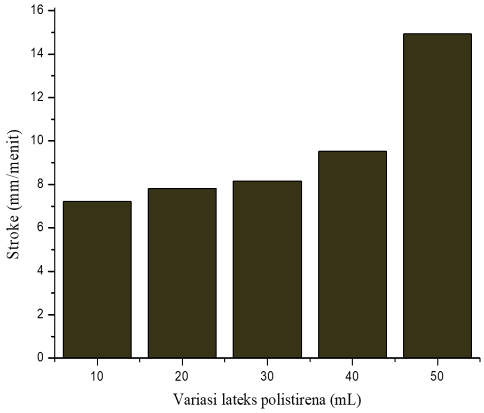


Figure 8. The bar chart of the strain of polystyrene latex and sand mixture

With the addition of 30 mL of polystyrene latex, the compressive strength value reached 2.679 x 106 N/m^2 and continued to increase to 6.302 x 10^6 N/m^2 with the addition of 50 mL of polystyrene latex. The results of the compressive strength test on a mixture of sand aggregate and polystyrene latex are known to have met and even exceeded the standard of SNI 03-6883-2002 where the compressive strength of the stabilized soil must have a compressive strength of 2.1 x 10^6 to 2.8 x 10^6 N/m^2.

3.7 Surface Analysis with SEM (Scanning Electron Microscopy)

The morphology of the mixture was uniform and homogeneous. Generally, the micro-morphology of the structure relates to the size, shape, and distance between particles, as well as the dispersion of the dispersed phase particles (polymer latex). This parameter was a factor that affects on the effect of the toughness of a mixture. The distance between the particles have an important role in the interaction of the stress field in various regions of the polymer matrix (Lynch, 2000).

SEM analysis was carried out to see the fracture surface structure of the sample with the addition of the optimum polystyrene latex, namely the mixture of sand aggregates with variations in the addition of 10 mL of polystyrene latex and 50 mL of polystyrene latex. SEM results from a mixture of sand with the addition of 10 mL of polystyrene latex and 50 mL of polystyrene latex were indicated in figure 9.

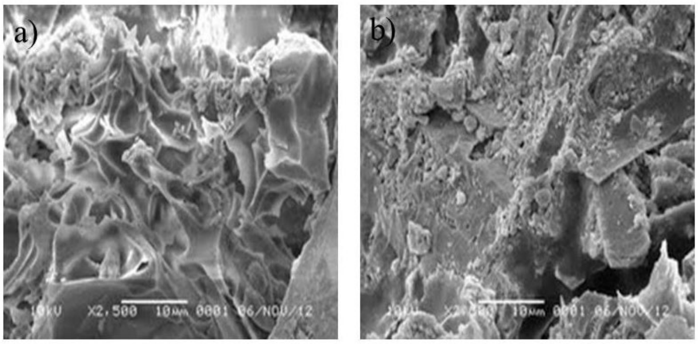


Figure 9. SEM image of a mixture of polystyrene latex (a) 10 mL and (b) 50 mL with 200 g of fine sand aggregate

Figure 9 showed that the morphology of the sand aggregate mixture with 50 mL polystyrene latex was more even and homogeneous than the sand aggregate mixture with 10 mL polystyrene latex. Changes in the volume of polystyrene latex showed a significant surface change, where a mixture of sand aggregate with 50 mL of polystyrene latex had smaller pores and fewer. This was caused by chemical interactions between polystyrene latex molecules and sand particles.

From the results of the analysis, the fracture surface of the sample shows that the increase in the composition of the polystyrene latex in the sample can close the pores of the sand aggregate more completely so the pores produced were smaller, and water becomes difficult to penetrate the surface of this mixture. This meant that surfactants have a role in increasing the strength of the emulsion polymer asphalt.

4 Conclusion

Based on the data obtained in this study, it can be concluded that:

1. Polystyrene latex with the best stability was at a ratio of 90:10 (concentrated polystyrene solution: water (v/v)) at all concentrations of SDS, with density values were 1.044 g/ml at SDS 10%, 1 g/ml at SDS 20%, and 0.998 at 30% SDS, respectively.

2. The technique of mixing polystyrene latex with fine sand aggregate was carried out using the most homogeneous and stable polystyrene latex, namely polystyrene latex at a ratio of 90: 10 with an SDS concentration of 30%. Where polystyrene latex was added little by little into the fine sand aggregate while stirring at 400 rpm for 15 minutes and molded at 150°C for 20 minutes to obtain a cube-shaped specimen.

3. Water absorption and surface morphology of emulsified polymer asphalt were obtained the best mixture was emulsified polymer asphalt with the addition of 50 mL polystyrene latex which provided a compressive strength of 14.93 mm/minute, the tension of 1606 Kgf, and density of good quality, as well as water absorption of 18%. The SEM also showed that emulsified polymer asphalt with the addition of 50 mL polystyrene latex showed a smoother surface than the addition of 10 mL polystyrene latex indicating that the number of pores or cavities in the micrograph of emulsified polymer asphalt with 10 mL polystyrene latex.

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