AN EVALUATION OF STRIPPING BETWEEN ASPHALT EMULSION AND AGGREGATE INCLUDING THE USE OF NATURAL RUBBER LATEX IN ASPHALT EMULSION.

Mightthai Ketsuwan[1,*] and Boonchai Sangpetngam.[2]

[1,2] *Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, THAILAND*
**Corresponding author; E-mail address: might.ket@gmail.com*

Abstract

Asphalt emulsion can be divided into 2 types of Cationic Asphalt Emulsion and Anionic Asphalt Emulsion. Because each type of aggregate has a different electric charge. and the mixing of natural latex with asphalt emulsion will change the charge of asphalt emulsion. The adhesion between asphalt and aggregate has a significant impact on asphalt road performance. and to avoid road surface stripping off which may cause premature deterioration of the road surface. This research aims to study and test the stripping between asphalt emulsion and different aggregates. with different electrical charges using the Rolling Bottle Test (RBT), which is a test to determine the percentage of asphalt coverage on the aggregate surface to assess the stripping between asphalt and aggregates. By using asphalt emulsion both cationic and anionic Including the using of natural rubber in the form of concentrated latex type Pre-vulcanized Latex mixed with anionic asphalt emulsion to test with all 3 types of aggregates, including Limestone from Chonburi province. Limestone from Saraburi Province and basalt from Buriram Province. The test took time to evaluate at 6 hours and 24 hours. From the test at 24 hours, it was found that Chonburi limestone, cationic asphalt emulsion had the average coverage percentage of asphalt more than that of negatively charged asphalt emulsion. Saraburi limestone Anionic emulsion asphalt had the average coverage percentage of asphalt more than cationic emulsion asphalt and Buriram basalt. Cationic emulsion asphalt had a higher average coverage percentage of asphalt than anionic emulsion asphalt. From mixing natural rubber latex to anionic and cationic asphalt emulsion, it increased the stripping resistance properties.

Keywords: : Asphalt Emulsion, Natural Rubber Latex, Stripping, Adhesion, Rolling Bottle Test

1. Introduction

Cold mix asphalt is most useful for repairs like small cracks and potholes or patches and can use in any weather such as cold temperature or rainy. The asphalt used in the cold mix will be used in the form of asphalt emulsion. Asphalt emulsion is divided into two types cationic and negatively charged, which in Thailand are mostly used as cationic asphalt emulsion. The anionic asphalt emulsion is not yet widely used and there are not many standards to support in Thailand.

Aggregates are an important part of asphalt road construction. And there are several types of aggregates. Each type of aggregate has suitable and unsuitable properties for mixing with asphalt emulsion. This is because aggregates have different compositions and different surface charges. This will affect the stripping resistance and adhesion properties between asphalt and aggregate. The stripping resistance and adhesion properties between asphalt and aggregate have a significant impact on asphalt road performance. To avoid road surface strip off which may cause premature deterioration of the road surface.

Therefore, this research paper has an idea to use both types of asphalt emulsion and different types of aggregate to evaluate the stripping resistance between asphalt and aggregate, natural rubber latex was also used. Because the addition of Natural Rubber Latex in asphalt emulsion can be change the charge of emulsion. This will affect the stripping between aggregate and asphalt emulsion. So that the addition of natural rubber to the binder has certainly improved the binder properties significantly and hence increase the resistant to stripping of the asphalt mixture [4].

The purpose of this research paper is to study and evaluate the stripping resistance properties by using Rolling Bottle Test

(RBT) according to EN 12697-11:2012 [1]. This test is used to determine the percentage coverage of asphalt on the aggregate surface to evaluate the stripping resistance between asphalt and aggregates. The test used asphalt emulsion both cationic and anionic and using the natural rubber in the form of Natural rubber latex mixed with anionic and cationic asphalt emulsion to test with all 3 types of aggregates, including limestone from Chonburi province. Limestone from Saraburi Province and basalt from Buriram Province. The test takes 6 hours and 24 hours to evaluate.

2. Materials

2.1 Aggregate

Aggregates are materials from natural sources such as rocks, gravel and sand. They are the main components in civil engineering such as road works, drainage structures. reinforced concrete building In road construction, aggregate is used mixed with asphalt cement as a material for paving the road surface. The aggregates to be used as asphalt mixtures must have properties that are strong, durable and have suitable shapes and sizes. In addition, each type of rock has mineral compositions that affect the adhesion of asphalt. Each type of aggregate has suitable and unsuitable properties for mixing with asphalt emulsion, three types of aggregates obtained from Thailand are used limestone from Chonburi province; Limestone from Saraburi province. Basalt from Buriram Province. Both types of limestone were selected because Each limestone in Thailand has different compositions that may affect the stripping resistance properties. Therefore, these two types of limestones were tested and compared. In terms of basalt, it is a strong stone suitable for road construction and can be easily obtained in Thailand.

2.2 Asphalt Emulsion

Asphalt Emulsion or Emulsified Asphalt is a type of bitumen that is produced by mixing asphalt cement that has been beaten to break down into small particles (colloidal particles) that are suspended in water. It has a liquid form and a dark brown color. Emulsifying agents are added to enable the asphalt cement to remain suspended in water. The type of emulsifier used determines the properties of the asphalt emulsion based on the type of charge, which can be either negatively charged (anionic) or positively charged (cationic). In this research, both positively and negatively charged Asphalt Emulsions with a bitumen content of 60% are used to evaluate their adhesive properties with different types and charges of aggregates due to the electrical charges on the surface of the aggregates. Additionally, the research also measures the adhesive properties of Asphalt Emulsion mixed with natural rubber latex, which alters the charge of the Asphalt Emulsion particles and affects its adhesive properties.

2.3 Natural rubber latex

The NRL (Natural Rubber Latex) can be easily found in Thailand because in the south of Thailand can produce a lot of natural rubber. The idea of using natural rubber latex began more than 31 years ago when it was used in asphalt surfacing to improve bitumen performance [9]. The use of NRL is considered as a good method for enhancing bitumen properties since it contains natural rubber and discrete rubber particles can be easily fused with bitumen. In cold weather, NRL acts as an elastic band which helps to prevent the formation of cracks while maintaining bitumen stiffness. As the temperature increases, natural rubber acts as a film which improves shear resistance which in turn prevents bitumen flow [10, 11]. It has been generally proven that the use of NRL significantly improves long-term pavement performance [4].

The NRL to be used in this research is pre-vulcanized latex, which is a type of natural rubber in the form of concentrated latex, with a dry rubber content of 60% according to the standard TIS. 980-2533. As the percentage of dry rubber in natural rubber latex is equal to the percentage residue of emulsion by distillation, they can be easily mixed in various proportions using the post-blending method. The Post-Blending is the NRL is added to the final asphalt emulsion either at the plant or in the field [4]. Sometimes, the post-blending method is discouraged due to the need for vigorous, continual and thorough mixing to ensure proper and homogeneous polymer dispersion [5].

3. Test Methods

3.1 Rolling Bottle test

The Rolling Bottle Test (RBT) according to EN 12697-11:2012 standard [1]. This European Standard specifies procedures for the determination of the affinity between aggregate and bitumen and its influence on the susceptibility of the combination to stripping. Susceptibility to stripping, as determined by these procedures, is an indirect measure of the power of a binder to adhere to various , or of various binders to adhere to a given aggregate [1]. In this research the Rolling Bottle Test (RBT) will be used to test the Stripping resistance between aggregate and asphalt. The Rolling Bottle test for determine the percentage of bitumen-covered on the aggregate surface area. In this research using three types of aggregates will be tested, limestone from Chonburi province, limestone from Saraburi province, and basalt from Buriram province. Two types of asphalt emulsions will be tested Anionic and Cationic, as well as two types of asphalt emulsions mixed with Natural Rubber Latex (NRL). Anionic mixed with NRL and Cationic mixed with NRL, with NRL being mixed at 10% and 20% of the weight of the binder. This NRL was added to assess whether stripping resistance properties could be improved.

3.2 Test Procedure

This test starts from Separate at least 600 g. of aggregate passing the 10 mm. test sieve and retained on the 6.3 mm. sieve in accordance with EN 12697-2 [2]. Place the aggregates in the ventilated oven set at (110 ± 5) °C and dry to a constant mass this process is to completely remove the water and moisture contained in the aggregate enabling the aggregates to fully absorb asphalt emulsion. Place a portion of 510 ± 2 g. aggregates is mixed with 17 ± 0.2 g. of bitumen, until a bitumen aggregate is achieved in accordance with EN 12697-35 [3]. The conditioning stage initially involves a period between 12 and 64 hours at an ambient temperature of 20 ± 5 °C, avoiding direct exposure to sunlight and contamination with dust. After this period, the material is fractionated into three parts of 150 ± 2 g. each and placed into three bottles filled to about 50% of the volume with distilled water at a temperature of about 5 ± 2 °C. Because the low initial water temperature prevents the bitumen coated aggregate particles from forming lumps before the rolling is started. The bottles are turned automatically at a speed of 60 rotations per minute accordance with EN 12697-11 [1]. when used modified binder, the rotation speed will be used at 60 rotations per minute. The rotation speed can be adjustable by bottle rolling machine as shown in Fig. 1. After 6 hours and after 24 hours the bitumen coated grains are put in a bowl for evaluation shown in Fig. 2. Estimate by visual observation and record the average degree of bitumen coverage of the particles to the nearest 5%. Use a lamp to facilitate the observation and estimation. Any thin, brownish, translucent areas shall be considered fully coated. For the reference for estimation of degree of bitumen coverage shown in Fig. 3.


Fig. 1 Bottle rolling machine

Fig. 2 The Rolling Bottle Test Result after 24 hours

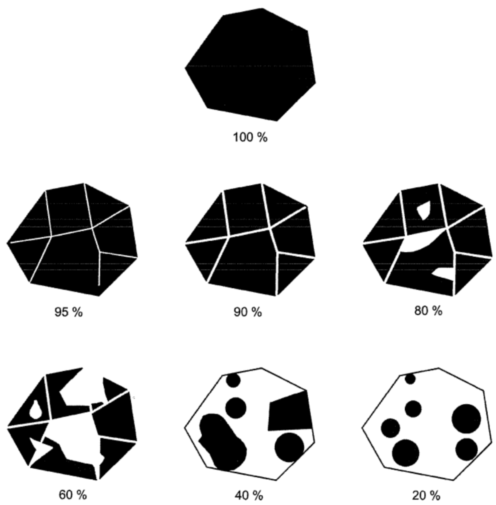

Fig. 3 Reference for estimation of degree of bitumen coverage [1].

3.3 X-ray Diffractometer (XRD)

It is a process of using X-ray radiation to analyze the components present in a sample and to study the detailed structure of the sample's crystalline structure using X-ray diffraction (XRD) principles. X-rays of known wavelengths are shot at the sample, causing the radiation to diffract at different angles. The measuring head receives the data, and since the degree of X-ray diffraction depends on the composition and structure of the substance in the sample, the obtained data can indicate the type of component present in the sample and can be used to study the details of the sample's crystalline structure. In addition, the obtained data can be used to determine the quantity of each type of component in the sample, the size of the crystals, the completeness of the crystals, and the purity of the components in the sample. Based on the principles described above, it is possible to use this method to identify various types of minerals that make up rocks.

The mineralogical and chemical composition of an aggregate is known to be an important factor in the susceptibility of an asphalt pavement to stripping. The mineralogical and chemical composition of an aggregate influences its surface energy and its chemical reactivity. It also accounts for the presence of adsorbed coatings on the aggregate surface [6]. With regard to their affinity for water, aggregates are typically classified as being either hydrophilic or hydrophobic. Hydrophilic aggregates are considered to be acidic with regard to their chemical nature and generally exhibit a high silica content. Hydrophobic aggregates, on the other hand, are considered to be chemically basic and exhibit a low silica content. Carbonate rocks such as limestone produce hydrophobic aggregate.

Aggregates are sometimes classified as alkaline or acidic, the alkaline types being limestone and marble and the acidic types being granite and quartzite. This type of aggregate classification is somewhat simplified as all aggregates contain a mixture of both alkaline and acid minerals. An important factor to the adhesion properties of an aggregate is its content of silica ($SiO2$) [13]. From the principles mentioned above In this research can be applied find various types of minerals that the composition of the stone and to assist in evaluating the stripping resistance properties between aggregate and asphalt emulsion.

4. Test Results and Discussion

4.1 Rolling Bottle Test Result

4.1.1 Result of Chonburi Limestone

The results of RBT testing between limestone from Chonburi Province and each type of Asphalt Emulsion is shown in Table 1 and shown in Fig. 4.

Table 1 The result of Rolling Bottle test with Chonburi Limestone

Limestone Chonburi		
Asphalt Emulsion type	Bitumen Coverage (%)	
	6 Hours	24 Hours
AN	66.85	19.51
AN + 10%NR	72.99	25.67
AN + 20%NR	45.69	8.98
HMA	93.85	59.25
CAT	60.1	27.09

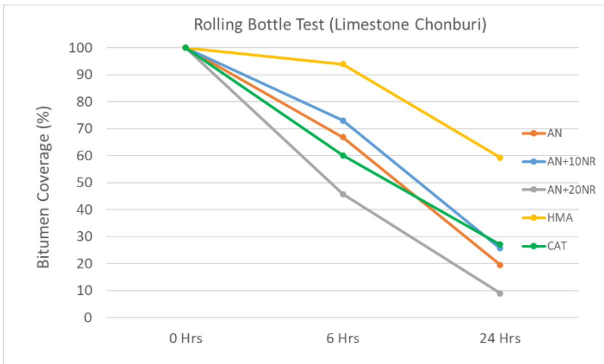

Fig. 4 The result of Rolling Bottle test with Chonburi Limestone

From the test results, it was found that during the 6-hour test, Anionic Asphalt Emulsion had a Bitumen Coverage percentage of 66.85%, which is higher than the Cationic value of 60.10%. However, at 24 hours, the Anionic had a Bitumen Coverage percentage of 19.51%, which is lower than the Cationic value of 27.09%. When NRL 10% was added to the Anionic, it was found that the Bitumen Coverage percentage increased during both the 6-hour and 24-hour tests, with values of 72.99% and 25.67%, respectively. However, the values decreased when NRL 20% was added, with values of 45.69% and 8.98% for the 6-hour and 24-hour tests, respectively. Additionally, it was found that when NRL was mixed with Cationic Asphalt Emulsion, it could not be used with limestone from Chonburi province. During the mixing process with NRL added to the Cationic Asphalt Emulsion, the asphalt particles were unable to adhere or coat the aggregate, making it impossible to use for further testing.

4.1.2 Result of Saraburi Limestone

Results from the RBT test between limestone from Saraburi Province and each type of Asphalt Emulsion is shown in Table 2 and shown in Fig. 5.

Table 2 The result of Rolling Bottle test with Saraburi Limestone

Limestone Saraburi		
Asphalt Emulsion type	Bitumen Coverage (%)	
	6 Hours	24 Hours
AN	57.97	26.7
AN + 10%NR	73.99	46.48
AN + 20%NR	62.46	36.89
HMA	92.47	64.01
CAT	45.18	22.32
CAT + 10%NR	66.88	52.02
CAT + 20%NR	54.15	47.95

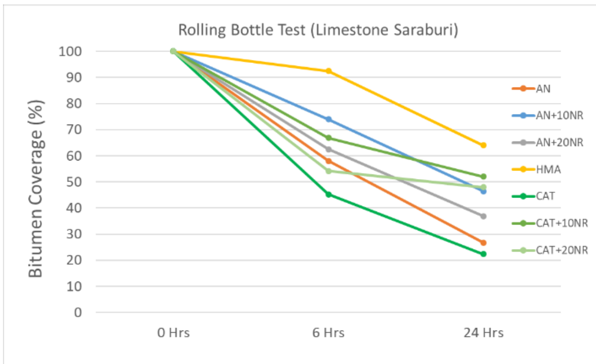

Fig. 5 The result of Rolling Bottle test with Saraburi Limestone

From the test results, it was found that at 6 hours and 24 hours of testing, Anionic Asphalt Emulsion had a Bitumen Coverage percentage of 57.97% and 26.70% respectively, which was higher than Cationic with values of 45.18% and 22.32% respectively. When NRL 10% was added to Anionic, the Bitumen Coverage percentage increased for both 6-hour and 24-hour tests, with values of 73.99% and 46.48% respectively. When NRL 20% was added to Anionic, the percentage decreased, but not lower than the value without NRL, with values of 62.46% and 36.89% for 6-hour and 24-hour tests respectively. Then, when NRL 10% was added to Cationic, the Bitumen Coverage percentage increased for both 6-hour and 24-hour tests, with values of 66.88% and 52.02% respectively. When NRL 20% was added, the Bitumen Coverage percentage decreased, but still higher than the value without NRL, with values of 54.15% and 47.95% for 6-hour and 24-hour tests respectively.

4.1.3 Result of Buriram Basalt

Results from RBT testing between basalt rocks from Buriram province and each type of Asphalt Emulsion is shown in Table 3 and shown in Fig. 6.

Table 3 The result of Rolling Bottle test with Buriram Basalt

Basalt Buriram		
Asphalt Emulsion type	Bitumen Coverage (%)	
	6 Hours	24 Hours
AN	89.49	37.11
AN + 10%NR	87.39	38.82
AN + 20%NR	82.74	31.46
HMA	93.09	67.17
CAT	64.68	45.73
CAT + 10%NR	52.34	37.41
CAT + 20%NR	37.34	26.85

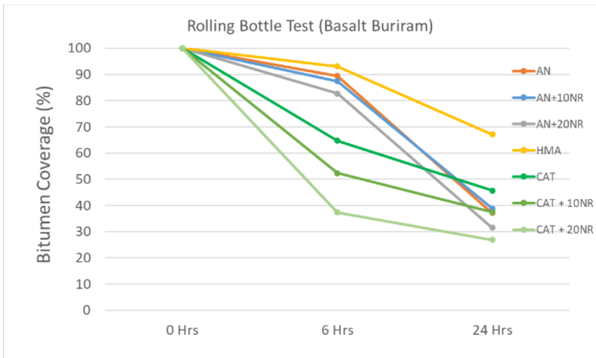

Fig. 6 The result of Rolling Bottle test with Buriram Basalt

Based on the test results, at the 6-hour testing time, Anionic Asphalt Emulsion had a Bitumen Coverage percentage of 89.49%, which is higher than Cationic with a value of 64.68%. At the 24-hour testing time, Cationic had a Bitumen Coverage percentage of 45.73%, which is higher than Anionic with a value of 37.11%. When NRL 10% was added to Anionic, the Bitumen Coverage percentage was found to be close to that of not adding NRL, both at the 6-hour testing time and the 24-hour testing time, with values of 87.39% and 38.82%, respectively. When NRL 20% was added to Anionic, the values decreased in both testing times, with values of 82.74% and 31.46%, respectively. Adding NRL 10% to Cationic resulted in a decrease in Bitumen Coverage percentage at both testing times, with values of 52.34% and 37.41%, respectively. When NRL 20% was added to Cationic, the Bitumen Coverage percentage decreased in both testing times, with values of 37.34% and 26.85%, respectively.

4.1.4 ANOVA test

In analyzing the statistical results of the rolling bottle test with ANOVA test, SPSS program was used as a tool for statistical testing. This test was done to determine the different types of asphalt emulsion had different effects on the stripping resistance of each type of aggregate. The hypothesis are as follows

Null hypothesis

H0: The different types of asphalt emulsion had no different effects on the stripping resistance of each type of aggregate.

Alternative hypothesis

H1: The different types of asphalt emulsion had different effects on the stripping resistance of each type of aggregate.

The results of the ANOVA test shown in Table 4 (Significant level at 0.05). From table 4 showed that Sig. = 0.000154 and 0.000002, which were less than 0.05 both values resulted in rejecting the null hypothesis or accepting alternative hypothesis. It can be concluded that the different types of asphalt emulsion had different effects on the stripping resistance of each type of aggregate at the significant level 0.05.

Table 4 The result of ANOVA test

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
AN	Between Groups	470.002	2	235.001	53.012	0.000154
	Within Groups	26.598	6	4.433		
	Total	496.600	8			
CAT	Between Groups	918.701	2	459.351	235.587	0.000002
	Within Groups	11.699	6	1.950		
	Total	930.400	8			

4.1.5 Post Hoc test

In the Post Hoc test, it is a statistical test of the results of the Rolling Bottle Test to see if the results obtained from the ANOVA test the different types of asphalt emulsion had different effects on the stripping resistance of each type of aggregate with different values to compare between Anionic and Cationic with the 3 types of aggregate, where 1). limestone from Chonburi province. 2). Limestone from Saraburi Province and 3). Basalt from Buriram Province. Which will be compare each pair. The result shown in Table 5

Table 5 The result of Saraburi Limestone XRD

Multiple Comparisons							
LSD							
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
AN	1	2	-7.185089*	1.7191	0.0058	-11.3916	-2.9786
		3	-17.602613*	1.7191	0.0001	-21.8091	-13.3961
	2	1	7.185089*	1.7191	0.0058	2.9786	11.3916
		3	-10.417523*	1.7191	0.0009	-14.6240	-6.2110
	3	1	17.602613*	1.7191	0.0001	13.3961	21.8091
		2	10.417523*	1.7191	0.0009	6.2110	14.6240
CAT	1	2	4.768301*	1.1401	0.0058	1.9785	7.5581
		3	-18.646732*	1.1401	0.0000	-21.4365	-15.8570
	2	1	-4.768301*	1.1401	0.0058	-7.5581	-1.9785
		3	-23.415033*	1.1401	0.0000	-26.2048	-20.6253
	3	1	18.646732*	1.1401	0.0000	15.8570	21.4365
		2	23.415033*	1.1401	0.0000	20.6253	26.2048
*. The mean difference is significant at the 0.05 level.							

From Table 5, it was found that all pairs had Sig. values less than 0.05, so it could be concluded that the stripping resistance of every pair was different. It can be concluded that Anionic asphalt emulsion Basalt from Buriram Province. has the highest stripping resistance followed by Limestone from Saraburi Province and the least is limestone from Chonburi province. In the case of Cationic asphalt emulsion Basalt from Buriram Province. has the highest stripping resistance followed by Limestone from Chonburi Province and the least is limestone from Saraburi province.

4.2 XRD of aggregate test result

4.2.1 XRD of Chonburi Limestone

The XRD test results of the Chonburi limestone shown in Table 6 revealed that this type of limestone mainly consists of Calcite and Quartz. Calcite accounts for 40.96% and Quartz accounts for 41.79%. The high amount of Silica (SiO_2) in Quartz classifies this limestone as Hydrophilic. so that the Hydrophilic aggregates are considered to be acidic. However acidic quartzite has been shown to be less susceptible to stripping than most basic aggregates [7].

Table 6 The result of Chonburi Limestone XRD

Chonburi Limestone		
% minerals	Name of Component	Component
41.79	Quartz,low	SiO_2
40.96	Calcite	$CaCO_3$
1.99	Phlogopite-1M	$KMg_3(Si_3Al)O_{10}F_2$
4.45	Cesium Bromide Thiourea	$C_4H_{16}BrCsN_8S_4$
10.80	Microcline,intermediate	$KAlSi_3O_8$

4.2.2 XRD of Saraburi Limestone

The XRD test results of the Saraburi limestone shown in Table 7 revealed that this type of limestone mainly consists of Calcite accounts for 69.55%, Dolomite accounts for 21.43% and Quartz account for 9.02%. The low amount of SiO_2 in Quartz classifies this limestone as Hydrophobic. It is generally observed that hydrophobic aggregates have a higher resistance to stripping of asphalt films [7]. Furthermore, stripping has been observed in mixes containing limestone aggregate, which is often considered to be immune to stripping [8].

Table 7 The result of Saraburi Limestone XRD

Saraburi Limestone		
% minerals	Name of Component	Component
69.55	Calcite	$CaCO_3$
21.43	Dolomite	$CaMg(CO_3)_2$
9.02	Quartz	SiO_2

4.2.3 XRD of Buriram Basalt

The XRD test results of the Buriram Basalt shown in Table 8 revealed that this type of Basalt stone mainly consists of Andesine accounts for 84.76%, Augite and Aluminum accounts for 11.95% and Chlorite accounts for 3.29%

Table 8 The result of Buriram Basalt XRD

Buriram Basalt		
% minerals	Name of Component	Component
84.76	Andesine	$(Na_{0.622}Ca_{0.368})(Al_{1.29}Si_{2.71}O_8)$
11.95	Augite, aluminum	$Ca(Mg, Fe_{+3}, Al)(Si, Al)_2O_6$
3.29	Chlorite	$Mg_6Si_4O_{10}(OH)_8$

5. Concluding

This research is a test to determine the stripping resistance value between different types of aggregate and each type of asphalt emulsion. The results are summarized as follows.

1. The different types of asphalt emulsion had different effects on the stripping resistance of each type of aggregate.
2. When Natural Rubber Latex is added to different types of asphalt emulsions, it is found to enhance the performance in terms of resistance to stripping between different types of aggregates. However, the performance decreases when Natural Rubber Latex is added in excessive amounts. From the experiments, it is observed that adding NRL at 10% by weight of the binder material can enhance the resistance to stripping between aggregates and asphalt emulsions but adding NRL at 20% leads to a reduction in performance. Moreover, when adding NRL at 10% to Anionic Asphalt Emulsion for limestone aggregates, there is no significant difference from not adding NRL, but adding NRL at 20% reduces the stripping resistance value. On the other hand, In a Basalt stone case when adding NRL at 10% and 20% to Cationic Asphalt Emulsion, a decrease in the Stripping resistance value is observed.
3. In testing the Stripping resistance of each type of Asphalt Emulsion, although adding NRL can increase the effectiveness of the Stripping resistance. But when compared to using Asphalt cement mixed by Hot mix, the Stripping resistance values are still significantly lower.

4. The two types of limestone have different SiO2 percentages. Limestone from Chonburi Province has a SiO2 percentage of 41.79 % is more than Saraburi limestone which has 9.02%. The high amount of Silica (SiO2) aggregates are considered. to be acidic and low amount of Silica (SiO2) aggregates are considered to be alkaline. As a result, Anionic asphalt emulsion has better stripping resistance between low SiO2 limestone than high among of SiO2 limestone. In the case of Cationic asphalt emulsion had better stripping resistance between high among of SiO2 limestone than less SiO2 limestone.

In this research, it can be used as a guideline to study or evaluate the suitability of various types of rocks available in Thailand for use in asphalt emulsion. The researcher sincerely hopes that in Thailand there will be more studies and use of anionic asphalt emulsion and natural rubber latex can be used more efficiently.

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