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Investigation of Asphalt Mixture Containing Crystalline Waterproofing Agent for Moisture Damage Resistance

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Abstract: Moisture damage is one of the common problems in road pavement. These failures are mostly due to stripping of aggregate and asphalt when making contact with moisture in any kind of ways. Loss of adhesion bond between aggregate and asphalt due to stripping cause the road pavement reduce the durability and performance. In order to enhance the performance of asphalt mixture, a modification towards the asphalt mixture where various mineral filler used to blend with asphalt mixture. In this study, Crystalline Waterproofing Agent (CWA) was used as a filler. The aim of this study is to determine the optimum CWA content to resist the moisture damage that may arise such as stripping and loss of strength to asphalt mixture from previous studies done using Static Immerse Test and Indirect Tensile Test. The tests done and result that have been obtained are including aggregate gradation, penetration test, softening test, Indirect Tensile Test and Static Immerse Test. Results shows that higher content of CWA in asphalt mixture resulted in higher value of TSR. In static immerse test, the results show the stripping between aggregate and asphalt binder are reduced as content of CWA increase. As conclusion, the use of CWA in mix design affected the performance of asphalt mixture as content of CWA gives higher value of TSR. It basically increased the resistance towards moisture damage.

Keywords: Moisture Damage, Stripping, Crystalline Waterproofing Agent

1. Introduction

Pavement is the road structure on top of subgrade. It must durable to support traffic loads. Mainly, there are two types of pavement namely flexible pavement and rigid pavement. Flexible pavement is a structure consisting of asphaltic concrete surface, base and subbase later, while rigid pavement consisting of a surface layer of reinforced concrete slab, base or subbase (optional) constructed on the subgrade.

Particularly, flexible pavement used asphalt as asphalt for asphaltic concrete surface layer. Asphalt is material that binds aggregates to produce strong and stable mixture and broadly used in road

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construction. Aggregate provides interlocking structure, sustain load and distribute to the layer beneath. Besides, portland cement is a filler to provide high strength asphalt mixture and provide resistance of high temperature to the pavement [1]. There are several distresses or failures may experience by the pavement such as fatigue cracking, rutting, thermal cracking, and moisture damage due to the low performance of the asphalt mixture. Generally, moisture damage can be defined as loss of strength and durability of an asphalt pavement [2]. Besides, fatigue cracking is one of the deterioration or deformation of road pavement due to moisture. Fatigue cracking is always a concern for an asphalt pavement because of stripping that occurs due to the loss bond aggregate and asphalt. Stripping, which is a major cause of asphalt pavement deterioration is considered to be the moisture sensitivity of hot mixed asphalt pavement. Stripping occurs usually at the lower layer of a pavement and progress upward. Insufficient mixture stability of an asphalt is one of the cause stripping occurs which lead to pavement deformation.

As to enhance the performance of asphalt mixture, an approach that has been commonly used is modification of an asphalt with additives or filler for the asphalt mixture. In order to avoid moisture damage, Crystalline Waterproof Agent (CWA) is to be added as a filler to replace portland cement as a whole or partially. CWA is known to be able to help self-healing of a construction material [3]. This modification is to enhance the performance of bonding between aggregate and asphalt that characterizing by its higher indirect tensile strength.

Some tests were performed on concrete using CWA to evaluate the capabilities of CWA in concrete [4]. Performance test such as compressive strength test, total absorption and under pressure water penetration. Result of these test shows an identical output of admixture using CWA as compared to ITS test or any other test using CWA. The test shows an increasing of compressive strength using CWA in compressive strength test. This study proved the effectiveness using CWA as filler in concrete as it increases the compressive strength by reducing water absorption and void by testing of total absorption and under pressure water penetration. Throughout the test done by the authors, it shows that using CWA has significant increase on the compressive strength of the concrete.

Static immerse test as done for loose mixture performance test has similar result on compacted test which was indirect tensile test made by previous study research. The results show the effectiveness of using CWA in moisture damage resistance. The stripping that occurs between aggregate and asphalt can be reduced when additives is added. These studies were proved by research where design mix can be strengthened when CWA were added [4] [5]. Process of crystal formation in the design mix is one of the benefits using CWA that increase compressive strength of the sample and also create waterproof toward the material when water making contact.

The main objectives of this research are to know the potential of CWA to improve the conventional asphalt mixture by replacing its filler with the CWA to avoid stripping of asphalt and aggregate. Test include are softening point test, penetration test, determination of optimum bitumen content, Indirect Tensile Test and Static Immerse Test. At the end of study, this study will reveal the effectiveness of CWA as filler in asphalt mixture.

2. Materials and Methods

Materials and methods that were conducted to investigate the moisture damage resistance of an asphalt mixture containing CWA are stated below.

2.1 Materials

The material used to conduct the experiment are asphalt grade 60/70, aggregate, portland cement and Crystalline Waterproofing Agent.

2.2 Softening Point Test

Softening Point Test was conducted to determine the softening point of asphalt based on the temperature applied to asphalt that need to be heated for various road application. Softening point of an asphalt was determined by using ring and ball apparatus. The softening point theory is the temperature at which the material approaches a certain degree of softening under a specified test condition. This implies that its softening value, which is greater softening point, is obtained by the asphalt sample, suggesting lower sensitivity to temperature [6]. The ring and ball test was conducted in accordance to ASTM D36 procedure (ASTM 2005c). Two horizontal asphalt disks, cast into a shouldered brass ring, are heated in a liquid bath at a controlled temperature, each holding a steel ball. The softening point is reported as the mean temperature at which the two disks soften enough to cause a distance of 25 mm from each ball enveloped in asphalt to fall.

2.3 Penetration Test

Penetration test was conducted to examine the consistency of a sample of asphalt by determining the distance in tenths of a millimeter that a standard needle vertically penetrates the asphalt specimen under known conditions of loading, time and temperature [7]. The penetration is measured with a penetrometer by means of which a standard needle is applied to the asphalt specimen under specific conditions. The test was conducted in accordance to ASTM D5. First, specimens are prepared in sample containers as specified in ASTM D5 and then will be placed in a water bath for at 25℃ for 1 hour to 1.5 hours before the penetration test begins. The dimensioned needle is loaded with 100g is brought to the surface of specimen at right angles and then allowed it to penetrate the asphalt for 5 seconds while the temperature of the specimen is maintained at 25℃. The penetration was measured in tenth of a millimeter.

2.4 Aggregate Gradation

Aggregate gradation is critical in the process of aggregate selection as it influence the performance of road layer. Coarse aggregate used in production of concrete contains various size of aggregate. These aggregates undergo sieve analysis to determine the particle size distribution. The aggregate gradation that was used is Nominal Maximum Aggregate Size 9.5mm.

2.5 Determination of Optimum Bitumen Content

The mix design determines the optimum bitumen content (OBC) for a particular aggregate blend and asphalt to be used. In order to obtain OBC, the criteria need to be fulfilled based on Superpave mix design data. In Superpave mix design, six parameters were calculated based from data of the Superpave mix design and graph are plotted against the asphalt content percentage. The parameters that need to be fulfilled the criteria needed are as below

Table 1: Criteria of Superpave Mix Design

Mix Property	Criteria
Percent Air Void	4.0%
Percent VMA	Min 13
Percent VFA	65-76
Dust Proportion	0.6-1.2

The mix design method is based on Superpave design method. The volumetric properties of asphalt mixes will be analyse based on JKR specification. The determination of OBC was based on 5.5 % asphalt content, and the specimen will be carried at ± 0.5% below estimated asphalt content and at +1% from estimated asphalt content.

2.6 Indirect Tensile Test

Indirect Tensile Test is a standard or common test used to evaluate the resistance of compacted asphalt mixture to moisture susceptibility. This process involves the preparation of specimens and the calculation of the change in diametric tensile strength due to the effects of water saturation and rapid freeze-thaw water cooling of compacted asphalt mixtures. The result may be used for further evaluation of stripping susceptibility of an asphalt mixture using filler. AASHTO T283 can be used to determine the effectiveness of additives covering hot mix asphalt to resistance of water [8].

This test is also known as Modified Lottman Test. The air void content of the compacted specimens is estimated to be between 6.5 % and 7.5 %. Firstly, vacuum is applied to a level between 70 % and 80 % to partly saturate specimens. Vacuum-saturated samples are kept in freezer at a temperature of -18℃ and then were immersed for 24 hours in a water bath at temperature of 60°C. The specimen was considered as conditioned. The other samples proceed to be unconditioned. On all samples (unconditioned and conditioned), indirect tensile measurements were measured at constant temperature 25℃ of the sample

2.7 Static Immerse Test

Static immerse test was conducted to evaluate the effect of coating that used into asphalt mix and the potential of stripping to occur to the asphalt mixture. Static Immerse Test was conducted in compliance with AASHTO T182. During the test, for 16-18 h glass bottles, samples of aggregates with sizes ranging from 6.3 to 9.5 mm coated with 5.5 g of asphalt were immersed in distilled water at certain temperatures for 16 -18 hours in glass bottles. The samples were observed through the water to measure the percentage of total visible area of aggregate surface that retains its asphalt coating. Three sample of 100 g aggregate coated with asphalt were tested and the average percentage coated estimated.

3. Results and Discussion

Laboratory tests and analysis that have been done to achieve the objectives of this project. The data analysis was presents using calculations, tables, and graphs to ensure that analysis results can be easily understood. The laboratory tests include gradation, penetration test, softening point tests and Superpave mix design to determination optimum bitumen content. Modified Lottman test and Static Immerse test were done to show CWA effectiveness as a filler in asphalt mixture.

3.1 Penetration Test

Table 2 below show the average penetration value result for asphalt grade 60/70 on three difference samples. There are five points were penetrated on each sample and its average were calculated. Result shows that the penetration values of the asphalt are within the standard range of penetration value for asphalt grade 60/70 accordance to MS541 that and can be classify as asphalt grade 60/70.

Table 2: Penetration test result

Sample	Softening Point
Average	53.0

3.2 Softening Point Test

Table 3 shows the average data samples of asphalt grade 60/70 undergo softening point test. Reading of the data were taken when the ball touches the bottom of the steel. The average value of the data shows that the asphalt is following the requirement range of softening point for asphalt grade 60/70.

Table 3: Softening point test result

Sample	Softening Point
Average	69.17

3.3 Aggregate Gradation

The aggregate gradation used in this project is NMAS 9.5 as shown in table below. The proportion of the aggregate and CWA used in mix are shown in Table 4.

Table 4: Aggregate Gradation

Sieve Size	% passing	% retained	Weight	50%	75%	100%
12.5	100	0	0	0	0	0
9.5	94	6	69	69	69	69
4.75	78	16	184	184	184	184
2.36	42	36	414	414	414	414
1.18	20	22	253	253	253	253
0.6	10	10	115	115	115	115
0.3	5	5	57.5	57.5	57.5	57.5
0.075	2	3	34.5	34.5	34.5	34.5
Pan	0	2	23	11.5	5.75	0
CWA				11.5	17.25	23
Total		100	1150	1150	1150	1150

3.4 Determination of Optimum Bitumen Content

Three graphs are plotted in order to meet the requirement as in accordance to Superpave mix design. The graphs include percent air void, percent VMA, percent VFA versus percent of asphalt content of asphalt mixtures and the result are shown in Table 5. For analysis of the OBC, it was determined from the graphs at 4% of air void; and the VMA and VFA of the asphalt mixture needed to comply with respective criteria. In accordance to the standard, graph are constructed to analyse. Graph resulted that the air void meets it criteria which was 4%. The asphalt content achieved was 5.9%. With 5.9% asphalt content, the result of VMA was complied with the minimum requirement which is 15.2 and the minimum is 13. Percent of VFA obtained is 73.5 which in the range of criteria of superpave mix design. Therefore, it can be conclude that the design OBC obtained was 5.9% based on the graph constructed and was accepted since it follows the design criteria of Superpave mix design.

Table 5: Design mix properties at 5.9% asphalt content

Mix property	Criteria	Result	Status
Percent Air Void	4%	4%	OK
Percent VMA	Min 13	15.2	OK
Percent VFA	65-76	73.5	OK

3.5 Indirect Tensile Test

Indirect Tensile Strength Test was conducted to evaluate the resistance of asphalt mixture to moisture susceptibility. TSR results show are to analyse the abilities and effectiveness of CWA in design mix. Summary of the results are as follow:

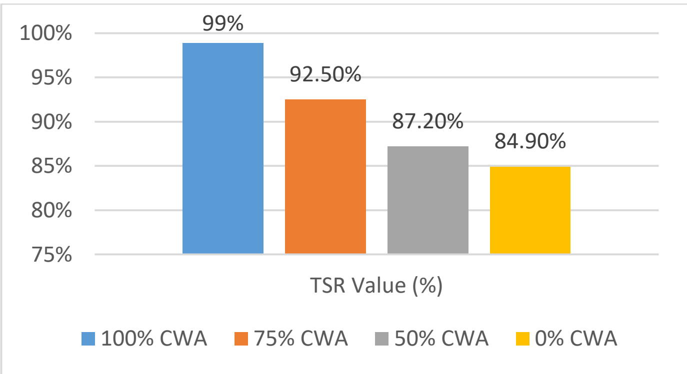

Figure 1: Summary of TSR result 1

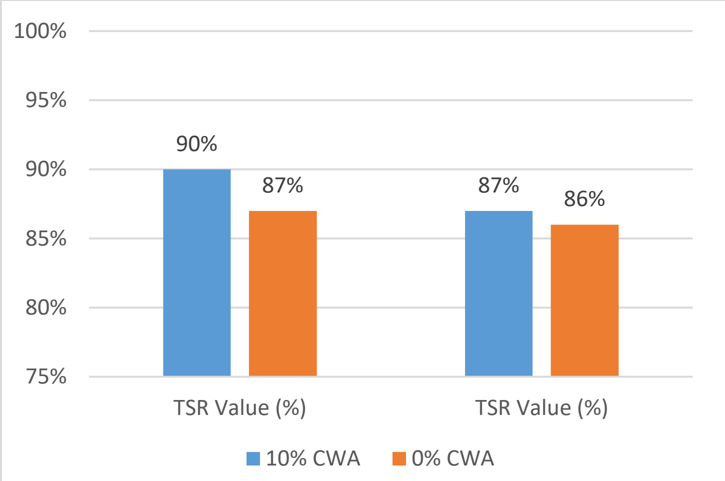

Figure 2: Summary of TSR result 2 and 3

Results shows the use of CWA in asphalt mixture was effective improved the performance of asphalt mixture on resistance moisture damage. The value of TSR increase as the content of CWA in asphalt mixture increased. From the first data of ITS test in Figure 4, it clearly shows the increment of tensile strength ratio of the specimen as the content of CWA increased. In accordance, 100% of CWA in asphalt mixture resulted in highest TSR value of 98% followed by 92.5%, 87.2% and 84.9% for CWA content of 75%, 50% and 0% respectively. While on the second and third data of ITS test as shown in Figure 5, asphalt mixture show higher TSR when 10% CWA was added compared to the control sample. Therefore, it can conclude that the use of CWA helps the asphalt mixture to increase its strength and decrease the potential of moisture damages.

4.6 Static Immerse Test

Static immerse test was done to observe the stripping that occurs to the loose mixtures. Figure 3 show 4 samples with various CWA content undergo static immerse test to evaluate the effectiveness of the additives. 0%, 10%, 20% and 25% are the percent of CWA used in 100g of aggregate. By visual observation, it shows the amount of stripping is small when using CWA in asphalt mixture. As according to Lu et al., (2019), the uses of CWA not only on its abilities on self-healing but also toward the strength of the cement as the result of pre pressure test on the cement shows the permeability of the cement using CWA is high because even having the lowest pre pressure, it still has better self-healing capabilities.

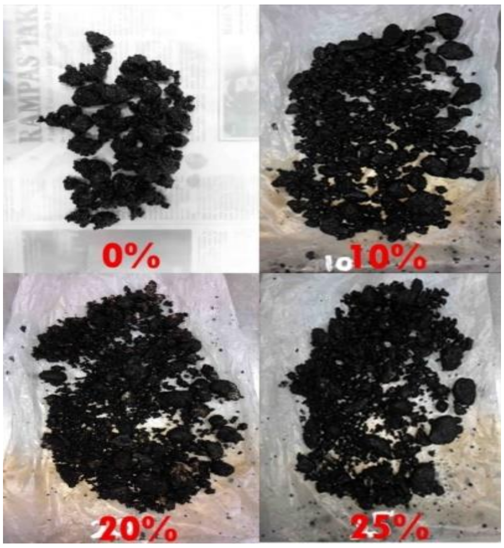

Figure 3: Static Immerse Test Result

4. Conclusion

Based on this study, the conclusion of data obtained are as follow:

1. Penetration test and softening point test are done to specify the grade of the asphalt. The asphalt tested results in the range required in grade 60/70.
2. Graph of air void, VMA and VFA are constructed to identify the optimum asphalt content followed to the criteria of Superpave mix design. The OBC obtained was 5.9% where all the parameters of Superpave mix design are fulfilled.
3. ITS test results show that TSR are higher as the percent of CWA in asphalt mixture increased
4. In static immerse test, the use of CWA can be seen to reduce the amount of stripping in loose mixture. The amount of stripping is reduced as the content of CWA in the asphalt mixture increased.
5. Use of CWA affect the performance of an asphalt mixture. The CWA was able to resist moisture damage as the less amount of stripping occurred on aggregates coated with asphalt and CWA in static immerse test and the high value of TSR of the asphalt mixture containing CWA in ITS test.

The recommendations for future works are as follow:

1. The use of Static Immerse test and Indirect Tensile test were seen to be useful in evaluating moisture damage resistance. However, several other test such as rutting test, wheel tracking test and fatigue test can be made to have further understanding and analysis on effectiveness of CWA.
2. Different nominal size of aggregate using Superpave standard need to be done to compare the strength of asphalt mixture. This can ensure the nominal size of aggregate with better performance in design mixture.
3. Testing of aggregate using Soundness and Aggregate Impact Value can be done to achieve the physical characteristic of aggregate. The disintegration of aggregate during weathering can be tested using soundness test and the strength of aggregate can be done by aggregate impact value test.

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