Assessing The Durability of Polymer Modified Asphalt Emulsions Slurry Seal

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Abstract. Slurry Seal is an application of road preservation in the form of impermeable non-structural thin layer with maximum thickness of 10 mm, which consisting of a cold laid mixture of asphalt emulsion with continuous graded fine aggregate, mineral filler, water and other added ingredients. Road preservation use slurry seal only functioning as a surface layer on the existing pavement structure. This preliminary research was conducted to determine the value of consistency, setting time, and indirect tensile strength of polymer modified slurry seal. The laboratory tests were conducted to determine the optimum residual asphalt content. The results show that the value of the optimum water content by pre-wetting 5% is getting smaller with increasing levels of residual asphalt emulsion. The addition of water 0 – 2.5% with 5% water for pre-wetting, the mixture provides a sufficient consistency in accordance with the specifications. The increasing levels of residual asphalt emulsion obtained the longer setting time at all slurry seal mixtures, but all of the mixtures still meet the specifications. The use of polymer modified asphalt emulsion on slurry seal was improved durability significantly, based on the value of indirect tensile strength.

1. Introduction
Slurry Seal is an application of road preservation in the form of impermeable non-structural thin layer with maximum thickness of 10 mm, which consisting of a cold laid mixture of asphalt emulsion with continuous graded fine aggregate, mineral filler, water and other added ingredients. Slurry seal is one kind of cold mix asphalt formulated precisely as maintenance materials, surface pavement treatment, or as an addition to the surface layer thickness. The addition of slurry seal will improve the pavement flatness by reducing roughness and rutting, coat the pavement surface, improve roughness without have to retexturing as well as its application is easy and fast because the traffic can be opened in a few hours [1].

Road preservation techniques already mentioned above is simply functioning as a surface layer of the existing structure pavement. One of the problems that occur in the surface layer is slick effects occurring because of road surface texture that is too smooth, therefore it is necessary of skid resistance which serves as a barrier so that the wheels of vehicles do not slip on the surface pavement. Skid resistance is an important parameter to functionally evaluation of the pavement performance, especially on roads that are planned by vehicles at high speed [2].
Another problem that occurs in surface layer is that the layers located on the top surface layer so it may change the characteristics mainly influenced by temperature. The aging process in asphalt mixture is one causes of the strength decline from flexible pavements, with the result that damage occurs earlier than service life of the pavements. It can be caused by some environmental factors such as air temperature and solar thermal. The cause of aging on asphalt mixture is the evaporation of the liquid portion of the asphalt for their heating so that the asphalt becomes brittle and loses adhesion. Declining in flexibility and adhesion of asphalt can damaged the road easily when receiving the traffic load [3].

Slurry seal is a mixture of asphalt emulsion without heating, with a content of finely graded aggregate, mineral filler, water and other additives that mixed evenly and overlay above the surface pavement as slurry. Asphalt emulsion is the asphalt dispersed in water. Terms of slurry seal characteristics can be seen in Table 1.

Based on research conducted by Oikonomou and Eskioglou [6] portland cement, fly ash, ladle furnace slag, cement klin dust and marble dust were tested as fillers in slurry seal and result showed that they can be used producing slurry seal according to specifications.

According to Read and David [5], setting time was defined as the time it takes since asphalt emulsion mixing then overlay until the time of asphalt starts to harden on the aggregate surface. This phenomenon is characterized by colour changes of asphalt emulsion. At the beginning of mixing indicated with brown (like mud) became blackish brown and when the settings have been completed, there are no brown spots on aggregate surface. At the time of slurry seal overlay has completed, it will be obtained black colour on road surface.

The aging of the asphalt mixture can occur due to warming caused by environmental conditions. Asphalt aging is a good parameter to determine the durability of asphalt mixture. It caused by two main factors, they are the evaporation of lighter oil fraction contained in the asphalt and the oxidation. Asphalt consists of a liquid part called maltenes and solid part called asphaltenes. The aging process that causes the asphalt become hard and brittle is caused by the evaporation of the light fractions in asphalt and changing the liquid fraction (maltenes) into a solid (asphaltenes). This aging causes hardening of the asphalt and will further increase the stiffness of asphalt mixture so that would affect the performance of the mixture.

**Table 1. Terms of slurry seal characteristics**

| Characteristics of Mixture | Testing Methods | Type of Mixture |
|---------------------------|----------------|-----------------|
| 1  | Asphalt residue, % to the dry weight | 10 - 16 | 7.5 - 13.5 | 6.5 - 12 |
| 2  | Cone consistency, cm | ISSA TB NO.106 | 2 - 3 |
| 3  | Wet stripping, % | ISSA TB NO.114 | Min. 90 |
| 4  | Cohesion | ISSA TB NO.139 |
|    | - 30 sec, kg-cm | ≥ 12* |
|    | - 60 sec, kg-cm | ≥ 20* |
| 5  | Setting time, sec | ISSA TB NO.139 | 15 - 720 |
| 6  | Curing Time, sec | < 720 |
| 7  | Wet Track Abrasion Test, 1 hour soak, g/m² | ISSA TB NO.100 | ≤ 500 |

* For fast traffic system

Source: Kementrian Pekerjaan Umum dan Perumahan Rakyat, 2015

Kliwer, et.al. [4] though Strategic Highway Research Program (SHRP) Project A-003A have been examined the relationship between the performance of asphalt concrete mixtures on the field and the
aging characteristics asphalt concrete mixtures that is performed on the laboratory. The aging procedure of asphalt concrete mixture on a laboratory to represent short-term aging or during the implementation is done by heating a loose asphalt concrete mixture in the oven for 4 hours at a temperature of 135°C before compacted. Whereas for simulate the long-term aging in the laboratory by heating the compacted asphalt concrete specimen at a temperature of 85°C. Duration of heating for 2 days represent of aging asphalt concrete pavement for 5 years. Then heating for 5 days to simulate the of aging asphalt concrete pavement for 10 years. Furthermore, to measure the result of aging carried out by calculating the resilient modulus at the temperature of 25°C with data from indirect tensile test accordance with AASHTO T 322-07.

According to Kementrian Pekerjaan Umum dan Perumahan Rakyat [7] mentions that the asphalt emulsion can also be modified with latex, where the asphalt emulsion formed in rubber particles. Latex does not mix with asphalt emulsion, but latex and granular asphalt formed three-dimensional structures. Latex can be separated with asphalt emulsion due to the difference in specific gravity. Mixing of polymer latex was recommended during blending it with hot asphalt, so that the polymer can be mixed perfectly. Some researchers suggest for polymer material in liquid form can be mixed after the emulsifying process is complete, because it can reduce the energy used for heating and minimize the risk of damage to the polymer as a result of the heating process while mixing [8].

For that reason, research is needed to determine the durability of slurry seal against the effects of aging. Laboratory testing on aging can be done through Short Term Oven Aging (STOA) and Long Term Oven Aging (LTOA). Short-term aging to simulate aging while mixing, transporting, deploying, and compacting in the field. While the long-term aging is the aging process when the service life of roads [4].

This research was conducted by using a polymer modified asphalt emulsion with addition of polymer latex in an effort to improve the durability of slurry seal over the service life. Polymer was divided into two types, namely the elastomer (elastic) and plastomer (high modulus stiffness). Examples of elastomer are styrene butadiene styrene (SBS) block copolymers, styrene butadiene rubber (SBR) latex, and natural rubber latex. While the examples of plastomer are ethylene vinyl acetate (EVA) and polyvinyl acetate (PVA). Plastomer used to modify asphalt to make it stiffer, while elastomers are used to modify asphalt to make it more stiff and elastic [5].

This research aimed to determine the effect of polymer modified asphalt emulsion to the durability of slurry seal. Type of polymer that used in this research is polymer latex. The use of polymer latex is expected to improve the characteristics of slurry seal in value of consistency, setting time, and indirect tensile strength.

2. Experimental
The design of slurry seal begins to test the quality of the base material consisting of aggregates and asphalt emulsion as a bonding agent. Based on the damage of pavement surface and road conditions (environmental factors and traffic), the type of slurry seal that use in this research is Type 3. It was suitable to repairs raveling, oxidation and improve the road surface roughness. Testing the consistency, setting time, and indirect tensile strength is used to determine the optimum residual asphalt content. The optimum residual asphalt content is determined by considering some aspects of slurry seal characteristics that must be met in Table 1. This optimum residual asphalt content used for next research to be tested the durability against aging. This research was conducted by making 5 variety of asphalt content in mixture, there are: 5.5%, 6.5%, 7.5%, 8.5%, and 9.5%. The type of asphalt emulsion that used are a standard asphalt emulsion CSS-1h (I), CSS-1h+latex 1% (II), CSS-1h+latex 2% (III) and CSS-1h+latex 3% (IV).

3. Results and Discussion
3.1. Cone Consistency Testing Results
This test is used to determine the level of workable and as a control on making sample of slurry seal. The results for this test is the optimum water content. The results show in Table 2. It show that the
value of the optimum water content by pre-wetting 5% is getting smaller with increasing levels of residual asphalt emulsion. The addition of water 0 – 2.5% with 5% water for pre-wetting, the mixture provides a sufficient consistency in accordance with the specifications (2 – 3 cm).

Greater consistency value obtained by increasing the residual asphalt content. This is because partly the composition of asphalt emulsion is in the form of water. Based on testing can also be seen that the use of polymer latex does not significantly affect to the value of setting time. However more affected by filler that provides a sufficient consistency in accordance with the specifications (2 – 3 cm).

Based on Table 4, then made correlation chart between residual asphalt content with value of ITS shown in Figure. Optimum residual asphalt content obtained when the test results show the optimum value of the indirect tensile strength. From Figure 1 it can be seen that optimum asphalt content for each type of asphalt emulsion that have been used was dissimilar. Optimum asphalt content for each type of asphalt emulsion (I, II, III, IV) were about 7.37%, 7.45%, 7.41% and 7.57%. The optimum asphalt content has a tendency to increase in line with the addition of a polymer latex. This

| Table 2. Cone Consistency Testing Results (cm) |
|-----------------------------------------------|
| **Material Mixture (%)**                      |
| **Asphalt Emulsion Type** | Aggregate | Filler | Water | Residual Asphalt Content |
| I     | 100  | 50  | 50  | 5 – 7.5 | 2.4 | 2.3 | 2.5 | 2.6 | 2.8 |
| II    | 100  | 50  | 50  | 5 – 7.5 | 2.3 | 2.3 | 2.4 | 2.7 | 2.8 |
| III   | 100  | 50  | 50  | 5 – 7.5 | 2.3 | 2.3 | 2.4 | 2.6 | 2.8 |
| IV    | 100  | 50  | 50  | 5 – 7.5 | 2.4 | 2.4 | 2.5 | 2.7 | 2.8 |

3.2. Setting Time Testing Results
Setting time is the time required by asphalt emulsion from the beginning of mixing until hard condition. At the beginning of mixing indicated with brown (like mud) became blackish brown and when the settings have been completed, there are no brown spots on aggregate surface. The results show in Table 3. The result show that with increasing levels of residual asphalt emulsion obtained the longer setting time at all slurry seal mixtures. Based on testing can also be seen that the use of polymer latex does not significantly affect to the value of setting time. However more affected by filler that used. In the cement filler, factors that affect the setting time is mixture workability. With higher workability, asphalt emulsion will be easier to cover the aggregate surface, produce thinner asphalt layer and possibility to make greater contact with the aggregate, so that the asphalt emulsion will be more rapidly breaking and setting conditions [9].

| Table 3. Setting Time Testing Results (minute) |
|-----------------------------------------------|
| **Material Mixture (%)**                      |
| **Asphalt Emulsion Type** | Aggregate | Filler | Water | Residual Asphalt Content |
| I     | 100  | 50  | 50  | 5 – 7.5 | 115  | 140 | 150 | 165 | 200 |
| II    | 100  | 50  | 50  | 5 – 7.5 | 110  | 125 | 150 | 160 | 190 |
| III   | 100  | 50  | 50  | 5 – 7.5 | 110  | 130 | 145 | 160 | 185 |
| IV    | 100  | 50  | 50  | 5 – 7.5 | 100  | 125 | 150 | 165 | 190 |

3.3. Indirect Tensile Strength Testing Results
Indirect tensile strength test of slurry seal mixture is intended to determine the value of tensile strength of the slurry seal mixture that have been made. Furthermore this test is used to determine the optimum residual asphalt content. The results show in Table 4.

Based on Table 4, then made correlation chart between residual asphalt content with value of ITS presented in Figure. Optimum residual asphalt content obtained when the test results show the optimum value of the indirect tensile strength. From Figure 1 it can be seen that optimum asphalt content for each type of asphalt emulsion that have been used was dissimilar. Optimum asphalt content for each type of asphalt emulsion (I, II, III, IV) were about 7.37%, 7.45%, 7.41% and 7.57%. The optimum asphalt content has a tendency to increase in line with the addition of a polymer latex. This
can be caused by concomitant addition of the polymer, the penetration value will decrease and the softening point value will further increase [10]. Higher penetration value, accordingly easier to cover up and fill the cavity between the grains aggregate so that require less bitumen content to achieve the optimum characteristics.

### Tabel 4. Indirect Tensile Strength Testing Results (kPa)

| Asphalt Emulsion Type | Aggregate | Filler | Water | Residual Asphalt Content |
|-----------------------|----------|--------|-------|--------------------------|
|                       | OPC      | LCFA   | 5–7.5 | 5.5 | 6.5 | 7.5 | 8.5 | 9.5 |
| I                     | 100      | 50     | 50    | 38.8 | 51.5 | 49.9 | 42.2 | 39.9 |
| II                    | 100      | 50     | 50    | 71.8 | 87.7 | 91.5 | 92.2 | 66.5 |
| III                   | 100      | 50     | 50    | 79.8 | 93.1 | 89.5 | 97.6 | 73.8 |
| IV                    | 100      | 50     | 50    | 53.4 | 75.9 | 69.4 | 67.9 | 60.2 |

The indirect tensile strength results tend to increase to the optimum point and then go down when the percentage of asphalt exceeds the optimum level. The use of polymer modified asphalt emulsion would increase the value of indirect tensile strength and optimum asphalt content that required on mixture. Based on these tests it was found that the use of asphalt type III (CSS-1h+latex 2%) gave the best results.

![Figure 1. Correlation between residual asphalt content with value of ITS](image)

**4. Conclusion**

The results show that the value of the optimum water content by pre-wetting 5% is getting smaller with increasing levels of residual asphalt emulsion. The addition of water 0 – 2.5% with 5% water for pre-wetting, the mixture provides a sufficient consistency in accordance with the specifications (2 – 3 cm). The increasing levels of residual asphalt emulsion obtained the longer setting time at all slurry seal mixtures, but all of the mixtures still meet the specifications (15 – 720 sec). Polymer modified asphalt emulsion show to improve the durability of slurry seal significantly. Based on the indirect tensile strength test showed that the use of asphalt type III (CSS-1h + latex 2%) gave the best results.
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