The Effect of Dustler on Reducing Stripping Failure in Hot Mix Asphalt Mixture

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Abstract. Hot mix asphalt (HMA) is one type of premix widely used in road construction worldwide. Aggregates for HMA are usually classified by size as coarse aggregates, fine aggregates, or mineral fillers. Moisture damage or stripping is one of the major concerns in HMA industry. The existence of water in asphalt pavement is often one of the major factors affecting the durability of HMA. The water-induced damage in HMA layers may be associated with two mechanisms: a loss of adhesion and loss of cohesion. The main focus of this study based on these two objectives which is to develop HMA that involves use of dustler in asphalt mixture and to investigate the performance of dustler against stripping failure. The asphalt mixture of combination virgin aggregate and this waste material was studied. The percentages of dustler used in this study were 0.5%, 1.0% and 2.0% respectively. The method used in this study was Superpave mix design method. From the laboratory test, the indirect tensile strength (ITS) test was conducted to show the stripping performance. The result from that test showed that the value of ITS for dry sample is higher compared to wet sample for all percentages. The moisture sensitivity was determined through tensile strength ratio (TSR) test. From the results, it showed that the percentages of dustler were fulfilled the minimum requirement of AASHTO T283 which is 80% minimum requirement of moisture susceptibility. The highest value of TSR is 0.5% of dustler sample which is 98.55% compared to 1.0% of dustler sample, control sample and 2.0% of dustler sample. So, it can be concluded that dustler inhibits great potential on reducing stripping failure in hot mix asphalt.

1. Introduction

Road pavements represent a huge investment. Most surfaced roads are made of flexible pavement. One of the most important problems in flexible pavement is stripping, which is the loss of adhesion between asphalt coating and aggregate in the bituminous mixture caused by the existence of moisture. Stripping might cause different types of distresses such as: creep, raveling, rutting, shoving, and cracking [1].

The trapped water in bitumen and aggregate interface causes adhesion failure that affects pavement strength and shorten the design life. Moisture damage is defined by loss of strength or durability in an asphalt mixture due to the effects of moisture measured by the asphalt mixtures loss of mechanical properties and the strength of aggregate-bitumen bonding presented as the integrity indicator [2-3]. Moisture damage is caused by water infiltrating the pavement surface and weakening bonds that hold
the pavements together. Moisture damage provides the opportunity for other forms of pavement distresses as well, further weakening and destroying the pavement [4].

Moisture damage is a factor affecting the durability and loss of strength asphalt pavement due to presence of water. Asphaltic concrete and porous asphalt are widely used in flexible pavement construction. Bitumen or asphalt binder is used in both mixes to bind together aggregate particles. Binders are known to deform and flow at high temperatures but become brittle at low temperature. The abrasive action of vehicle wheel on pavement surfacing, especially on high stressed areas, can initiate particle loss while the action of water results in stripping [5].

This study evaluated the performance of dustler as filler in asphalt pavement. Dustler is a waste from the batching plant and was chosen because it was the most environmentally friendly alternative which is, it replace the used of conventional mineral filler. Based on previous study, the performance of asphalt pavements is related to cohesive and adhesive bonding within the asphalt-aggregate system. The loss of cohesion (strength) and stiffness of the asphalt film, and the failure of the adhesive bond between aggregate and asphalt in conjunction with the degradation or fracture of the aggregate were identified as the main mechanisms of moisture damage in asphalt pavements [6].

Stripping is the process that results in separation of asphalt binder and aggregate due to the loss of adhesion at the interface of these materials in the presence of water or water vapor. Stripping as adhesion failure is most likely occurring at the pavement surface or internally within the mixture. Stripping starts occurring at the weak points such as pavement joints and areas of high air void content due to improper compaction.

The waste material used for this study was taken from Southern Premix Sdn. Bhd. Sedenak, Johor. This material based on production of dust stone from the process of asphalt batching plant and it was removed to prevent from release into the air. Figure 1 shows the asphalt batching plant at Southern Premix Sdn. Bhd. Figure 2 is funnel smoke out and Figure 3 illustrates the place of dustler collected.

Figure 1 Asphalt batching plant at Southern Premix Sdn. Bhd

Figure 2 Funnel smoke out
2. Methodology

The materials used in this study were aggregate, chevron bitumen grade 80/100 and dustler used as filler. The percent of 0.5%, 1.0% and 2.0% dustler were used respectively in this study. Table 1 show the mass of aggregate and dustler for each percent and also size needed. The sample of mixture was prepared according to Superpave mix design method. The American Society for Testing and Material (ASTM) and the American Association of State Highway and Transportation Official (AASHTO) were referred to carry out the mixture sample. The entire samples were used for the performance testing, which was ITS test and TSR test.

Table 1  Mass of aggregate and dustler for each percent and size need

| SIZE, mm | CONTROL SAMPLE | 0.5 % DUSTLER | 1.0 % DUSTLER | 2.0 % DUSTLER |
|----------|----------------|---------------|---------------|---------------|
| 12.5     | 0              | 0             | 0             | 0             |
| 9.5      | 96             | 96            | 96            | 96            |
| 4.75     | 360            | 360           | 360           | 360           |
| 2.36     | 204            | 204           | 204           | 204           |
| 1.18     | 156            | 156           | 156           | 156           |
| 0.6      | 132            | 132           | 132           | 132           |
| 0.3      | 72             | 72            | 72            | 72            |
| 0.15     | 96             | 96            | 96            | 96            |
| 0.075    | 60             | 60            | 60            | 60            |

PAN = 24 Dustler = 6 Dustler = 12 Dustler = 24
PAN =18 PAN =12

TOTAL (g) 1200 1200 1200 1200

Figure 3 The place of dustler collected
2.1 Sample Testing
There are two performance tests that were used in this study which are Indirect Tensile Strength test and Moisture Sensitivity test for unconditioned subset (dry) and conditioned subset (wet). The bitumen testing that had been done for this study were softening point test and penetration test, while for aggregate test were sieve analysis and flakiness and elongation. Result for softening point test is 47.2ºC which is in the range of 45ºC - 52ºC (ASTM D36), while for penetration the value is 80.98 which are in the range of 80-100 (ASTM D5). Results for determination of aggregate properties were referred according to JKR/SPJ/2008.

2.1.1 Indirect Tensile Strength Test (ITS)
The AASHTO Standard Method of Test T283, ‘Resistance of Compacted Bituminous Mixture to Moisture Induced Damage’, is the most commonly used procedures for determine the moisture susceptibility of asphalt mixture. ITS test was conducted after the sample was fully prepared. ITS test used the equipment at UTHM laboratory named as California Bearing Ratio (CBR). Once the optimum bitumen content (OBC) is determine, the sample is prepared by using gyratory compactor.

After the specimens have been prepared, all the dry subsets and wet subset of the both types of asphalts were having pre-conditioned before conducting the indirect tensile strength (ITS) test and tensile strength ratio (TSR). The specimens were tested to determine their indirect tensile strengths for both wet and dry of the control, 0.5%, 1.0 % and 2.0 % specimen. The indirect tensile strength (ITS) is calculated as below:

\[ ITS = \frac{2000p}{\pi t D} \]

Where,
- ITS = the indirect tensile strength, Kpa
- P = maximum load, Newton
- t = specimen thickness, mm
- D = specimen diameter, mm

2.1.2 Moisture Sensitivity Test
The test procedure was same as ITS procedure but by using wet sample. This test was held to get the percentage reduction from dry and wet sample. The test prepared to evaluate the strength of dustler on the moisture sensitivity. The ITS will also use to evaluated the resistance of the mix effects of water, calculated from the ratio of the ITS of moisture – conditioned samples to the ITS of unconditioned samples. A minimum of 80% TSR has been typically used as a failure criterion according to AASTHO T283. Resistance to stripping will assessed based on the TSR. The tensile strength ratio is calculated as follow:

\[ TSR = \frac{S2}{S1} \]

Where,
- S1 = average tensile strength of the dry subset, psi (Kpa)
- S2 = average tensile strength of the conditioned subset, psi (Kpa)

3. Results
3.1. Determination of Optimum Bitumen Content
Before preparing the sample, the value for optimum binder content was conducted first. The result for the optimum binder content was 5.88%. In this Superpave mix design method, the OBC of 5.88% obtained was fulfilling the acceptable volumetric property criteria. Table 2 shows the average
theoretical maximum specific gravity and average bulk specific gravity for every trial percent bitumen blend. From that average, the air void values were calculated to get the OBC. From that average, the air void values were calculated to get the OBC. Figure 4 shows the graph of percent of air void vs bitumen content to get the 5.88% OBC.

**Table 2** Average theoretical maximum specific gravity and average bulk specific gravity for every trial percent of bitumen

| Percent bitumen | Theoretical maximum specific gravity | Bulk specific gravity |
|-----------------|--------------------------------------|-----------------------|
| 5.0             | 2.4048                               | 2.2648                |
| 5.5             | 2.3718                               | 2.2645                |
| 6.0             | 2.3428                               | 2.2517                |
| 6.5             | 2.3234                               | 2.2498                |

![Figure 4 Percent of air voids vs bitumen content](image)

**4. Discussion and Findings**

4.1. Indirect Tensile Strength Test and Tensile Strength Ratio Analysis

Figure 5 shows the comparison result of ITS values for dry and wet samples. Generally it shows that the value of ITS for dry sample is higher for all percentages compared to the ITS value for wet sample. This is because the presence of water will reduce the tensile strength of the mixture. According to Chen [7], the effect of moisture or known as a presence of water will reduce the strength and durability in asphalt mixtures.

![Figure 5 Results of the ITS values (dry and wet)](image)

The moisture sensitivity was determined through tensile strength ratio (TSR). The TSR results used as an indication in evaluate the performance of HMA containing dustler in terms of stripping failure. Table 3 summarized the TSR for the control, 0.5%, 1.0% and 2.0% of dustler sample. From the
results, it shows that the TSR for 0.5% of dustler is higher than the other percentages. According to AASHTO T283, the minimum requirement of 80% TSR has been typically used as failure criterion. So, from this study, the dustler for the 0.5% had higher TSR of dry sample.

| Sample | Tensile Strength Ratio, TSR (%) |
|--------|-------------------------------|
| Control | 95.63 |
| 0.5% | 98.55 |
| 1.0% | 97.90 |
| 2.0% | 94.15 |

5. Conclusions
From the results obtained, this study can be concluded that the dustler can be used as a replacement of filler as a new alternative in asphalt mixture. In conclusion, by using the recycled material it can help in conservation of natural resources by reducing the need for new material. For the performance test of HMA that containing 0.5%, 1.0% and 2.0 % of dustler are acceptable for the moisture damage resistance. This is because the proportion that containing dustler in HMA were fulfilled the minimum requirement of AASHTO T283 because the TSR value is higher than 80 % minimum requirement.

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