Effects of reclaimed asphalt pavement on indirect tensile strength test of foamed asphalt mix tested in dry condition

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Abstract: Indirect tensile strength (ITS) test was conducted to analyse strength of the foamed asphalt mixes incorporating reclaimed asphalt pavement. Samples were tested for ITS after cured in the oven at 40°C for 72 hours. This testing condition known as dry condition or unconditioned. Laboratory results show that reclaimed asphalt pavement (RAP) contents insignificantly affect the ITS results. ITS results significantly affected by foamed bitumen contents.

1. Introduction

Pavements are designed to last 10 to 40 years depending on type of highway. Once pavement reach the terminal serviceability index means that pavement no longer can be use, rehabilitation is needed. In some cases the road surfacing needs to be milled creating a milling waste material known as Reclaimed Asphalt Pavement (RAP). The RAP material which contains aggregate and asphalt binder are recyclable and has been used widely as granular base course material in asphalt and Portland cement concrete pavement construction as well as incorporated back into asphalt concrete mixtures for new pavement construction. Incorporating RAP to the asphalt concrete mixtures for highway construction is one of significant ways to ensure sustainable development since aggregate materials are non-renewable natural resources, therefore using RAP helps to reduce demand for extraction of new aggregate and helps to reduce deposits at the landfills.

This paper focuses on the investigation of RAP contents and foamed bitumen contents on tensile strength of dry conditioned samples. With accordance to Malaysia specification REAM-SP 1/2005 [1], the minimum strength for indirect tensile test for samples tested in dry condition is 0.2 MPa.
2. Methodology

Preparation of samples was followed closely to Marshall Procedure in accordance with ASTM D6926 [2] and tested with accordance to D6931 – 07 (2007) [3]. Samples were compacted with the Marshall Compactor with 75 blows for both surfaces and sample was leave in the mould for 24 hours, allowing sufficient strength to develop before extracting. Samples were cured in the oven at 40°C for 72 hours and allowed to cool to ambient temperature. Samples were then tested for Indirect Tensile Test (ITS). The tensile strength of samples was determined by Equation (1).

\[ S_t = \frac{2 \times P_{ult}}{\pi \times d \times t} \]  

Where:
- \( S_t \) = tensile strength of specimens
- \( P_{ult} \) = applied load to fail specimens
- \( t \) = thickness of the specimens
- \( d \) = diameter of the specimens

3. Materials and mix design

The proportion of RAP, crusher run (CR) and foamed bitumen used in this study are shown in Table 1. The RAP used in this study was obtained from the rehabilitation project of Jalan Pandamaran Klang in Selangor, Malaysia. In this study, samples prepared with 50% RAP were compared with the control sample prepared with 100% CR. Different percentages of foamed bitumen namely 1%, 2%, 3% and 4% were incorporated in the mixes. A 2% Ordinary Portland cement was used as mineral filler. Aggregate gradation with accordance to REAM-SP 1/2005 was used in sample preparation.

| Mix Designation | Mix Proportion | Foamed Bitumen Content, (%) |
|-----------------|----------------|-----------------------------|
| Mix A           | 0% RAP + 100% CR | 1,2,3,4                      |
| Mix B           | 50% RAP + 50% CR | 1,2,3,4                      |

4. Results and analysis

4.1. Indirect Tensile Strength Test

ITS results were averaged based on results of three specimens. Figure 1 shows result of the ITS test for Mix A and Mix B prepared with different percentages of foamed bitumen. Generally the results show that the indirect tensile strength increases with an increase in foamed bitumen content to an optimum value, however a further increase in foamed bitumen content results in a decreasing tensile strength. For both mixes, optimum ITS was achieved by the mixes prepared with 2% foamed bitumen.

It can be found from Figure1 that ITS value for Mix A is greater than Mix B at any foamed bitumen content. This finding showed by comparing Mix A (0% RAP) and Mix B (50% RAP + 50% CR) at each foamed bitumen content. It seems that ITS roughly decreases when RAP content
increases. However, effect of RAP content to ITS is not significant as showed by two-way analysis of variance in Table 2. The result shows that the probability value obtained is more than the predetermined alpha value ($p = .323 > .05$), thus RAP contents provide insignificant difference on the ITS. Besides of RAP content, interaction factors (RAP * FOAMED BITUMEN) seems to have no effects at all on the ITS which exhibit a probability value greater than the predetermined alpha value ($p = .977 > .05$). This implies that the application of RAP and interaction between factors (RAP*FOAMED BITUMEN) are not significant to effects the ITS value of the mixes. In addition, all mixes achieved the minimum strength requirement of 0.2 MPa. Statistical analysis shows only foamed bitumen give a significant effect to ITS as the probability is less than predetermined alpha value ($p = .00 < .05$).

### Figure 1. Indirect tensile strength for unconditioned samples

| Source                          | Type III Sum of Squares | df | Mean Square | F      | Sig.  |
|---------------------------------|-------------------------|----|-------------|--------|-------|
| Corrected Model                 | 32253.960*              | 7  | 4607.709    | 12.274 | .000  |
| Intercept                       | 2019618.184             | 1  | 2019618.184 | 5379.814 | .000  |
| RAP                             | 391.234                 | 1  | 391.234     | 1.042  | .323  |
| FOAMED BITUMEN                  | 31787.655               | 3  | 10595.885   | 28.225 | .000  |
| RAP * FOAMED BITUMEN            | 75.071                  | 3  | 25.024      | .067   | .977  |
| Error                           | 6006.507                | 16 | 375.407     |        |       |
| Total                           | 2057878.650             | 24 |             |        |       |
| Corrected Total                 | 38260.466               | 23 |             |        |       |

a. R Squared = .843 (Adjusted R Squared = .774)

5. Conclusions
Incorporating RAP to foamed asphalt mix and tested with indirect tensile strength test under dry condition shows that RAP contents did not offer significant effect on tensile strength of the mixes. This shown by statistical analysis two-way ANOVA with probability value obtained is more than the predetermined alpha value ($p = .323 > .05$). This reveals that incorporating RAP to the mixes offers
similar strength as samples prepared with virgin aggregate. Since RAP contents do not affect strength of the mixes, therefore this is very advantageous in the context of the environment and sustainability to develop sustainable pavement based on green technology and concept. In this study, foamed bitumen contents significantly influence the tensile strength of the mixes as shown by statistical analysis $p = .00 < .05$. Therefore optimum amount of foamed bitumen in sample preparation is essential to produce superior mixes.

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