Effects of reclaimed asphalt pavement on indirect tensile strength test of conditioned foamed asphalt mix

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Abstract. This paper presents the results of Indirect Tensile Strength (ITS) Test for samples prepared with reclaimed asphalt pavement (RAP). Samples were conditioned in water at 25°C for 24 hours prior to testing. Results show that recycled aggregate from reclaimed asphalt pavement performs as well as virgin aggregate.

1. Introduction

Many works related to sustainable environment have been done by researchers and engineers including turning waste materials from civil engineering construction and maintenance works to something valuable. Due to greater demands for natural resources conservation and sustainability, there are many attempts to recycle aggregates obtained from milled pavement to be use in new pavement construction and rehabilitation.

G.-P. He and W.-G. Wong [1] revealed that bitumen grade and RAP content affect the indirect tensile strength of the sample. ITS decreases with an increase of RAP content tested under dry and soaked conditions. Results also showed that bitumen grade and ageing of RAP material have significant impact on moisture susceptibility in permanent deformation. Other researchers found that incorporating RAP improves some engineering properties like tensile strength, rutting performance, fatigue and stiffness [2, 3]. However there is also reported that hot mix asphalt incorporating RAP provides inferior fatigue and thermal performance when compared with virgin mixes [4].

This paper focuses on the investigation of reclaimed asphalt pavement contents and foamed bitumen contents on tensile strength of conditioned samples. Samples were conditioned by immersing in water at 25°C for 24 hours. Minimum strength requirement for Indirect Tensile Test on conditioned samples with accordance to Malaysia specification REAM-SP 1/2005 is 0.15 MPa [5].
2. Methodology

Samples compacted 75 blows per side were prepared with accordance to ASTM D6926 [6] and tested with accordance to D6931 – 07 [7]. Gradation limits as shown in Figure 1 was used in samples preparation. Samples were prepared with different percentages of RAP and different percentages of foamed bitumen as shown in Table 1. Three replicates samples were prepared for each mixture. Samples were cured at 40°C for 72 hours. After samples cool to room temperature, samples were then immersed in water at 25°C for 24 hours prior to testing. The ITS of bituminous mixtures is conducted by loading a cylindrical specimen across its vertical diametral plane at 50mm/min deformation rate and 25°C test temperature. The peak load at failure is recorded and used to calculate the indirect tensile strength of the specimen. Statistical analysis two-way ANOVA was utilized to analyze the effect of RAP and foamed bitumen to ITS value. The tensile strength of samples was determined by Equation (1).

\[
S_t = \frac{2xP_{ult}}{\pi xd^2t}
\]

(1)

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

![Figure 1: Aggregate gradation (REAM, 2005)](image)

**Table 1**: Mix Designation according to different proportion of RAP, crusher run and foamed bitumen

| 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                      |
3. Results and analysis

The ITS result for conditioned samples is depicted in Figure 2. Results show that all mixes exceed the minimum strength requirement, 0.15 MPa. Similar profile was observed for both mixes. It is shown that the ITS increases with increase of the foamed bitumen content to a maximum value, further increase in foamed bitumen results in a decrease in the ITS value. Mixes prepared with 2% foamed bitumen showed the highest ITS value. This finding shows the importance of bitumen content on the ITS value. Adding excessive bitumen would affect the aggregate interlocking hence affects the performance of the samples.

Generally, ITS value for Mix A is similar with Mix B at any bitumen contents as shown in Figure 2. This indicates that ITS value not affected by incorporating RAP to the mixes. Even by conditioning the samples in water at 25°C for 24 hours, the performance of Mix B is in par with Mix A. This shows that absorption capacity of samples prepared with RAP (Mix B) is similar with samples prepared with virgin aggregates (Mix A).

Effects of foamed bitumen content and RAP contents to ITS value were further analysed using statistical two-way analysis of variance (ANOVA). Table 2 presents the results of ANOVA which shows the effects of factors (RAP and foamed bitumen content) and interaction between factors on the ITS of conditioned samples. The results show that the probability value obtained by foamed bitumen is less than the predetermined alpha value (p = .000 < .05) whereas probability value obtained by RAP (p = .275 > .05) and interaction factors (p =.899 > .05) are greater than the predetermined alpha value, thus only foamed bitumen content provide a significant difference on the ITS. This statistical analysis shows that incorporating reclaimed asphalt pavement insignificantly affects the ITS value. This means that mixes prepared with 50% RAP (Mix B) provide similar strength with mixes prepared with 100% virgin aggregates (Mix A).
Table 2: Single and interaction effects on indirect tensile strength for conditioned samples

| Source                        | Type III Sum of Squares | df  | Mean Square | F       | Sig.  |
|-------------------------------|-------------------------|-----|-------------|---------|-------|
| Corrected Model               | 40921.213               | 7   | 5845.888    | 119.315 | .000  |
| Intercept                     | 1562436.540             | 1   | 1562436.540 | 31889.443 | .000  |
| RAP              | 62.727                  | 1   | 62.727      | 1.280   | .275  |
| FOAMED BITUMEN               | 40830.083               | 3   | 13610.028   | 277.782 | .000  |
| RAP * FOAMED BITUMEN         | 28.403                  | 3   | 9.468       | .193    | .899  |
| Error                         | 783.927                 | 16  | 48.995      |         |       |
| Total                         | 1604141.680             | 24  |             |         |       |
| Corrected Total              | 41705.140               | 23  |             |         |       |

a. R Squared = .981 (Adjusted R Squared = .973)

4. Conclusions

Samples prepared with different percentages of RAP contents and foamed bitumen contents conditioned in water at 25°C for 24 hours were tested for indirect tensile strength test. Results show that RAP contents provide insignificant effects whilst foamed bitumen contents have significant effects on the strength of the mixes. Based on the results, it seems that water absorption for both mixes gives similar effects to ITS. Therefore it can be conclude that recycled aggregate from reclaimed asphalt pavement performs as well as virgin aggregate.

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