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Evaluation of Cold In-Place Recycling Mix using Polymer Modified Asphalt Emulsion

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ABSTRACT

This paper details a study conducted to evaluate the performance of cold in-place recycling (CIPR) using polymer modified asphalt emulsion (PMAE). The asphalt emulsion was modified using natural rubber latex (NRL). Four proportions of reclaimed asphalt pavement (RAP) which are 0%, 25%, 50% and 75% were mixed with natural aggregates and modified asphalt emulsion using natural rubber latex (NRL). The results showed that the optimum modified asphalt emulsion for each proportion of RAP decreased due to the increase in RAP content. Results obtained from Indirect Tensile Strength (ITS) and Uniaxial Compressive Strength (UCS) test for the mixes complied with the requirements of the Road Engineering Association of Malaysia (REAM) specifications. The unsoaked and soaked ITS values obtained were 0.2 MPa and 0.15 MPa respectively, and the minimum compressive strength of CIPR mix obtained was 0.7 MPa. Based on the evaluation of performance for the four RAP proportions, it was determined that 50% of RAP gave the best combination of the CIPR mixture.

Keywords: Cold-in-place recycling, natural rubber latex, polymer modified asphalt emulsion, reclaimed asphalt pavement

INTRODUCTION

CIPR is one of the most preferred structural rehabilitation techniques to be used by highway authorities. Among the advantages of CIPR are low cost, low energy consumption and eco-friendly. CIPR is a rehabilitation technique that reuses existing pavement materials in-situ without involving heat.

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The stabilizing agent frequently used for CIPR mixture are cement, asphalt emulsion, and foamed asphalt, which binds the individual aggregate particles together. Previous studies conducted on polymer modified asphalt were carried out on hot mix asphalt (HMA). At present, there is a lack of research performed on CIPR using PMAE. PMAE is not only safe to apply and environmentally friendly, but it can also improve the properties of the CIPR mixture. The use of PMAE appears to result in a more evenly distributed polymer network compared to the use of hot polymer modified binders, and they therefore have greater potential to improve the pavement performance (Forbes, Haverkamp, Robertson, Bryant, & Bearsley, 2001). A mixture of cold recycled mixes with asphalt emulsion has a lower modulus compared to cold recycled mixes with foamed asphalt due to fewer voids and drop asphalt cohesion method in foamed mixes (Yan, Ni, Tao, & Jia, 2009). In China, the results of laboratory testing and field inspection showed that the CIPR with asphalt emulsion used as a stabilizing agent is a suitable technique for rehabilitation of deteriorated asphalt pavement (Yan, Ni, Yang, & Li, 2010).

The main competitive edge of Malaysia's integrated rubber industry compared to other producing countries is the comprehensive R&D which has largely enhanced Malaysia's productivity in terms of output per unit of land, labour and capital (Lembaga Getah Malaysia (LGM), 2016). In 2004, Ruggles mentioned that the first application of natural rubber latex in road construction took place in 1929 in Singapore, then the use of NRL in asphalt had been studied extensively in the 1950's and 1960's. He also stated that, at low temperatures the natural rubber reduces thermal cracking associated with bitumen. As a result of this, road surfaces are resistant to defects and durability of a road surface is increased markedly. Malithong and Thongpin (2010) revealed that by using PR vulcanized NRL to modified asphalt emulsion could serve as a standard asphalt emulsion and are applicable for highway construction.

RAP is widely used throughout the United States to preserve investment by reutilizing valuable aggregate assets. Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) support and promote the appropriate use of recycled materials in highway construction in public policy statements and the resolution of the AASHTO Standing Committee on Highways on "Use of Recycle Materials" (Caltrans, 2005). The use of RAP for highway construction offers many benefits including reduction in the use of virgin materials, reduce land use for disposal of RAP, and saving of energy used to transport RAP waste. Researcher found that incorporating RAP improves some engineering properties like tensile strength, rutting performance, fatigue and stiffness (Huang, Zhang, & Kinger, 2004). Based on a study conducted by Kim and Lee (2006), fine RAP gradation was found to produce higher Marshall Stability and indirect tensile strength values compared to coarser RAP gradation.

MATERIALS AND METHOD

The study focuses on the performance of recycled pavement with different combinations of RAP proportions and new aggregate. Asphalt emulsion was modified by adding NRL as the modifier. Asphalt emulsion used in this study meets the requirements of REAM specification for cold in-place recycling (Road Engineering Association of Malaysia, 2005).

The gradation used for this study was designed to fit in Superpave control points and also to meet REAM grading limit specification. Ordinary Portland Cement (OPC) was used as mineral filler in this mixture and the total amount used is 2% by weight of the combined aggregates as stated by REAM. The combination of aggregate and RAP used are 0:100 for 0% RAP, 25:75 for 25% RAP, 50:50 for 50% RAP, and 75:25 for 75% RAP.

The mix was prepared manually and materials were weighed by proportion consisting of natural aggregate, RAP, and cement and mixed with asphalt emulsion for 15 minutes or until all the aggregates are well coated. Then, the mix was compacted in a 100-mm diameter mould using the Superpave Gyratory Compactor (SGC) by applying 100 gyrations at 1.25° Gyratory angle. The compacted samples were cured at 40°C for 72 hours and allowed to cool to ambient temperature. Prior to testing for UCS and ITS test, the sample is conditioned in water at 25°C for 24 hours. ITS test and bulk density were conducted on the specimens at various PMAE content to obtain the optimum PMAE. The optimum value of ITS and bulk density was used to determined optimum PMAE for each percentage of RAP by averaging both optimum values. The specimens for the compacted recycled mix were then prepared at optimum emulsion content for every RAP proportion. The specimen was tested soaked and unsoaked for the ITS to obtain the Tensile Strength Retained (TSR) value for moisture susceptibility evaluation and UCS to identify its performance at different RAP contents. The TSR is calculated as follows:

$$TSR = \frac{St_{soaked}}{St_{unsoaked}} \times 100\% \qquad (1)$$

where;

T_{SR} = Tensile Strength Retained

$S_{t\ soaked}$ = tensile strength of soaked sample, kPa

$S_{t\ unsoaked}$ = tensile strength of unsoaked sample, kPa

RESULTS AND DISCUSSION

Mix Design

This section focuses on the design of gradation and determination of optimum polymer modified asphalt emulsion. The process for this study was initiated by obtaining RAP and new aggregate. RAP materials were taken from the milled section of the old pavement under restoration (Klang Valley area) while the new aggregate was taken from the quarry (Kajang Rock Quarry). Natural rubber latex and asphalt emulsion were supplied by ACP-DMT Port Klang.

Gradation. Figure 1 shows the gradation that was designed to fit in Superpave control points and also to meet REAM grading limit specification. Ordinary Portland Cement was used as mineral filler in this mixture and the total amount used was 2% by weight of the combined aggregates as stated by the specification.

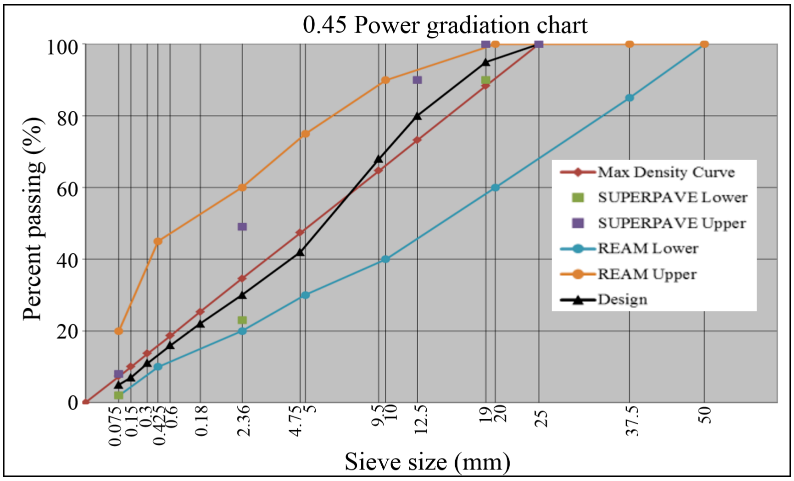

Figure 1. Design aggregate gradation

Optimum Polymer Modified Asphalt Emulsion. ITS test and bulk density at various polymer modified asphalt emulsion content was conducted on the specimens to obtain the optimum polymer modified asphalt emulsion. The optimum value of ITS and bulk density was used to determine the optimum PMAE for each percentage of RAP by averaging both optimum values. The variation of ITS with PMAE content is presented in Figure 2. It can be seen that the higher use of RAP in the mixture will give the least optimum PMAE; this may be due to the existence of bitumen in the RAP. Figure 3 shows the bulk density with total PMAE content. It was observed that, the optimum value of bulk density for each percentage of RAPs is nearly the same within the range of 5.0 to 5.2. This might be due to the same amount of cement used (2%) in all proportion of RAPs which did not affect the overall mixture.

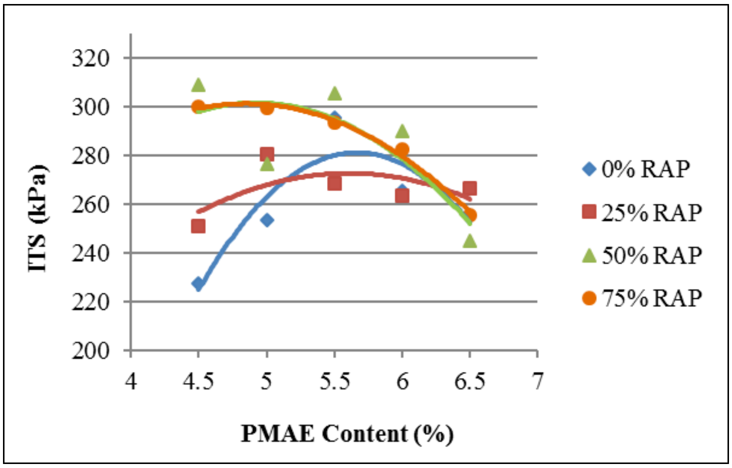

Figure 2. Variation of ITS value with total PMAE content

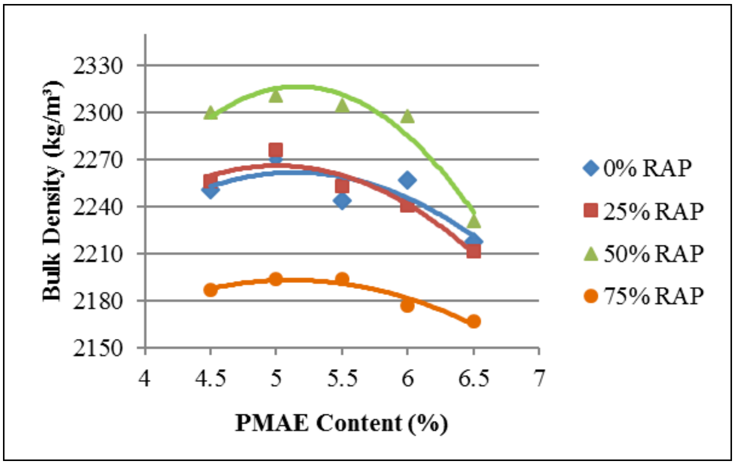

Figure 3. Variation of bulk density with total PMAE content

Table 1 presents the summary of the mix design test results for each percentage of RAPs conducted to obtain optimum PMAE. These optimum PMAE contents were used for the preparation of specimens for performance evaluation.

Table 1
Optimum PMAE for each percentage of RAP

Percentage of RAP	ITS	Bulk Density	Optimum PMAE
0%	5.7	5.1	5.4
25%	5.4	5.0	5.2
50%	4.9	5.2	5.1
75%	4.8	5.1	5.0

Performance Test

Effects of the Indirect Tensile Strength (ITS). Figure 4 shows the indirect tensile strength of unsoaked and soaked conditioned for each percentage of RAP. It can be seen that both unsoaked and soaked at different percentages of RAP complied with the minimum strength specified by the specification. ITS values for the unsoaked specimen at 75% RAP gave the highest ITS values of 0.275 MPa and for soaked specimen, the highest value is 0.236 MPaat 50% RAP. Mixes with 0%, 25%, and 75% RAP have relatively low tensile strength retained (TSR) values. Figure 5 shows the TSR for different percentages of RAP indicates that TSR increases to the optimum value as the RAP content is increased. The highest TSR value was observed for samples with 50% RAP. This is likely due to the amount of water absorbed into the natural aggregate particles that caused a decrease in the resistance to moisture susceptibility. A lower percentage of RAP has a greater capacity to absorb water, while for the mixture containing the higher percentage of RAP the existing bitumen in RAP coat the aggregate particles that prevents water to be absorbed. All samples exceeded the minimum TSR requirement of 75%.

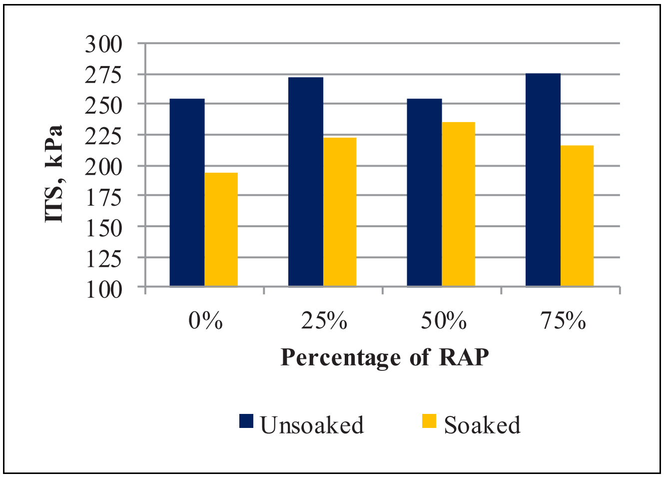

Figure 4. Indirect tensile strength for unsoaked and soaked conditioned for each percentage of RAP

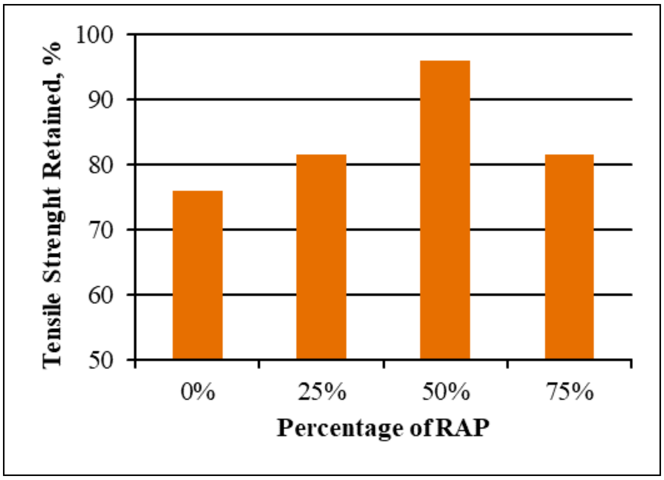

Figure 5. Indirect tensile strength retained (TSR) for each percentage of RAP

Effects of Unconfined Compression Strength (UCS). Figure 6 shows the results of UCS test prepared with different percentages of RAP. They show that the compression strength increases to the optimum value as the percentage of RAP increase, however a further increase in RAP percentage results in a decrease in compression strength. The highest compressive strength value is 2.963 MPa at 50% RAP and lowest at 75% RAP with UCS values of 2.436 MPa; this may be due to the lower fines aggregate content that can be mixed with the asphalt emulsion and therefore, the excess asphalt emulsion acts as a lubricant and reduces the strength. However, the UCS value for all samples exceeded the specification minimum UCS requirement of 0.7 MPa.

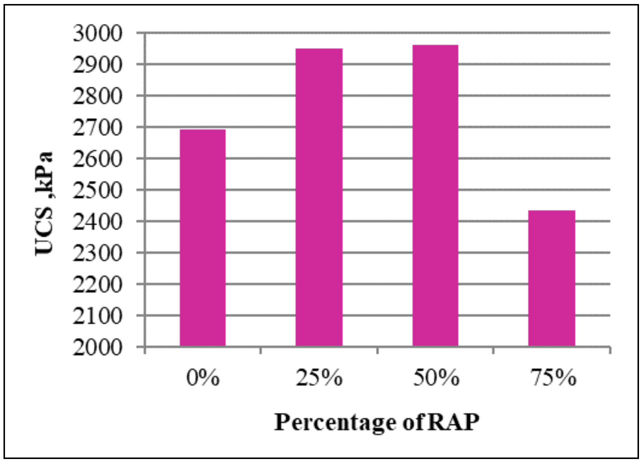

Figure 6. Unconfined compression strength for each percentage of RAP

CONCLUSION

The conclusion of the study are: (1) The value of optimum PMAE content is indirectly proportional to the percentage of RAP used in the mix due to the quantity of bitumen in the RAP providing enough strength to the mix; (2) Mix design procedures for CIPR with PMAE using Super pave gradation system and SGC is acceptable because they fulfilled the REAM specification requirements; and (3) The optimum RAP proportion is 50% because the results presented in ITS and UCS, 50% RAP proportion was the highest compared to other RAP proportions.

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