Global Journal of Engineering and Technology Review
Journal homepage: http://gjetr.org/
Global Journal of Engineering and Technology Review 1 (1) 57 – 62 (2016)

Performance of Hot Recycling Mix with Variable RAP Content

Ahmad Kamil Arshad[1]*, Mohd Azli Ayob[2], Ekarizan Shaffie[3] and Wardati Hashim[4]

[1]Institute for Infrastructure Engineering and Sustainable Management, UiTM Shah Alam, Malaysia
[2]Faculty of Civil Engineering, UiTM Pulau Pinang, Malaysia
[3,4] Faculty of Civil Engineering, UiTM Shah Alam, Malaysia

ABSTRACT

Objective – To investigate the volumetric properties and performance of Hot Recycle (HR) mixes using rejuvenating agent.
Methodology/Technique – Marshall design method was used to produce all HR samples, which consists of 70%, 80%, 90% and 100% of RAP. Volumetric properties including bulk density, air voids in compacted mix, voids filled with bitumen as well as Marshall stability and flow were carried out to determine the effect of rejuvenating agent on the HR mixes. Then, the performance of HR mixes was evaluated by conducting the resilient modulus test, stripping test and rutting test.
Findings – The results showed that the performance of RAP mixes are comparable to that of conventional mixes, thus the use of HR mixes such as in the HIPR method should be encouraged, to save the cost of pavement maintenance.
Novelty – This paper demonstrates the performance of hot recycling mix with variable RAP content.
Type of Paper: Empirical

Keywords: Reclaimed asphalt pavement; Hot recycling; Marshall Design Method; Rejuvenating agent, Stripping.

---

1. Introduction

Most rehabilitation and maintenance method are costly, energy consuming, material intensive and geometrically restrictive [1,2]. Hence, better maintenance program will contribute to cost effectiveness and durable pavements. Full reconstruction may create other problems such as waste materials disposal, which involve extra transportation costs and deterioration to the environment [3,4].

Recycling of old pavement is a potentially attractive proposition as it offers several advantages over the use of conventional materials. There are many reasons to rehabilitate the existing pavement such as to improve the riding quality, reduce the cost of reconstruction and repair pavement distress. The rehabilitation techniques may require removal of paving asphalt material that exhibit pavement distresses. The removal of the paving

* Paper Info: Revised: July, 2016
Accepted: November, 2016
* Corresponding author:
E-mail: drahmadkamil@salam.uitm.edu.my
Affiliation: Instititute for Infrastructure Engineering and Sustainable Management, Universiti Teknologi MARA, Malaysia

asphalt material, also known as Reclaimed Asphalt Pavement (RAP), contains asphalt and aggregates that are typically used for rehabilitation or reconstruction projects [5]. By recycling this old asphalt and aggregates, it will help to reduce truck traffic, eliminate the disposal of waste material and produce a safer environment [6]. In order for pavement recycling to be beneficial and successful, RAP should be cost effective and perform similar or better to the conventional hot mix asphalt (HMA). RAP can be used in many ways such as an addition to the regular HMA, granular base course for fill or embankment material and aggregate in Hot In-Place Recycling (HIPR) method [7].

HIPR technique consists of mixing the existing pavement material with rejuvenating agent and/or the addition of virgin HMA to the material [8]. This technique requires the addition of rejuvenating agent in the mixture to rejuvenate the existing aged asphalt in the RAP. There are various types of rejuvenating agent that is used in the pavement recycling process such as fly ash, lime, cement, foamed bitumen and bitumen emulsion. The virgin HMA is added to the recycled material to improve the properties of the existing RAP and to ensure that sufficient amount of asphalt mix is produced, particularly in pavement where rutting is the major distress.

Recycled mixtures can achieve volumetric properties similar to the conventional HMA mixtures when the mixture is properly designed [9,10]. The objective for this study is to investigate the volumetric properties of asphalt mixes with different RAP proportions using Marshall Design Method and to evaluate the performance of these mixes in terms of stiffness, rutting and moisture susceptibility. The asphalt mixes consists of 70%, 80%, 90% and 100% of RAP. The results of this study can be used to improve mix design techniques of recycled asphalt mixes, such as in HIPR.

2. Methodology

Virgin granite aggregates used for control mix and additional aggregates for the HR mixes was sourced from the Kajang Rock Quarry, Selangor, Malaysia. The RAP materials were obtained from the milling of one of the primary roads that was rehabilitated in Kuala Lumpur. The virgin and RAP aggregates were tested for their physical properties as to verify and comply with that recommended PWD Malaysia's specification [11]. The gradation of the HR samples used for this study is Type 1 according to PWD Malaysia's specification to produce the recycled mix (Fig.1). RAP gradation was determined after the binder was extracted from RAP through the ignition process in the bitumen content test. Two samples from the same RAP sources were used for this test to determine the average gradation of the RAP, as shown in Fig. 1. The virgin binder used for virgin mixtures in the control mix and additional mixtures for HR mixes was binder 80/100 penetration. The Ignition Oven Method (ASTM D6307) was used to determine the bitumen content of the RAP. The Extraction Process (ASTM D2172) and Recovery Process (ASTM D5404) was used to remove binder from the RAP. The recovered binder was used to determine the softening point (ASTM D36) and penetration value (ASTM D5).

The rejuvenating agent used in the HR mixes is Shell Bitumen Rejuvenating Oil-500 (Shell RJO-500) that is produced from crude oil. The rejuvenating agent is used to rejuvenate the hardened binder in RAP materials by improving and restoring the binder's visco-elastic properties [12]. A nomograph for penetration obtained from the rejuvenator manufacturer was used to calculate the required rejuvenator content used in HR mixes. Based on the nomograph, the required amount of rejuvenating agent need in the HR mixes is 1.1%. Since the value obtained from the nomograph is only approximation of the required amount of rejuvenating agent, the Marshall Design Method is used to determine and confirm the optimum rejuvenator content to be used in the mixes. Two values before 1.1 % and two values after 1.1 % at increments of 0.3 % were used in the Marshall Design Method. Therefore, the values of rejuvenating agent that were tested in determining the optimum rejuvenating agent are 0.5 %, 0.8 %, 1.1 %, 1.4 % and 1.7 %.

Two types of gradation were used in this study. The conventional HMA mixture without RAP (0% RAP) was prepared as control mix using virgin aggregates and mixed with binder 80/100 penetration. For control mix, AC14 was used while Type 1 mix for Hot In-Place Recycling Method as per PWD Malaysia's Specification is used for the HR mixes. The recovered aggregate gradation line obtained from the RAP materials is shown in Fig. 1. The gradation line is within the specification limits. The proposed design grading used for the HR mixes is the mid-point of the specification grading envelope, also shown in Fig. 1. As for the HR mixes, samples were prepared with combinations of RAP mixture and fresh mixture in the ratios of 70:30 (RAP70 mix), 80:20 (RAP80 mix), 90:10 (RAP90 mix) and 100:0 (RAP100 mix) respectively. Additional fresh mixture in HR mixes was prepared similar to control mix. The samples were compacted using standard Marshall compactor with 75 blows per face. The properties of the samples produced for the mixes were determined by carrying out the Marshall standard test procedure (ASTM D1559). The samples were then tested for Marshall Stability, Density and Flow for the determination of Optimum Binder Content (OBC) for the control mix (0% RAP) and Optimum Rejuvenator Content (ORC) for HIPR mixes. The OBC and ORC were taken as the arithmetic mean from the plotted smooth curves and must comply with the required parameters in PWD Malaysia's Specification for Road Works [11].

The specimens were prepared for performance evaluation stage at OBC for control mix and ORC for HIPR mixes. The resilient modulus test was carried out in accordance with ASTM D4123. The samples for this test were divided into two sets conducted at two different temperatures. Each set was conditioned at 25^{o}C and 40^{o}C respectively for 24 hours prior to testing. Three samples for each design were prepared and for each sample, the test was carried out twice and the results averaged to obtain the resilient modulus.

The Modified Lottman Test (AASHTO T283) was used to evaluate moisture susceptibility of the samples. Six samples were prepared for control mix and HR mixes. Samples for the test were prepared at 7 + 0.5 percent air voids. The indirect tensile strength (ITS) test was carried out for the samples in dry and wet condition. The Tensile Strength Ratio (TSR) was obtained from the ratio of the ITS of wet condition to ITS of dry condition.

The Automated Asphalt Pavement Analyzer (APA) was used to carry out the Hamburg Wheel Tracking Test for rutting susceptibility in accordance with AASHTO T324. Gyratory compactor was used to compact the samples until 7.0 + 0.5 percent of air voids obtained. The test was run at a rate of 50 passes of the steel wheel per minute with a load of 705± 22 N. The test was conducted until the maximum number of 20,000 passes has occurred or until the maximum rut depth value of 20 mm has been reached.

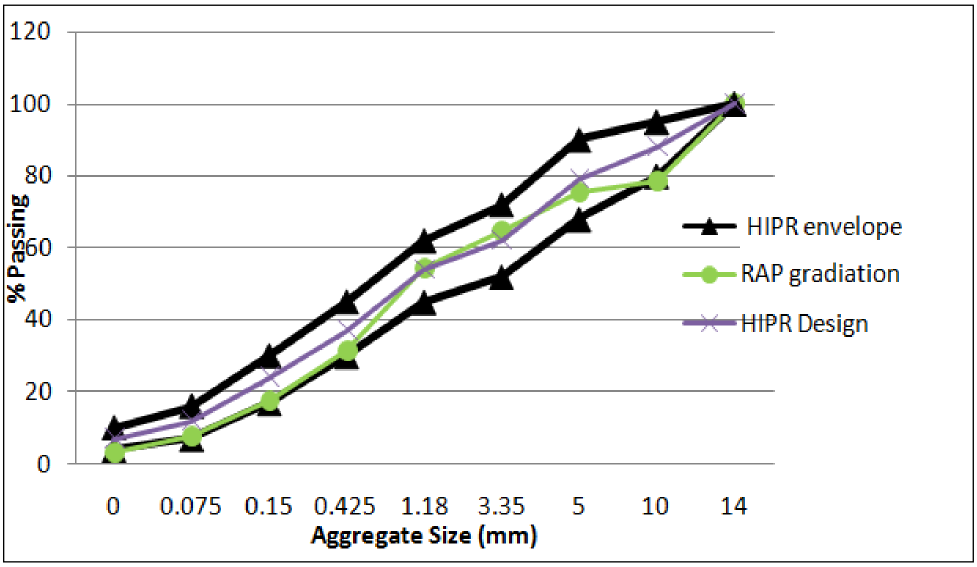

Figure 1. The gradation of existing RAP aggregate and HIPR design grading

3. Results and Discussion

From the Marshall test result, the optimum binder content (OBC) for control mix is found to be 5.1% whereas the optimum rejuvenator content (ORC) for each percentage of RAP content in HR mixes is 1.0%. These criteria were determined from the graph of Marshall properties by plotting the OBC for Control mix and ORC at different percentages of RAP content for the HR mixes. The control mix with 5.1% binder content has the highest Marshall stability compared to recycled mixes. Nevertheless, the RAP70 mix with 1.0% rejuvenator content has the highest Marshall stability compare to other RAP content in recycled mixes. The RAP100 mix with 1.0% rejuvenator content has the lowest Marshall stability. The details of mix design properties for each mix type is shown in Table 1.

Table 1. Mix Design Selection Criteria

Mixture Type	**Density (kg/m^3)**	**Air voids (%)**	**VFA (%)**	**Stability (kg)**	**Flow (mm)**	**OBC (%)**	**ORC (%)**
Control	2.327	4.2	73.00	2440	3.2	5.1	-
RAP70	2.320	3.2	76.28	2300	3.2	-	1.0
RAP80	2.322	3.0	76.80	2150	3.2	-	1.0
RAP90	2.328	3.1	77.18	1810	3.1	-	1.0
RAP100	2.328	3.5	77.65	1500	3.0	-	1.0

Tests including resilient modulus, moisture susceptibility and rutting were carried out on the designed mix samples in the laboratory to determine the performance of the mixes according to the specifications and procedures. The testing was carried out at optimum binder content (OBC) for control mix and optimum rejuvenator content (ORC) for the recycled mixes.

The results of resilient modulus test for the different RAP contents at temperatures of 25°C and 40°C are shown in Figure 2. The result shows that the resilient modulus of the mix decreases with increasing of RAP content. Control mix has the highest resilient modulus under both testing temperatures compared to the recycled mixes. RAP70 mix has the highest resilient modulus compared to other RAP mixes. The resilient modulus for the different RAP mixes decrease significantly with increasing temperature from 25°C to 40°C. The highest reduction of resilient modulus from 25°C to 40°C is RAP100 mix. The result shows that the resilient modulus of the mixture decreases with the increase in RAP.

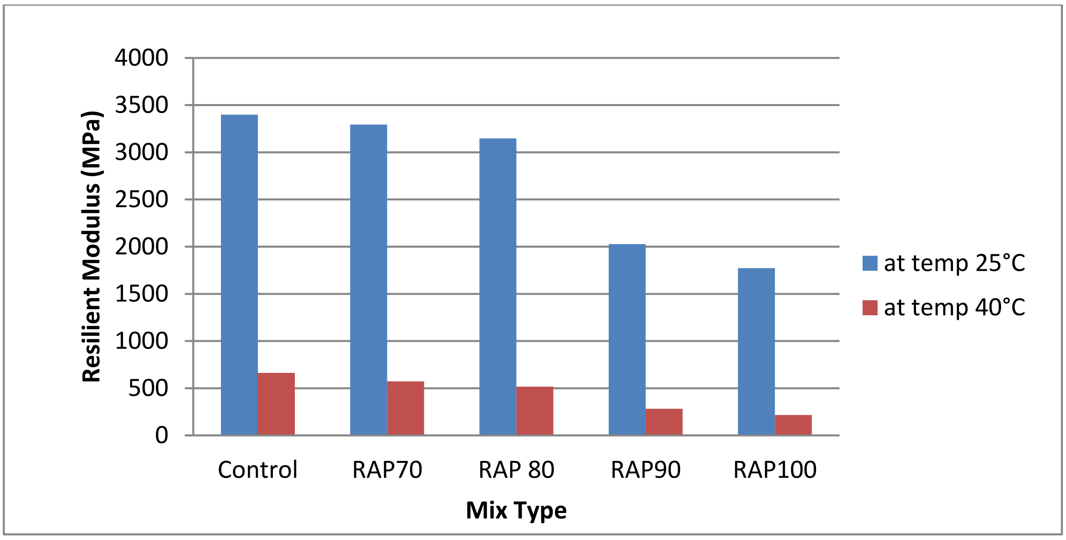

Figure 2. Resilient Modulus for different RAP contents at 25°C and 40°C

The Tensile Strength Ratio (TSR) values for different percentages of RAP content in the HR mixes are shown in Figure 3. The highest TSR value is 94.31% for control mix, while the lowest TSR value is 80.61% for RAP100 mix. The TSR value for the HR mixes appears to be more susceptible to moisture damage compared to the control mix. Overall, the TSR values for all mixes are higher than the minimum required value of 80%, although the HR mixtures with different percentages of RAP content are slightly more sensitive to the presence of water, as the values are lower than the control mix.

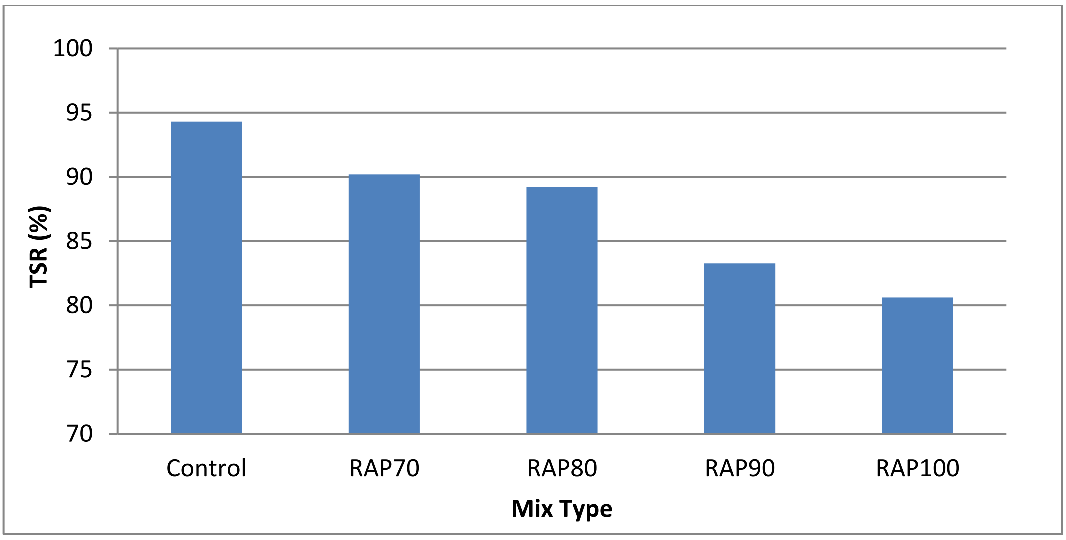

Figure 3. Tensile Strength Ratio for different RAP mixes

Fig. 4 shows the rutting test results for the control and HR mixes. It can be seen that the rut depth increases with increasing number of passes. The rut depth for all mixes showed similar behavior with gradual increases from 0 wheel passes to 20,000 wheel passes. The rate of increase in rut depth for all mixes are rapid up to approximately 5000 wheel passes. Then, the relationship between rut depth and number of passes become relatively linear. The rut depth significantly increases with increasing of RAP content in the HR mixture. The control mix exhibit higher resistance to rutting compared to the recycled mixes, as the rut depth attained after 20,000 passes is the lowest (7.0 mm). As the recycled mixes exhibit average rut depth of between 8.7 mm to 11.3 mm (lower than the 12.5 mm failure criterion), it can be concluded that the recycled mixes provide adequate rut resistance although the rut depths are higher than the control mix

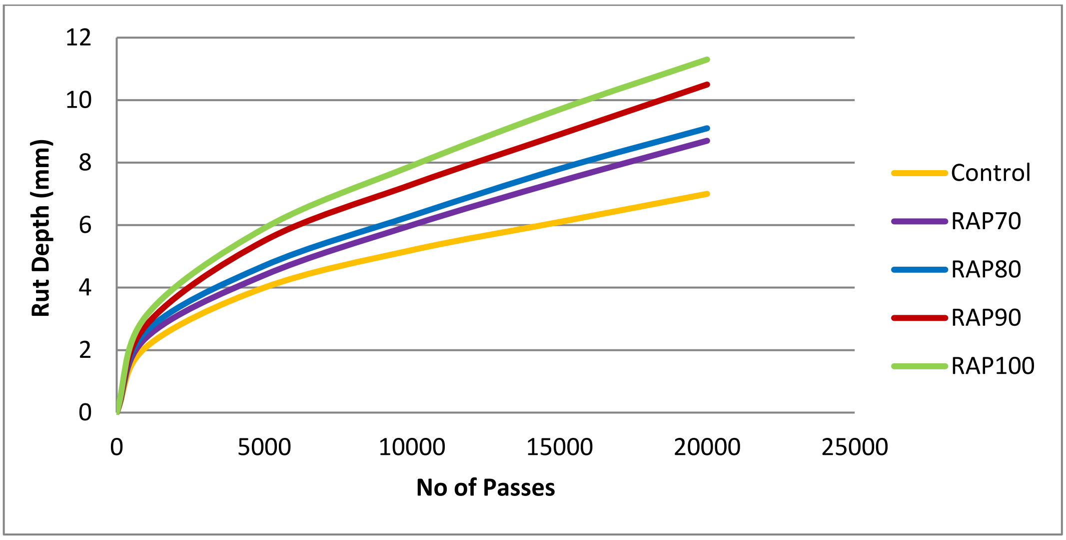

Figure 4. Rut depth for Hamburg wheel tracking test for different HR mixes

Conclusion

The results of the study of showed that the HR mixes satisfied the requirements of PWD Malaysia's specification. The optimum rejuvenator content was found to be 1.0% by weight of the HR mix. The HR mixes produced acceptable performance properties in terms of stiffness, moisture susceptibility and rutting. This study confirmed the suitability of local RAP materials to be used in the recycling technique. RAP materials are suitable to be used for pavement recycling, particularly the hot in-place recycling, thus reducing the cost of pavement maintenance.

Acknowledgements

The author would like to acknowledge the Research Management Institute (RMI), Universiti Teknologi Mara (UiTM) for the provision of research fund under the Dana Kecemerlangan Grant.

References

Asphalt Recycling and Reclamation Association (ARRA), Basic Asphalt Recycling Manual, United State, 2000.

Chen JS, Huang CC, Chu PY, Lin KY (2007), Engineering Characterization of Recycled Asphalt Concrete and Aged Bitumen mixed Recycling Agent, Journal of Material Science, 42(23) : 9867-76.

Chiu CT, Hsu TH, Yang WF (2008), Life Cycle Assessment on Using Recycled Materials for Rehabilitating Asphalt Pavements, Resources Conservation and Recycling, 52(03) : 545-56.

Arshad, A. K. (2004), Pavement Recycling: An Overview, Jurutera, IEM Bulletin, Malaysia, pp.14-17.

Emery, John (1992), Mineral aggregate conservation: reuse & recycling, Ontario Ministry of Natural Resources, Ont., Canada.

Arshad, A. K, (2005), Hot In-Place Recycling: An Introduction, Jurutera, IEM Bulletin, Malaysia, 10-12.

Karlsson, R. (2002). Investigations of Binder Rejuvenation Related to Asphalt Recycling, Division of Highway Engineering, KTH, Stockholm.

Epps, J.A., Little, D.N., O'Neal, R.J. and Gallaway, B.M. (1977), Mixture Properties of Recycled Central Plant Materials, American Society for Testing and Materials (ASTM), STP 662, Philadelphia, PA.

National Cooperative Highway Research Program (2013), Improved Mix Design, Evaluation and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content. NCHRP Report 752, National Academy of Sciences, Washington D.C.

Austroads (2015), Maximising the reuse of Reclaimed Asphalt Pavement. Technical Report AP-286-15, Sydney: Austroads.

Public Works Department of Malaysia (2008), Standard Specification for Road Works. Malaysia: Public Works Department of Malaysia.

Hossain, M., Haritha, M., Sabahfer, N. (2012), Use of High-Volume Reclaimed Asphalt Pavement (RAP) for AsphaltPavement Rehabilitation Due to Increased Highway Truck Traffic from Freight Transportation, Mid-America Transportation Center, Lincoln, Nebraska.