DEGRADATION AND ABRASION OF RECLAIMED ASPHALT PAVEMENT AGGREGATES

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ABSTRACT

Reclaimed asphalt pavement (RAP) is considered waste product from rehabilitation works of old pavements. However, it is a common practice to recycle the material back into roadway by incorporating into asphalt paving. Its incorporation is either by hot or cold recycling technique or sometimes used in base or sub-base construction. The aggregates of the RAP material are still valuable and in fact still retain the properties as required for use in virgin mix of the wearing course. This study focused on the aggregates extracted from reclaimed asphalt from both milling and full depth method of recovery which can cause degradation to the aggregates. The aggregates obviously degrade by further refinement of aggregate size but still maintain substantial strength to resist wear and abrasion. The gradation of the extracted aggregates showed that the bulk volume of aggregates retained on sieve size 3.35 mm and 1.18 mm which allow the aggregates to be considered for potential use in virgin mix.

Key words: *Reclaimed Asphalt Pavement, Degradation, Abrasion, Aggregates*

INTRODUCTION

Hot Mix Asphalt (HMA) materials are 100% recyclable since studies have shown that materials present in old asphalt pavements which contain both asphalt and aggregates still retain considerable value which can be incorporated into virgin asphalt mixtures. The term Reclaimed Asphalt Pavement (RAP) for these reusable pavements has proven to be economical and environmentally sound with the use of RAP aggregates in highway construction. This has become a widely accepted practice in many state highway agencies in the United States [1] and researched on the properties of recycled aggregates in pavement construction is limited to unbound pavement layers. In Malaysia, various recycling techniques are adopted for rehabilitation work of flexible pavements. There are approximately 1,190 kilometers of highways and expressways, 13,592 kilometers of paved federal roads and 36,263 kilometers of paved state including municipal roads [2]. Rehabilitation of existing road by recycling of pavement materials can offer environmental benefits include reduced extraction of primary aggregates and disposal of existing materials and reduced haulage of construction materials. The recycling of bituminous surfacing is commonly used to restore the pavement profile, improve skid resistance, and rectify cracking caused by binder hardening [3].

In every 3 to 5 years, the wearing course is disposed of in large volumes in the form of waste. It indicates the replacement of pavement layers will need large quantities of good quality aggregates from quarrying production of these materials [4]. The common operation involves in recycling of pavements involves mixing of the existing milled pavements with virgin material of a modifier. In this study, a preliminary investigation on the degradation of RAP aggregates is carried out to determine the aggregate properties extracted from RAP intended for use with virgin aggregates for a new asphaltic mix. Degradation of the RAP aggregates is focused on the mass of RAP aggregates retained due to method of extraction of the RAP materials. Another important aspect of aggregates for use in wearing course is the strength of aggregates against crushing effect. The RAP aggregates are also evaluated for resistance to crushing to determine the strength after the extraction process and being in service for several years.

METHODOLOGY

The study focused on areas located in the Klang Valley i.e. the most busies region in Malaysia, where rehabilitation works were carried out by Roadcare Sdn. Bhd. The bulk of wearing course disposal was collected and the aggregate physical properties were carried out in accordance with the ASTM and BS standards. Initially, the RAP samples were collected from each stretch of road at 3 different chainage. Two different methods of extraction were involved in the extraction of RAP samples as indicated in Table 1 The conventional full depth method using a backhoe to scrap the pavement were taken from Rawang, Kepong, and Section 7and 8, Shah Alam while stockpiles from Sg. Pelik, Sepang and Sg. Rasah sites was extracted using the modern milling method. The RAP samples for this study consist of both ACW 14 and ACW 20 which is normally used by the Public Work Department, Ministry of Works (JKR) for road design mix. Figure 1 showed the stockpile located at Section 7 Shah Alam, which is disposed along the road after rehabilitation work.

Table 1: Reclaimed Asphalt Pavements Site Location

Site Location	Extraction Method	JKR Specification
Sg. Rasah, Padang Jawa (SR)	Milling	ACW 14
Sg. Pelik, Sepang (SP)	Milling	ACW 14
Kepong (KP)	Scrapping	ACW 14
Section 8, Shah Alam (SA8)	Scrapping	ACW 20
Section 7, Shah Alam (SA7)	Scrapping	ACW 20
Rawang (RAW)	Scrapping	ACW 20

Figure 1 RAP Stockpile at Section 7, Shah Alam

Sampling and Extraction of RAP Aggregates

RAP materials are still valuable even when the pavements have reached the end of their service lives and when used with virgin mixtures are found to perform well[5]. RAP samples should accurately reflect the material available for

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use to avoid segregation. However, RAP materials extracted using the full depth recovery method are not likely to segregate because the asphalt binder in RAP helps keep coarse and fine aggregates bound together. The moisture content of RAP stockpiles normally increases especially when exposed and may be as high as 7 to 8 percent [6], and therefore, lengthy stockpiling is not encouraged.

In this study random sampling is used to get the best representation of the materials present [7]. The RAP sample is carefully brought back to the laboratory and placed under shelter in open space condition. Two common methods can be used to extract aggregates from RAP which are the solvent method and ignition method. However, solvent method is widely ban in many countries due to hazardous solvent such as the dichloromethane to man and environment. The later method is used in this study using the Asphalt Content Tester. To avoid any segregation, the samples are carefully extracted by quartering on a large tray. RAP samples extracted by full depth method should first be broken down to avoid lumps of aggregates bounded together. The RAP samples are then carefully placed in a tray with approximately 1.4 kg to 1.7 kg of RAP material. The oven should first be heated up to the temperature as required by the standards before burning process is carried out with asphalt content tester chamber temperature of 560^{0}C and after burner temperature of 900^{0}C. Figure 2 shows a sample of RAP material before and after the burning process with only RAP aggregates left in the tray with all the asphalt binder completely burnt in the ignition oven.

(a) *(b)*

Figure 2: RAP samples (a) before and (b) after extraction process using the ignition oven method

The aggregates extracted from the ignition oven are analyzed to determine the gradation and abrasion or crushing effect to determine the strength of the aggregates after the burning process. The aggregates should be completely cooled naturally before handling in the laboratory for further investigation. The RAP aggregates were sieved according to AASHTO T27, "Sieve Analysis of Fine and Coarse Aggregates". Approximately 1.5 kg of RAP aggregates was sieved to determine the aggregate gradation. During processing, the gradation of RAP aggregates obtained obviously will be finer than the virgin aggregates. A sample gradation of virgin aggregates or ACW 14 and ACW 20 mix is carried out to compare results obtained from RAP samples. Although the extraction of the asphalt binder from RAP samples are not within the scope of this study, the asphalt extraction is recorded automatically and is in the range of 4.5 to 6 percent as obtained from most wearing surface mixes. However, recovered asphalt from RAP usually exhibits low penetration and relatively high viscosity values depending on how long it has been in service. Besides obtaining the gradation of the RAP samples, the resistance to crushing test is carried out to determine the strength when subjected to loading. This test is important because the properties of RAP depend on the properties of the constituent materials and type of asphaltic mix. Aggregates used for wearing course should be of high quality and high resistance to friction compared to aggregates used in base or subbase of the pavement layers.

RESULTS AND DISCUSSIONS

The extraction of aggregates has also enabled the percentage of asphalt binder content present in the RAP samples to be determined. From the 8 sites, Figure 3 shows that the optimum asphalt binder content is within the range of 4.5 to 6.5 percent of a normal HMA mix normally used for Marshall method. Sepang (SP) showed the highest value of 5.99 percent optimum asphalt binder of the mix with Shah Alam Section 7 (SA7) showing the minimal optimum binder content of 4.5 percent. The optimum asphalt binder of RAP samples are within the range of the design mix.

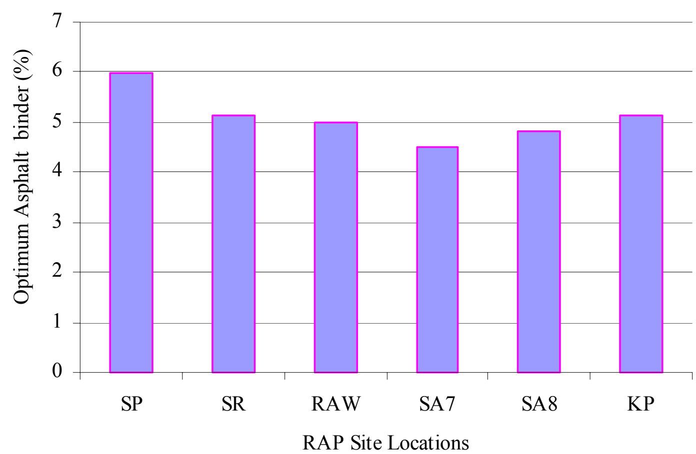

Figure 3: Percentage of optimum asphalt binder of RAP samples

The gradation and properties of the aggregates from RAP may change because some of the aggregates break down or are lost in the oven. A study[8] have shown that before and after milling process, the pavement fraction passing a 2.36 mm sieve can be expected to increase from 41 to 69 percent to 52 to 72 percent after the process. The fraction passing a 0.075 mm sieve can be expected to increase from approximately 6 to 10 percent to a range of 8 to 12 percent. The aggregate gradation is determined by sieving the extracted aggregates with selected sieve sizes for the HMA mix. The sieving complies with AASHTO T27 standard and results of the gradation are as shown in Figure 3. It is obvious that the size of aggregates is finer than the virgin aggregates due to the milling or scrapping process of the wearing course. The results clearly showed that both milling and scrapping causes aggregate degradation which is normally finer and denser than the virgin aggregates. However, full depth or scrapping does not cause much degradation as milling.

The trend for most of the RAP samples extracted using the full depth recovery and milling method showed a quite similar trend in variation of the percentage of RAP aggregates retained compared to the normal mix. An abrupt change in the percentage retained of RAP aggregates can be observed at sieve 3.35 mm and 1.18 mm for the RAP samples as shown in Figure 4 and Figure 5. The coarse aggregates for nominal size 14 mm mix seems to reduce in size with an abrupt increment of aggregates retained at sieve size as mentioned above. The RAP aggregates at sieve 14 mm is refined and decrease to approximately 10.9 percent when using milling method of extraction (SP and SR site) and 3.9 percent for RAP aggregates using full depth method (RAW site) compared to normal mix. This is obvious due to method of extraction of the RAP samples. At 10 mm for site SP and SR, the percentage retained decreases by approximately 5.9 percent and slight variation again for RAW samples. However, an abrupt increase in aggregate retained is obvious at sieve size 3.35 mm with percentage increment of RAP aggregate averaged at 21.8 percent for both milling and full depth recovery method of extraction. Aggregates retained at sieve 1.18 mm showed an approximate increase of 10 percent refined aggregates. The percentage of retained aggregates decreases as the sieve size is finer as shown in Figures below.

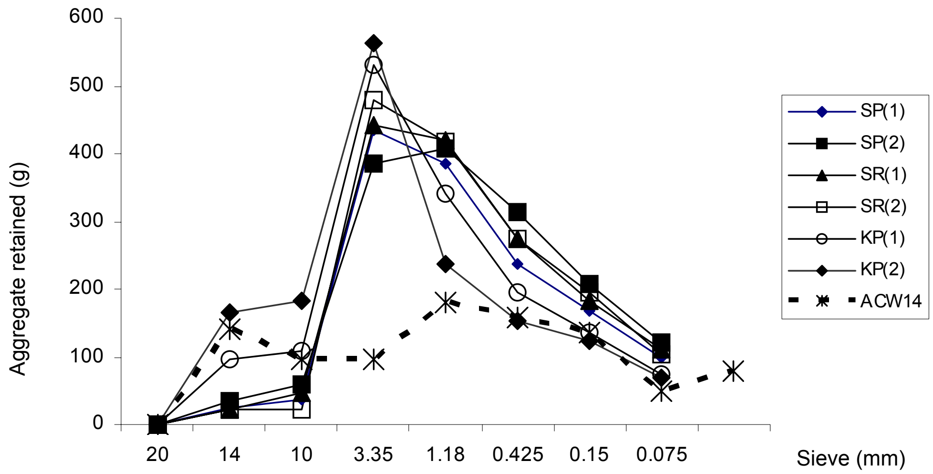

Figure 4 : Weight of aggregate retained (ACW 14)

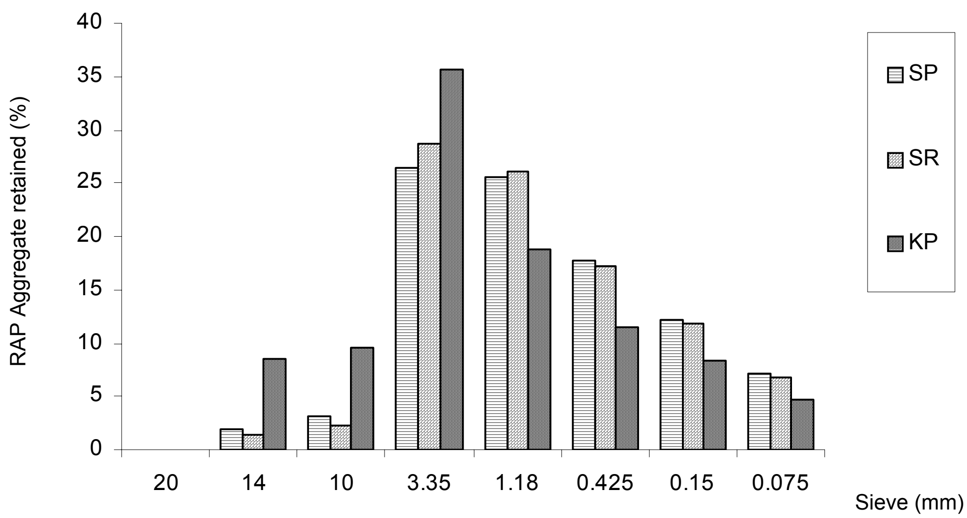

Figure 5 : Percentage of retained RAP aggregate (ACW 14)

The RAP samples for the ACW 20 mix extracted using the full depth recovery also showed similar trend to the above ACW 14 mix. The coarse aggregates retained at sieve 20 mm and 14 mm is approximately 8 percent less than the normal ACW 20 mix used in this study as comparison. However, the aggregates increased in percentage retained on sieve 3.35 mm with an increment of 13.2 percent and approximately 6.2 percent at sieve 1.18 mm. Again this indicates that the bulk of aggregates that can be extracted from RAP samples are within this sieve size. Increment of fine RAP aggregates is approximately 2 percent of the RAP samples from the study location. Figure 6 and Figure 7 clearly indicate the aggregate size which can be produced in large quantity for use with virgin aggregates in virgin mix.

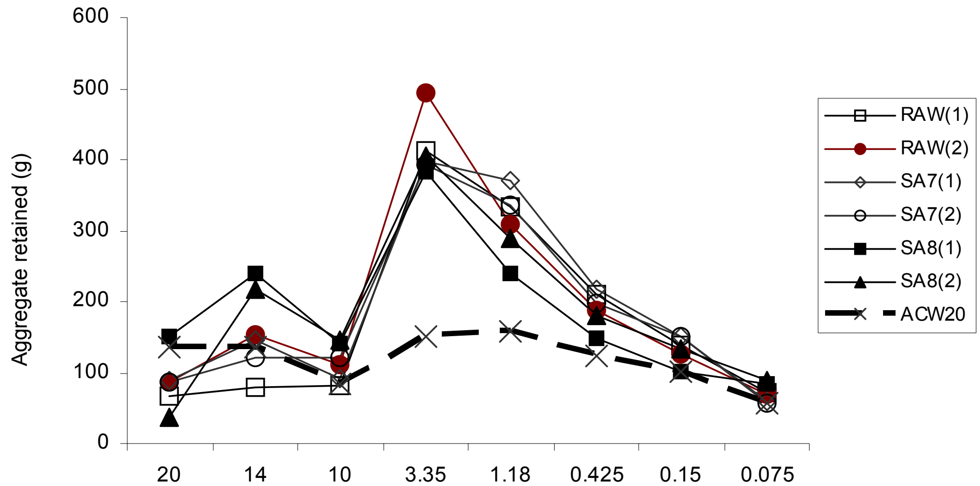

Figure 6 : Weight of aggregate retained (ACW 20)

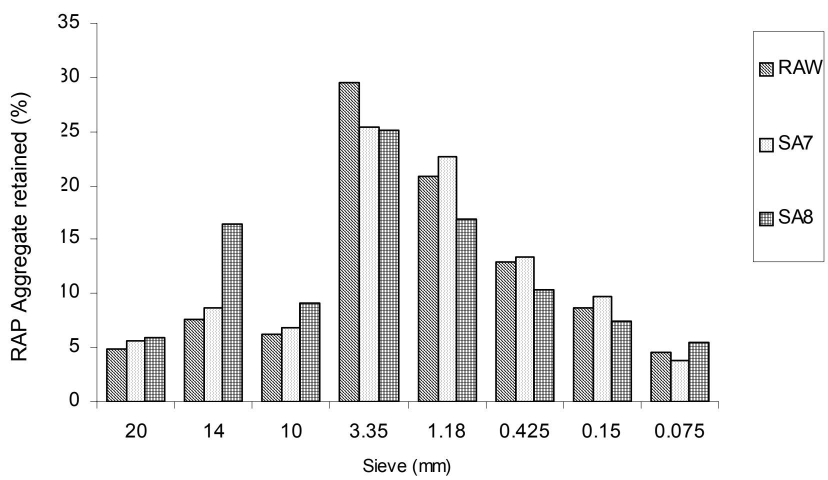

Figure 7 : Percentage of RAP aggregate retained (ACW 20)

Other than the gradation, the aggregate crushing value (ACV) is the relative measured of the resistance of the aggregate to crushing under compressive load gradually. The test is carried out in accordance to BS 812: Part 3 which indicates that the acceptable value range is between 10 to 35 percent of the ACV. Results showed that the representative RAP aggregates from various locations of the study area are still within the acceptable range of 28.81 to 21.26 percent. However, when compared to the virgin aggregate, the later gives a lower value which means they are stronger compared to RAP aggregates. Aggregates above 35 will indicate that the aggregates are too weak and not suitable for use in asphaltic mix as shown in Figure 8. Aggregate impact value (AIV) is another test to measure the resistance of the aggregate to crushing that measure resistance of the aggregate to sudden shock or impact. According to BS 812, this test gives an indication of the toughness or resistant of the aggregates to resist fracture under the impact of moving load. The values of the AIV for RAP aggregates are within the range of 10 to 35 percent as required by the standards. The lower the AIV values, the stronger are the aggregates. The RAP aggregates however gave higher values of AIV compared to virgin aggregates.

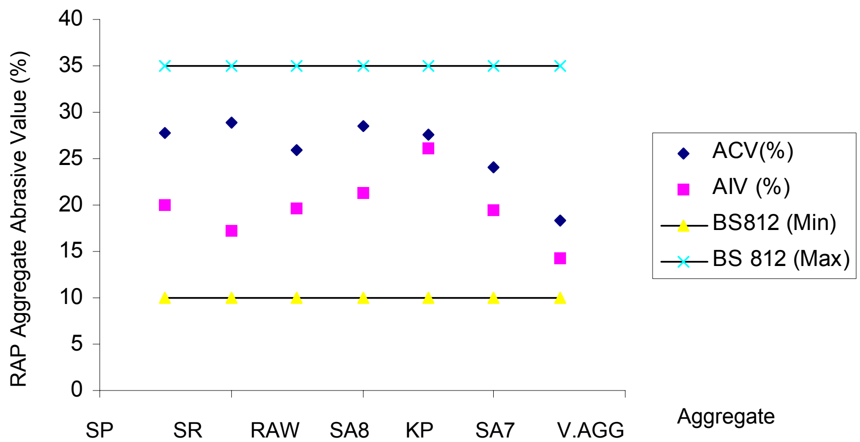

Figure 8 : RAP aggregate abrasion

CONCLUSION

Waste materials generated in rehabilitation work of asphalt pavements have certainly generate more RAP stockpiles which are indeed recyclable and valuable. This study has provided an insight on the usefulness of these aggregates to resist wear although the service life of the pavement has ended which means that the strength is still within the limitations set by the standard. A large amount of aggregates extracted from RAP materials will indeed reduce cost and waste produced when recycled in new HMA mix. The concluding remarks within the scope of this study indicate that the aggregates are still workable and have potential use with proper evaluation and processes involves in extracting the RAP aggregates.

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