A Study to Enhance the Understanding of Material Variability of Reclaimed Asphalt Pavement (RAP)

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ABSTRACT: Reuse of asphalt pavement in the construction of hot mix asphalt (HMA) pavement is both economically beneficial and environmentally friendly. Reclaimed asphalt pavement (RAP) is milled from the pavement and stored as either single or mixed stockpiles. The inclusion of RAP in asphalt pavement increases the variability in HMA, thereof decreasing the performance of the HMA. In order to minimize the variability, it is essential to quantify the variability of RAP stockpile. The asphalt content and aggregate gradation directly reflect the RAP variability within the stockpile. As the percentage of RAP in the mix is increased, the determination of the asphalt content is essential to determine the volumetric properties and the variability. Two commonly used methods of determining asphalt content are the solvent extraction method (AASHTO T319) and ignition oven (IO) (AASHTO T308). Solvent extraction is a cumbersome process and is more variable when compared to the IO. Since the percentage of asphalt content in the RAP is not known, the process of determining IO correction factor is difficult to determine accurately. Since plants regularly use IO as a standard method of determining asphalt content, an incorrect correction factor may have significant impact on the volumetric properties of asphalt concrete. There is a need to determine a methodology of determining an accurate IO asphalt content for RAP stockpiles The purpose of this paper is to determine the methodology of determining the accurate IO asphalt content for RAP and allowable percentage of RAP for each of the three plants in New Jersey.

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KEY WORDS: Reclaimed asphalt pavements, asphalt content, ignition oven.

1 INTRODUCTION

RAP material is obtained by milling the original pavement which sometimes contains patches, chip seal, and other maintenance treatments. The stockpiled RAP material may be from the base, the intermediate, or the surface courses and the stockpile may consist of several projects containing different types of RAP. RAP from private works, which is not built to the same original standards as public works, may also be included in stockpiles. This RAP variability is one of the main concerns a pavement engineer has when using RAP.

To ensure that all the properties of RAP samples taken from asphalt plants have low variability, standards must be set for stockpiling in the state of New Jersey. In order to do this, all stockpiling methods must be analyzed to determine which methods minimize variability. Research has already been conducted for the development of stockpiling procedures within the states of Indiana, Illinois, and Florida ((Iowa DOT, 2006) (McDaniel & Anderson, 2001). The US Department of Transportation also has set stockpiling procedures in an effort to minimize variability within aggregate stockpiles (USDOT, 2006).

It is important that RAP has minimal stockpile variability in order to quantify the effects that it will have on the virgin binder. Variation in stockpiles is determined through a variety of asphalt property tests such as moisture and asphalt content, maximum specific gravity, and viscosity. The gradation of RAP stockpiles is also used to quantify their variability (Newcomb, 2007).

In recent years, the state agencies are increasingly emphasizing the grading of the plant depending upon RAP stockpile variability. Depending upon this grading of the plants, the maximum allowable percentage of RAP for the plant can be determined. This allowable percentage of RAP depends upon the standard deviation of the RAP aggregate gradation and RAP binder content. RAP aggregate gradation and binder content can be determined either by ignition oven method or solvent extraction method.

To determine the allowable percentage of RAP, the accurate binder content and the aggregate gradation is essential. For this paper, two different methods are used to calculate the binder content; Solvent Extraction (AASHTO T319) and Ignition Oven (IO) (AASHTO T308). Solvent extraction method (T319) is a cumbersome process and is highly variable as compared to ignition oven. Because of this, using solvent extraction on a regular basis to measure the asphalt content is not a cost effective option.

For the ignition oven, the asphalt content is calculated by the weight loss in the furnace at high temperatures. The weight loss may also include a small portion of aggregate mass at high temperatures. This may often lead to the asphalt content by Ignition being higher than the solvent extraction method (McKeen, 1997). This difference is compensated by the correction factor. The Ignition Oven correction factor for virgin aggregates is determined by burning the hot mix asphalt of known binder content. However, since the percentage of asphalt content in the RAP is not known, the IO correction factor is difficult to measure accurately. Since plants regularly use IO as a standard method of determining asphalt content, an incorrect IO correction factor may have significant impact in the volumetric properties of asphalt concrete. Therefore, there is a need to determine a methodology of calculating accurate IO for RAP stockpiles.

2 OBJECTIVES

1. To determine the accurate asphalt content of RAP from Ignition Oven
2. To determine the maximum amount of RAP that can be added to the mixture for three different plants in the state of New Jersey.

3 SAMPLING PROTOCOL

The RAP samples were collected from the different plants in the following manner. Three RAP samples were collected at the base of the stockpile. An effort was made to have the samples equidistant from each other. The fourth sample was the mixture of the three samples. A schematic showing this sampling method is shown below in Figure 1.

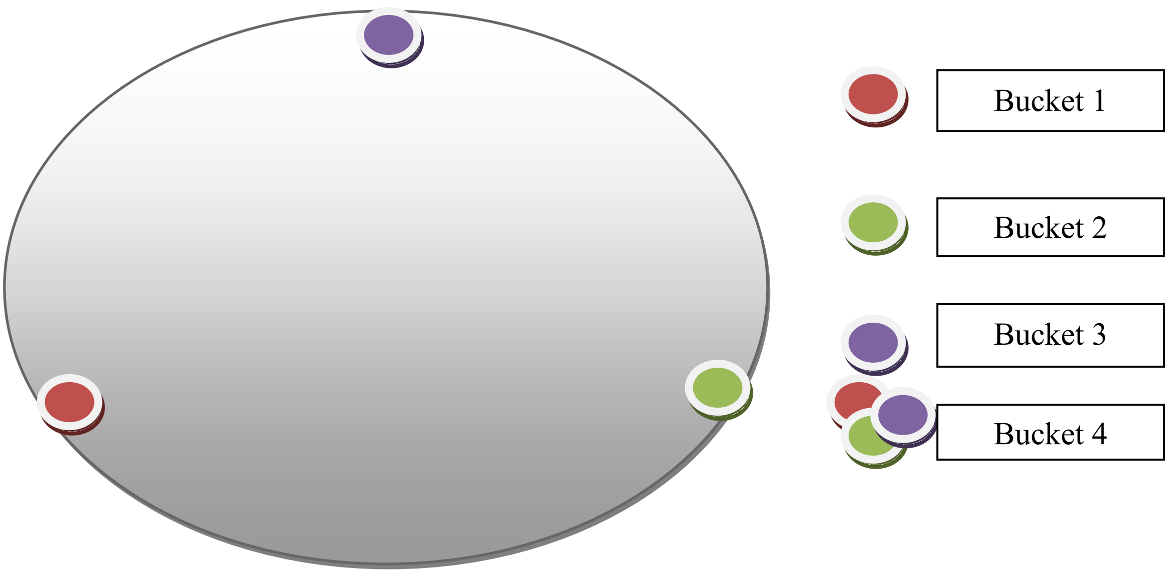

Figure 1: Schematic of stockpile sampling

The above mentioned sampling protocol was selected to capture the variability of the RAP samples within the stock-pile. The experimental design to capture the RAP variability is explained in the following section.

4 EXPERIMENTAL DESIGN

The variability of the RAP is captured by standard deviation in gradation and asphalt content based on National Cooperative Highway Research Program (NCHRP), Project 9-33. For each plant, the binder content and the aggregate gradation from all the buckets were measured and were compared amongst each other. Two different methods were used: Solvent Extraction and Recovery by AASHTO T319 (T319) and the Ignition Oven Method (IO). The following table explains the experimental design.

Table 1: Experimental design (the numbers represent number of replicates)

	Asphalt Content and Gradation					
	Plant 1		Plant 2		Plant 3	
	T 319	T 308	T 319	T 308	T 319	T 308
Bucket 1	1	1	1	1	1	1
Bucket 2	1	1	1	1	1	1
Bucket 3	1	1	1	1	1	1
Bucket 4	1	1	1	1	1	1

5 DETERMINATION OF ACCURATE ASPHLAT CONTENT OF RAP FROM IGNITION OVEN

In this section, a step-by-step procedure of determining the ignition oven correction factor is presented.

Step 1) Determine the asphalt content by Ignition Oven method (AASHTO T308) and Solvent extraction method (AASHTO T319). Figure 2 shows asphalt content by ignition test plotted versus asphalt content by extraction and recovery. The asphalt content measured by Ignition Oven appears to be higher than that measured by the extraction and recovery test.

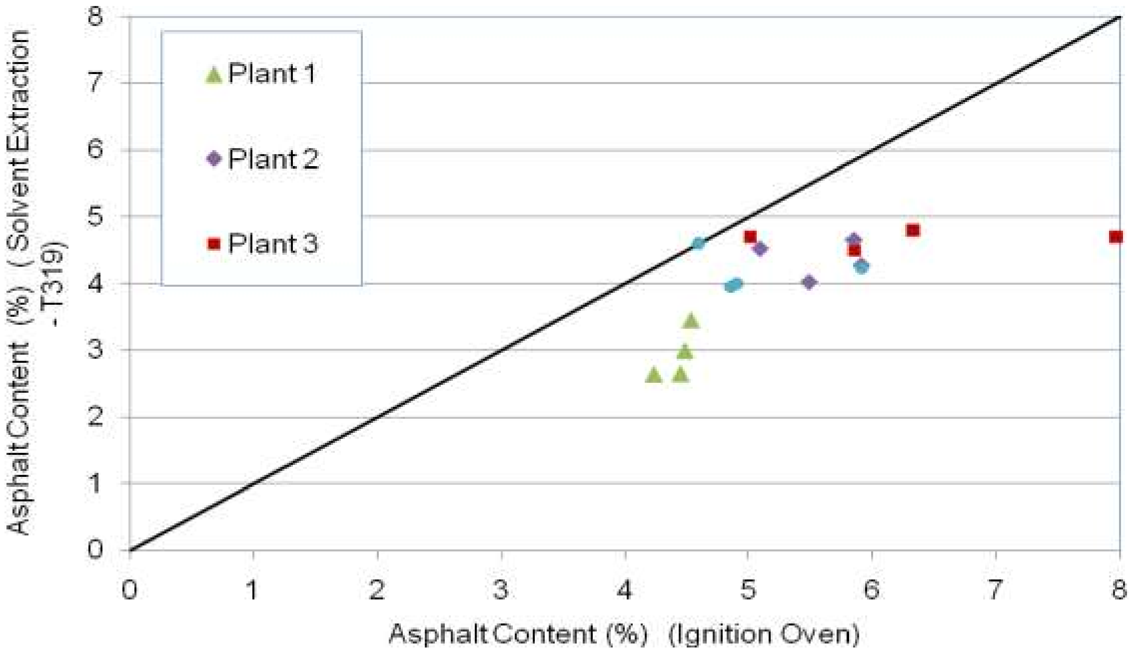

Figure 2: Comparison of asphalt content for ignition oven and extraction and recovery

Step 2) The extracted aggregate from the solvent extraction method (T319) was burned in the Ignition Oven to quantify the difference in asphalt content from ignition oven and solvent extraction. The mass loss may be due to loss of fines during the ignition process.

Figure 3 shows the comparison of percentage passing on each sieve for the extracted aggregate before and after Ignition Oven from plant 1. Shown below in figure 3, it is observed that the gradation of the extracted aggregate sample becomes finer after burning in the ignition oven. This indicates that the Ignition oven burns of a portion of aggregate particles other than the asphalt content.

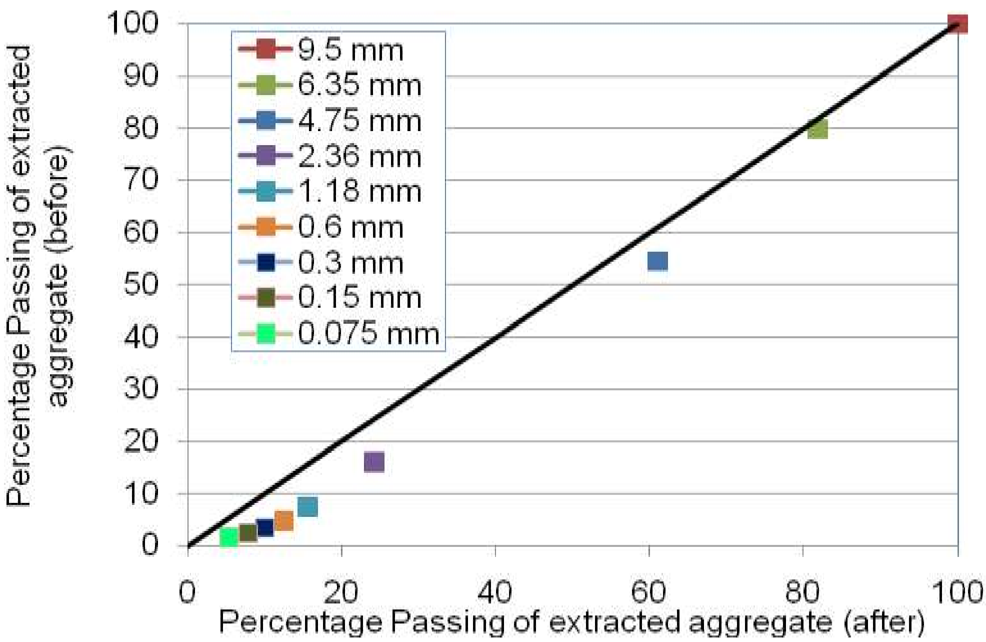

Figure 3: Comparison of percentage passing on each sieve of extracted aggregates "before" and "after" ignition.

Step 3) Calculate asphalt content:

The asphalt content based on sample calculation is shown below:

A) Let A be the Asphalt Content (%) measured from Ignition Oven (IO)

B) Let B be the Asphalt Content (%) measured from Extraction and Recovery

C) Let C be the percent of difference in the weight when extracted aggregate from the T319 method is burned in the Ignition oven.

Asphalt not captured by solvent extraction = A – B -C (1)

$$Corrected\ IO = A - C \quad (2)$$

Example:

Asphalt content (%) measured from Ignition Oven of RAP sample= 4.48%

Asphalt content (%) measured from Solvent Extraction of RAP sample B= 3.00%

Weight loss (%) of extracted aggregate burned in the ignition oven = C = 0.54%

Therefore, asphalt not captured by solvent extraction = A – B - C

= 4.48% - 3.00% - 0.54%

=0.94%

The corrected IO asphalt content (%) = A - C

= 4.48% - 0.54%

= 3.94%

Table 1 shows the results asphalt content from ignition oven and solvent extraction of asphalt content, and the corrected IO for bucket 1 for each plant.

Table 1: Asphalt Content from Ignition Oven, Solvent Extraction, and Loss of fines.

	Plant 1

Ignition Oven (IO)	4.48
Solvent Extraction (AASHTO T319)	3.00
Loss of fines	0.54
Asphalt not captured by solvent extraction	0.94
Corrected IO AC (%)	3.94
	Plant 2
Ignition Oven (IO)	5.49
Solvent Extraction (AASHTO T319)	4.02
Loss of fines	0.66
Asphalt not captured by solvent extraction	0.81
Corrected IO AC (%)	4.83
	Plant 3
Ignition Oven (IO)	6.33
Solvent Extraction (AASHTO T319)	4.80
Loss of fines	1.43
Asphalt not captured by solvent extraction	0.10
Corrected IO AC (%)	4.90

6 DETERMINATION OF ALLOWABLE PERCENTAGE OF RAP

The National Cooperative Highway Research Program (NCHRP), Project 9-33 has compiled *A Mix Design Manual for Hot-Mix Asphalt (*Harrigan, 2006). Methods mentioned in this manual to design RAP mix are based primarily on the NCHRP report 452. As per this manual, the maximum amount of RAP that can be added to the mixture is governed by the amount of dust (below 0.075 sieve) and the variability of the RAP. The variability of the RAP is captured by standard deviation in the gradation and asphalt content. This standard deviation is used to determine allowable percentage of RAP. In this paper, *HMA Tools* developed during the NCHRP 9-33 is used to determined allowable percentage of the RAP. The average standard deviation and maximum allowable RAP for each of the three plants are displayed below in Tables 2, 3, and 4.

Table 2: Average Standard Deviation and Maximum Allowable RAP for Plant 1

Sieve Size, mm	Average	Std Dev.	Maximum Allowable RAP %
50.00	100.00	0.000	100
37.50	100.00	0.000	100
25.00	100.00	0.000	100
12.50	100.00	0.000	100
9.50	98.94	0.965	100
6.35	77.66	4.642	21
4.75	54.81	3.372	37
2.36	18.97	2.585	44
1.18	10.28	2.594	43
0.60	6.82	2.540	33
0.30	4.88	2.271	39
0.15	3.53	1.916	36
0.075	2.35	1.395	38
Asphalt Content	3.48	0.133	86
Overall Maximum Allowable RAP			21

Table 3: Average, Standard Deviation and Maximum Allowable RAP for Plant 2

Sieve Size, mm	Average	Std Dev	Maximum Allowable RAP %
50.00	100.00	0.000	100
37.50	100.00	0.000	100
25.00	100.00	0.000	100
12.50	100.00	0.000	100
9.50	90.45	5.181	22
6.35	75.14	5.865	13
4.75	65.59	5.813	13
2.36	48.86	4.396	17
1.18	32.16	3.094	32
0.60	18.86	2.506	33
0.30	8.42	1.322	85
0.15	3.61	1.022	88
0.075	1.31	0.873	76
Asphalt Content	4.98	0.201	49
Overall Maximum Allowable RAP			13

Table 4: Average Standard Deviation and Maximum Allowable RAP for Plant 3

Sieve Size, mm	Average	Std Dev	Maximum Allowable RAP %
50.00	100.00	0.000	100
37.50	100.00	0.000	100
25.00	100.00	0.000	100
12.50	100.00	0.000	100
9.50	98.88	1.013	22
6.35	85.93	2.138	13
4.75	75.80	4.069	13
2.36	53.86	6.005	17
1.18	32.95	5.234	32
0.60	21.11	4.525	33
0.30	12.03	3.663	85
0.15	6.79	2.552	88
0.075	3.45	1.643	76
Asphalt Content	6.24	1.196	0
Overall Maximum Allowable RAP			0

7 SUMMARY AND CONCLUSIONS

The following conclusions can be drawn from the study:

1. A step by step procedure of determining the accurate asphalt from Ignition oven for RAP samples was developed.

2. On the basis of the above sampling and testing, it is shown that plant 1 has less variability within the stockpile which allows for higher percentage of allowable RAP as compared to plants 2 and plant 3.

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