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The Investigation of Rutting Resistance of Asphalt Mixture Containing Crumb Rubber

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Abstract: Dry process was conducted by adding the crumb rubber directly to the aggregate as another ingredient in the mix. It has potential to consume larger quantities of recycled crumb rubber compared to the wet process resulting in greater environmental benefits. Rutting was frequently reported while applying rubberised mixture for pavement and has become one of the major distress forms with the increase in traffic volume, tire pressure and axial load. Therefore, the objective of this study is to investigate the performance of crumb rubber in asphalt mixture for rutting resistance based on laboratory test results from previous study. In accordance, the result show that the mixes with the largest percentages of crumb rubber showed the lowest mean final deformation values and the use of crumb rubber in bituminous mixes is effective and significantly improves mix response to plastic deformation. The addition of crumb rubber to the aggregate asphalt mixture improved the performance of the modified asphalt mixture and increased rutting resistance when compared to the asphalt mixture without crumb rubber.

Keywords: Dry Process, Crumb Rubber, Rutting

1. Introduction

During the life of an asphalt pavement, it is subjected to a variety of stresses. Rutting is one of the most common problems. The accumulation of permanent deformation in the pavement layers is referred to as rutting. Due to a combination of densification and shear deformation, it shows as longitudinal depressions in the wheel tracks and minor upheavals to the sides. One approach for preventing permanent deformation in asphalt pavement layers is to utilise mixtures prepared with asphalt rubber. Crumb rubber from scrap tyres mixed into asphalt is an useful way to get rid of them and can be used to improve the properties of conventional asphalts [1]. The addition of crumb rubber to the aggregate asphalt mixture improved the performance of the modified asphalt mixture and increased rutting resistance when compared to the asphalt mixture without crumb rubber.

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There are two techniques have been used to add crumb rubber to bituminous mixes. That are wet process and dry process. Mainly, wet process is that the crumb rubber is added to hot asphalt. While dry process is that the crumb rubber is simply utilized as asphalt mixture filler in dry method to substitute a portion of fine aggregates [2]. Therefore, as dry process was found to be more effective than by the wet process and has potential to consume larger quantities of recycled rubber this study focussed on using dry process to investigate the performance of crumb rubber in asphalt mixture for rutting resistance.

The aim of this research is to investigate the performance of crumb rubber in asphalt mixture for rutting resistance based on laboratory test results from previous study. To analyze the rutting performance, rut depth and Wheel Tracking slope were discussed. These tests were widely used to verify the rutting performance.

1.1 Rubberised asphalt mixture

Crumb rubber has proved itself as one of the most important alternative materials for reducing the negative environmental impact of transportation infrastructures, particularly the operation caused by tires replacement on a frequent basis [3]. In terms of permanent deformation and fatigue cracking, rubber asphalt mixtures prepared by the dry process perform well. Larger crumb rubber was used, which resulted in more air voids (which allowed more moisture to penetrate the mix) and weaker cohesion, resulting in a less satisfactory reaction to moisture action. The amount of crumb rubber in the mix had a substantial impact on its mechanical performance, as shown by the mix's response to water sensitivity and plastic deformation. [4]. As the crumb rubber particle size increases, the elastic recovery of modified asphalt increases, indicating increased mechanical properties.

The performance of the materials is assessed by measuring the resultant rut depth [5]. Asphalt mixture modification of crumb rubber 1.25%, an increase in the rut depth on cycles, showed the lowest value compared to other asphalt mixtures. The addition of crumb rubber has shown the optimum content of 1.25% of the asphalt content in the aggregate asphalt mixture and has achieved better-modified asphalt mixture performance and higher rutting resistance than asphalt mixture without crumb rubber. Based on the previous data, the mixes with the lowest mean final deformation values were those with the largest percentages of crumb rubber [4].

2. Materials and Methods

This section discussed about detailed description of the test methodology used to evaluate the rutting characteristic of the mixture.

2.1 Materials

The material used in this study were aggregate, bitumen and crumb rubber. All materials are prepared in accord with the JKR road design specification.

a) Material for asphalt mixture

In this project, the mixtures of bitumen concrete that used is 9.5 mm size as nominal maximum aggregates size. Sieve analysis determined the proportion of different aggregate sizes and will not exceed the Superpave gradation limit. Rubber tube is added to hot aggregates at the plant, similar to reclaimed asphalt pavement (RAP), and then combined with binder in the dry process.

b) Bitumen

Bitumen used in this study was grade 60/70. In order to ensure the bitumen satisfied the standard, penetration and softening point test was conducted.

c) Crumb rubber

Cryogenic grinding was used to create the crumb rubber modifier. Only one batch of crumb rubber modifier was utilised throughout the investigation to ensure that the consistency of the crumb rubber modifier was maintained. The crumb rubber powder size used in this study was sieved on a No. 90# (163 m) sieve and then retained on a No. 100# (149 m) sieve. The crumb rubber materials were mixed with the aggregate in the dry process before the asphalt cement was added to the blended mixture.

2.2 Methods

Superpave mixture was used to obtain the optimum bitumen content (OBC). The process for the design of Superpave mixes includes the selection of asphalt and aggregate materials that comply Superpave requirements and volumetric analysis of mix specimens compacted with the Superpave gyratory compactor. Trial bitumen content 5.5%was used because the nominal maximum aggregates size that used is 9.5 mm.

Sieve analysis is a method for determining the grading of an aggregate stockpile. This is to assure that the proportion of aggregates used in the mixture is within or satisfies the Superpave Standard's requirements. The aggregate and binder mixing process is affected by aggregate gradation, which is a crucial element in mixing design.

Binder testing in this study involved penetration and softening point test. The penetration test is an empirical measurement of a material's consistency based on the distance a standard needle sinks into over a specified loading time as requirement as ASTM D5. Softening point is measured by ring and ball method in accordance (ASTM D36). Its purpose is to determine the temperature at which the phase changes occur in the bitumen cement.

To determine OBC, corelok was selected to specify Gmm and Gmb. Corelok is a system for sealing asphalt samples so that the density of the sample can be measured by the water transfer method. Samples are automatically sealed in thick plastic bags. It involves compacted (Gmb) and loose (Gmm) samples to obtain OBC. The sealed sample was placed on equilibrium and then placed in a water bath. The plastic is cut when the sample is completely immersed in water. The sample's weight in water was recorded. The sample was taken out of the water, dried as quickly as possible with a damp towel, and the dry mass of the surface was determined.

3. Results and Discussion

The result is computed and displayed as tables and graphs to assure that the analysis' outcome can be easily stated and described. The analysis was carried out to ensure that all testing was appropriate to this issue and that the objective was satisfied. Table 1 shows sieve size and percentage of aggregate passing for aggregate gradation. For obtain bitumen content (OBC) determination, crushed granite aggregate was dried and sieved into selection size range according to specific gradation. The aggregate gradation with nominal size 9.5mm was used.

Table 1: Sieve size and percentage of aggregate passing

Sieve size(mm)	Percentage passing (%)	Percentage retained (%)	Weight of sample(g)
12.5	100	0	0
9.5	94	6	69
4.75	78	16	184
2.36	42	36	414
1.18	20	22	253
0.6	10	10	115
0.3	5	5	57.5
0.075	2	3	34.5
Pan	0	2	23
Total		**100**	**1150**

Table 2 shows the average penetration value of the samples satisfied the standard in MS 541 penetration test which in the range 60-70.

Table 2: Penetration test result

Sample	Penetration Depth(mm)
Bitumen 60/70	69.17

Table 3 shows the average softening point of the bitumen sample followed the standard in MS687 of softening point test which in the range of 49-56.

Table 3: Softening point test result

Sample	Softening point
1	50.9
2	52.8
Average	**51.9**

Table 4 shows that when there is a higher percentage of trial asphalt content, the percentage of air void decreases. However, for design purposes, only 4% of air void is required to determine OBC. To obtain OBC, this standard used to plot graph (see figure1, figure2 and figure 3) of three parameters against asphalt content that involved percent air void, percent VMA and percent VFA.

Table 4: Result obtained from Superpave mix design

Asphalt Content %	Gmm	Gmb	Gsb	Va	Ps	VMA	VFA
5%	2.447	2.331	2.588	4.74	95.64	13.86	65.79
5.50%	2.414	2.314	2.588	4.14	95.93	14.23	70.89
6%	2.364	2.272	2.588	3.89	95.88	15.83	75.41
6.50%	2.331	2.245	2.588	3.69	96.81	16.02	76.96

Table 5 shows that the percent of the VWA is 15.2% that is higher than minimum value of design criteria, 13% minimum value. Percent of VFA obtained is 73.5% that also slightly lied between 65 to 75%limitation. Thus, the design OBC obtained was 5.9% and accepted because as it is following the Superpave design criteria.

Table 5: Design mixture properties at 5.9% bitumen content

Mix property	Result	Criteria	Status
Air void	4%	4%	Ok
VMA	15.2	min 13	Ok
VFA	73.5	65-76	Ok

Table 6 shows that asphalt mixture modification of crumb rubber 1.25%, an increase in the rut depth on cycles, showed the lowest value compared to other asphalt mixtures. Crumb rubber was added to the aggregate asphalt mixture at a rate of 1.25 percent of the asphalt content, resulting in improved modified asphalt mixture performance and stronger rutting resistance than asphalt mixtures without crumb rubber [6]. Thus, the usage of the crumb rubber in asphalt mixture could be encouraging to increase in pavement lifespan by high traffic conditions.

Table 6: Rut depth

Crumb rubber(%)	No of cycle	Rut depth(mm)
0	500	1
	1000	1.2
1.25	500	0.4
	1000	0.6
2.5	500	0.7
	1000	0.8
3.75	500	0.8
	1000	0.9
5	500	0.8
	1000	0.9

Table 7 shows that the mixes with the largest percentages of crumb rubber showed the lowest mean final deformation values. This shows that using crumb rubber in bituminous mixes is effective and increases the mix's responsiveness to plastic deformation significantly. The addition of a large amount of crumb rubber (1.5 %) to the mix significantly increased its reactivity to plastic deformations. It outperformed the reference mix in this category.

Table 7: Wheel Tracking Slope (WTS) ($mm/10^3$ $load\ cycle$)

0% crumb rubber	**0.5% crumb rubber**	**1.0% crumb rubber**	**1.5% crumb rubber**
0.05	0.045	0.07	0.027
0.05	0.063	0.063	0.026
0.05	0.069	0.076	0.035
0.054	0.053	0.067	0.041
0.046	0.037	0.075	0.037

Table 8 shows the calculated F(8.497) is larger than F critical (6.927),so H_0 is rejected. Therefore,H_a is accepted, which states that the population means are not all equal. The mean of the WTS are not same in each percentage of additional crumb rubber in the mix. It is likely that the WTS are related to the mixes' resistance to plastic deformations.

Table 8: Anova analysis of WTS

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.00117	2	0.000585	8.496852	0.005026	6.926608
Within Groups	0.000826	12	6.88E-05			
Total	0.001996	14				

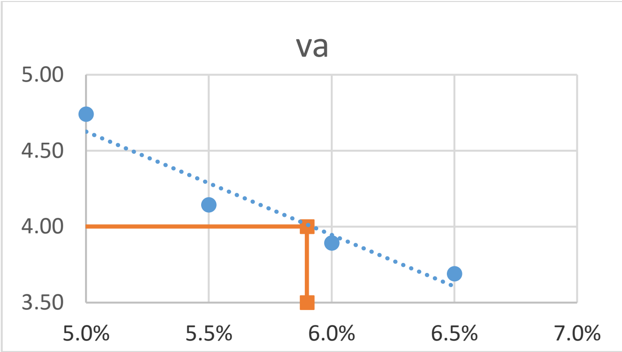

Figure 1: A graph of Air void versus Trial asphalt content

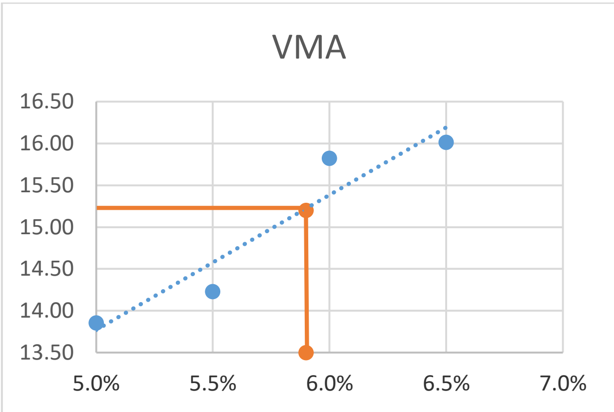

Figure 2: A graph of VMA % versus Trial asphalt content

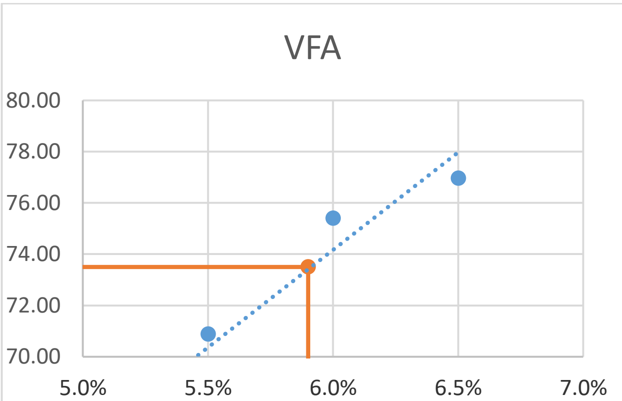

Figure 3: A graph of VFA % versus Trial asphalt content

4.0 Conclusion

In this study, the physical and mixtures performance test of bitumen, dry process with additional of tyre rubber and aggregate gradation were investigated using tests that stated in ASTM, ASHTO and MS. The 60/70 grade of bitumen used is satisfied with the standard of penetration and softening point test. The mixtures that contained much more crumb rubber had the lowest mean final deformation values. Crumb rubber in bituminous mixtures is effective and enhances the mix's responsiveness to plastic deformation greatly.

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