EFFECT OF CRUMB RUBBER ON PERFORMANCE OF BITUMINOUS MIX

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Approved by,

(Dr. Madzlan Napiah)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contain herein not been undertaken or done by unspecified sources or persons.

(Ahmad Izaidi bin Abd Azis)

ABSTRACT

Rubberized asphalt has been used for more than 20 years to resurface highways. While it helped reduce the disposal of used tires, it recently has been recognized for its reduction of traffic noise but the rise in road traffic and lack of maintenance has weakened the road structure and damage the surface. This research project is to study the effect of crumb rubber on the performance of bituminous mixture. The implementation of the crumb rubber on the bituminous mixture is to test whether the crumb rubber can possibly strengthen the conventional bituminous mix to reduce the damage and to reduce maintenance of road and also to compare with the result with the conventional bituminous mix. The scope of this study is the performance of modified bituminous mix by adding the crumb rubber as portion of fine aggregates and the performance of the sample will be tested using two testing methods which are wheel tracking test and creep test. This project started with the preliminary research followed by case study and literature review by collecting journals, determining percentage of crumb rubber, laboratory works where characteristic of materials, composition of mixture, test methods and type of compaction selected, manufacturing samples and testing sample done. After the laboratory works done, data gathered and processed and analyzed, then result and discussion produced and last but not least conclusion and recommendation. As a conclusion of this project, the crumb rubber cannot be applied for fine aggregates for partial replacement in dry process mixing in order to strengthen the bituminous mix.

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Alhamdulillah, most thankful to Allah Almighty, for giving me the strength and good health during this Final Year Project.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

There are two main categories of pavement, rigid and flexible and also known as concrete pavement and asphaltic pavement. The wearing surface of rigid pavement is usually constructed with Portland cement concrete (PCC). These types of pavements are called "rigid" because they are significantly stiffer than flexible pavements due to PCC's high stiffness. In the other hand, flexible pavement surfaced with bituminous (or asphalt) materials commonly used in most country. This pavement is called "flexible" since the pavement structure bends or deflects due to traffic loads. A flexible pavement structure is generally composed of several layers of materials such as surface, base, and subbase which can accommodate this "flexing". Figure 1.1 shows the structural differences between flexible pavement and rigid pavement and figure 1.2 show the difference of load for flexible pavement and rigid pavement.

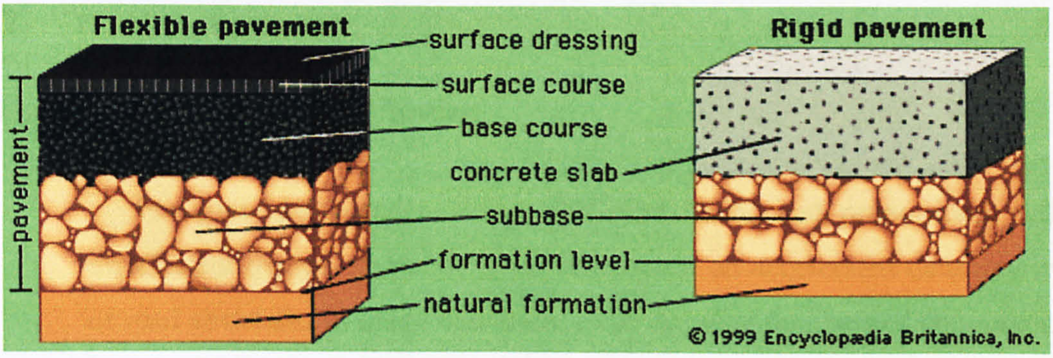


Figure 1.1: Flexible pavement and rigid pavement structure

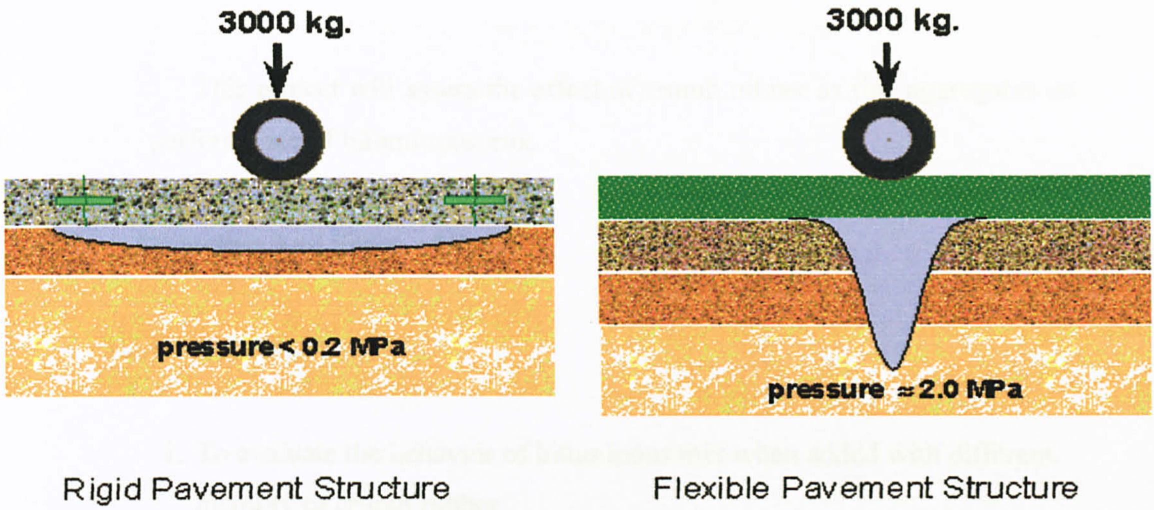


Figure 1.2: Traffic load transferred by flexible pavement and rigid pavement

There are few studies conducted before to assess the effect of applying crumb rubber in asphaltic pavement in which crumb rubber is mix with bitumen that eventually enhance the bituminous mixture. However, no study has been conducted to assess the effect of crumb rubber as fine aggregates to bituminous mix. Thus, effect of crumb rubber as fine aggregates on performance of bituminous mix identified to be a relevant topic for this final year project.

1.2 Problem Statement

1.2.1 Problem identification

For past two decades increase in road traffic and proportional with insufficient degree of maintenance has caused an accelerated deterioration of road structures in many countries. Even growing numbers of commercial vehicles with super single tires and increase axle loads take their toll and it is obvious that this trend will go on in the future. As for nowadays, the performance of asphaltic bitumen is also being questioned, given that they are brittle and hard in cold environment and soft in hot environments [1]. For this reason, crumb rubber applied into the bituminous mix in order to evaluate the characteristic of bituminous layer.

1.2.2 Significant of Project

This project will assess the effect of crumb rubber as fine aggregates on performance of bituminous mix.

1.3 Objective And Scope of Study

1.3.1 Objectives

1. To evaluate the behavior of bituminous mix when added with different quantity of crumb rubber.
2. To compare the result with conventional bituminous mix.

1.3.2 Scope of Study

The scope of this study is the performance of modified bituminous mix by adding the crumb rubber as portion of fine aggregates and the performance of the sample will be tested using two testing methods which are wheel tracking test and creep test.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1. Literature Review

2.1.1 Study of Journal

Soon e*t al* [2] investigated the aging attribute of binder due to response with crumb rubber. The result from this study showed that the asphalt binder with higher rubber content showed a higher large molecular size (LMS) value and increase in rubber content is measured to result in extra loss of the low molecular weight in asphalt binder. After subjecting to the long-term aging, the asphalt mixtures with the control and rubber modified binder were found very similar aging level. Soon *et al* [2] examine that in wet process, the longer blending time for production of rubber-modified binders seems to lead to an increase in the viscosity. Soon *et al* [2] found that the binder with the higher rubber content in wet process, exhibited slightly higher large molecular size (LMS) values and the increase in rubber content is thought to result in the additional loss of the molecular weight maltenes of the asphalt binder during blending. Pasetto *et al* [3] indicate that the tire rubber has a positive influence on the performance characteristic, depends also on the grading and volumetric properties of the mix being studies: an interesting increase of fatigue life, better stiffness behavior at lower temperature and a bigger permanent deformation resistance at high temperatures are guaranteed. Katman *et al* [4] investigate that the dry process in preparing rubberized porous asphalt give better performance compared to samples prepared using wet process. Samples prepared with dry process provide excellent resistance to raveling and resistance to stripping. M. Hossain *et al* [5] state that the use of rubber chunks (up to a maximum size of 12.5 mm) in Crumb Rubber Asphalt Concrete (CRAC) as a replacement for traditional large aggregates results in a weaker mix than without rubber. Since rubber is not as hard as the crushed stone aggregates, it follows that the Marshall stability of an asphalt-aggregate-chunk rubber mix would be lower than a mix without chunk rubber. However, it was also surmised that the larger rubber chunks tend to absorb some of the energy imparted to compact a CRAC sample, resulting in a weaker aggregate structure than a mix without any chunk rubber.

2.2 Theory

2.2.1. Crumb Rubber

The use of crumb tire rubber as an additive in bituminous mix construction not only solves a waste disposal problem and offers the benefit of resource recovery; it is also of interest to the paving industry because of the extra elasticity imparted to the binder and pavement system and also reduces the binder inherent temperature susceptibility. According to Robert *et al* [6], adding tire rubber to the bituminous mixture can increase fatigue and reduce rutting. Crumb tire rubber usually obtained by shredding and grinding (milling) the tire rubber at or above ordinary room temperature. This process produce a sponge-like surface on the granulated rubber crumbs which have considerably greater surface area for a given size particle than do cryogenically ground rubber particles. Increase of surface area increases the reaction rate with the bitumen.

According to Sikora M. [7], Asphalt rubber pavements may last up to twice as long as conventional materials before needing maintenance or replacement. Another asphalt rubber cost advantage is that some applications can be placed at half the thickness of conventional pavement, saving on material and installation costs as well as construction time. Also, numerous case studies have proven again and again that using an asphalt-rubber binder in a pavement provides better resistance to cracking and fatigue caused by heavy traffic which leads to a smoother road and lower operating costs.

2.2.4 Aggregate

Numbers of tests are suggested in the specifications to judge the properties of the aggregates, e.g. strength, hardness, toughness, durability, angularity, shape factors, clay content, adhesion to binder etc. Angularity ensures adequate shear strength due to aggregate interlocking, and limiting flakiness ensures that aggregates will not break during compaction and handling.

Theoretically, according to Sennov [10] and Aberg [11], it is difficult to forecast the aggregate volumetric parameters, even the resultant void ratio, when the gradation curve is known. The Fuller's experimental study for minimum void distribution [12] still forms the basis of these exercises. Strategic Highway Research Program (SHRP), USA formed a 14 member Expert Task Group for evolution of appropriate aggregate gradation to be used for Superpave. The group, after several rounds of discussions decided to use 0.45 power Fuller's gradation as the reference gradation, with certain restricted zones and control points. The controlled zone and control points are integrated in order to ensure certain percentage of fines for (i) proper interlocking of aggregates (ii) to avoid the fall in shear strength of mix due to excess of fines and (iii) to maintain requisite Voids in Mineral Aggregates (VMA). These control points and restraint zones are more as guidelines for selecting a gradation than an obligation to be followed. A large number of researches have been reported which have studied performances of various alternative gradations.

METHODOLOGY/ PROJECT WORK

3.1 Flow Chart

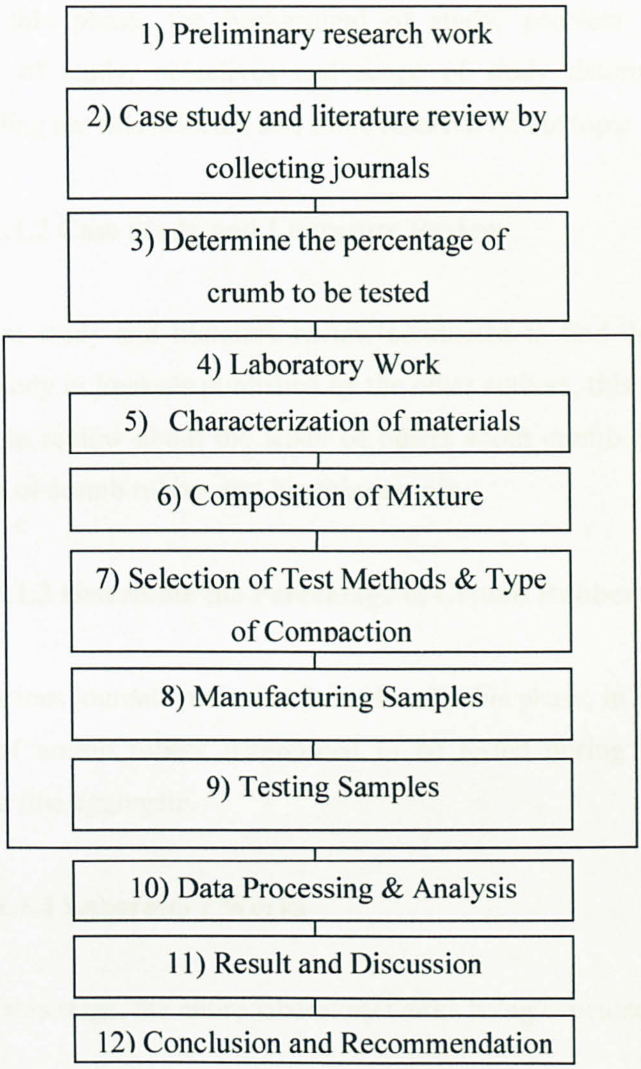


Figure 3.1: Elements of a methodology for bituminous mixtures with different quantity of crumb rubber study (shaded areas are parts where testing has to be done)

3.1.1. Brief Description about Flow Chart

3.1.1.1. Preliminary Research Work

In this phase, the background of study, problem identification, significant of study, objectives and scope of study determine by fully understanding the title selected and some research on the topic.

3.1.1.2 Case Study and Literature Review

Case study and literature review conducted to find the evidence of previous study in journals published by the other authors, this phase is really important to review about the study of others about crumb rubber and the interaction of crumb rubber and bituminous mix.

3.1.1.3 Determine the Percentage of Crumb Rubber

Various journals review to precede with this phase, in return, 1%, 3% and 5% of crumb rubber determined to be tested during the project as addition to fine aggregate.

3.1.1.4 Laboratory Works

In this stage, the entire laboratory works being executed.

3.1.1.5 Characterization of Materials

This section performed by doing some experiment to test the entire materials used in this project. The tests conduct to determine the characteristic of coarse aggregates, fine aggregates, filler, binder, and also crumb rubber.

3.1.1.6 Composition of Mixture

In this stage, the gradation of coarse aggregates, fine aggregates and filler determined. The gradation of above materials is determined by doing some sieve analysis. The data gathered from the sieve analysis analyzed and the proportion catered to be fixed with some excel program to obtain the proportion of mixture.

3.1.1.7 Selection of Test Methods and Type of Compaction

Before the samples manufactured, this stage is really important to determine the type of compaction to get the accurate result. Test methods are selected in order to ensure that all the equipment needed available at laboratory.

3.1.1.8 Manufacturing Samples

In this phase all the samples for Marshall Mix Test, Wheel Tracking Test and Creep Test were manufactured. Samples manufactured according to gradation of materials that has been done earlier.

3.1.1.9 Testing Samples

In order to evaluate the samples, this stage is mandatory. There are two stages for this phase. The first one is Marshal Mix test, which will evaluate the six characteristics of the samples and also determined the optimum binder content of the samples. It wills also affecting the next test that will be conducted after Marshall Mix test. The second stage is, Wheel Tracking Test and Creep Test that will evaluate the performance of the bituminous mix.

3.1.1.10 Data Processing and Analysis

All the data obtain from the test gathered and analyze in order to get the result.

3.1.1.11 Result and Discussion

In this phase, from the observation, experiment, and analysis that has been done the result produced and discussion of the result will be done.

3.1.1.12 Conclusion and Recommendation

After all the result analyzes and discussion made, the project will be concluded in this phase. There is also recommendation/s to improve the result and findings for the next experiment of this topic.

3.2 Tests Conducted

3.2.1. For Bitumen

For bitumen, it is essential for having the characteristic test to differentiate grade from one to another. Three (3) types of tests need to be done to characterize the bitumen which is softening point test, penetration test and ductility test.

- **Ring-and-Ball Softening Point Test**

  The ring and ball softening test is used to measure the susceptibility of blown asphalt to temperature changes by determining the temperature at which the material will be adequately softened to allow a standard ball to sink through it.

- **Penetration Test**

Penetration test gives an empirical measurement of the consistency of a material in terms of the distance a standard needle sinks into that material under a prescribed loading and time. Figure 3.2 shows the tool used for this test.

Figure 3.2: Semi-automatic Penetrometer

- **Ductility Test**

Ductility is the distance in centimeters a standard sample of asphaltic material will stretch before breaking when tested on standard ductility test equipment at 25°C. The result if this test indicates the extent to which the material can be deformed without breaking. Figure 3.3 show the initial sample position inside of ductilometer.

Figure 3.3: Sample in Ductilometer

- **Specific Gravity Test**

This purpose of this test is to determine the specific gravity and density of bituminous materials by using a pycnometer.

3.2.2. For Aggregate

In Malaysia, the aggregates used in the bituminous mixture must followed particular requirements provided by Jabatan Kerja Raya (JKR). Hence, there are six (6) tests used for determine the physical properties of the aggregate.

- **Sieve Analysis Test**

The aggregate's particle size distribution, or gradation, is one of its most influential characteristics. Gradation helps determine the almost important property of bituminous mix such as stiffness, stability, durability, permeability, workability, fatigue resistance, frictional resistance and etc. Because of this, gradation is a primary concern in bituminous mix design and thus most agencies specify allowable aggregate gradations.

- **Particle Density (Specific Gravity) & Water Absorption Test**

  Specific gravity test is a measurement that determines the density of minerals. The specific gravity of a mineral determines how heavy it is by its relative weight to water. The specific gravity value is expressed upon how much greater the weight of the mineral is to an equal amount of water. Water has a specific gravity of 1. If a mineral has a specific gravity of 2.7, it is 2.7 times heavier than water. Minerals with a specific gravity under 2 are considered light, between 2 and 4.5 averages, and greater than 4.5 heavy.

- **Los Angeles (LA) Test**

  Aggregates used in pavement should durable so that they can resist crushing under the roller. Many abrasion tests have been developed in order to evaluate the difficulty with which aggregate particles are likely to wear under attrition from traffic. A common test used to characterize toughness and abrasion resistance is the Los Angeles (L.A.) abrasion test.

- **Flakiness Index and Elongation Index**

  Flakiness and elongation indexes are the measures of particle shape. Particle shape is important in that excessive amount of flaky or elongated material in aggregates can affect the workability of concrete. In bituminous mixtures flaky aggregate makes for a harsh mix and may also crack and break up during compaction by rolling.

3.2.3. Filler Material

Filler also have their own specific requirement which passes a 0.060 mm (No. 30) sieve, with at least 65 percent of the particles passing the 0.075 mm (No. 200) sieve. There are two (2) tests used to determine the physical properties for filler.

- **Specific Gravity Test**

  Specific gravity test is a measurement that determines the density of minerals to the density of water. Figure 3.4 shows the apparatus and samples used during the experiment.

Figure3.4: Pycnometer

3.2.4. For Samples

- **Marshall Mix Test**

Marshall Mix Test – Rational approach to selecting and proportioning two materials, asphalt proportion, and mineral aggregates to obtain the specified properties in the finished asphalt concrete surfacing structure. The method is intended for laboratory design of paving mixtures. In other words, Marshall Mix Test will be use to obtain the optimum binder content that meet certain standard. Several sample of the specimen with different binder proportion and aggregates proportion need to be prepared in order to obtain the optimum binder content.

- **Wheel Tracking Test**

Wheel Tacking Test – Use to determine the plastic deformation of asphalt based road surface wearing courses under temperature and pressure closely similar to those asphalt road which in use in hot weather and traffic load on top of it. According to Stephen [13] this test will prevent road surfaces being under laid, which rut in hot weather and need to be re-laid. The performance of the materials is assessed by measuring the resultant rut depth after a given number of passes.

- **Creep Test**

Creep is high temperature progressive twist at stable pressure. "High temperature" is a relative term reliant upon the resources involved.

A creep test involves a tensile specimen under a constant load maintained at a constant temperature. Measurements of strain are then recorded over a period of time

Creep occurs in three stages: Primary or Stage I; Secondary, or Stage II: and Tertiary, or Stage III. Stage I, or Primary creep occurs at the beginning of the tests, and creep is mostly transiently, not at a steady rate. Resistance to creep increases until Stage II is reached. In Stage II, or Secondary creep, the rate of creep becomes roughly steady. This stage is often referred to as steady state creep. In Stage III, or tertiary creep, the creep rate begins to accelerate as the cross sectional area of the specimen decreases due to necking or internal voiding decreases the effective area of the specimen. If stage III is allowed to proceed, fracture will occur.

CHAPTER 4
RESULT AND DISCUSSION

4.1. Bitumen Characteristic Testing

4.1.1. Standard Penetration Test

Table 4.1: Result of Standard Penetration Test

Standard Penetration Test				
Temperature : 25°C		Load : 100 g		Time : 5 seconds
Trial No.	Determination 1	Determination 2	Determination 3	Mean
A	88	88	85	87.00
B	86	86	84	85.33

4.1.2 Ductility Test

Table 4.2: Result of Ductility Test

Ductility Test				
Sample	Mould No. 1	Mould No. 2	Mould No.3	Mean
A (Grade 80)	104.0cm	111.2cm	121.3 cm	112.17 cm

Ductility value of grade 80 bitumen = **112.17 cm**

Table 4.2 shows the experimental value for ductility test of bitumen grade 80 was 112.17cm. The sample has been fabricated three (3) times into a dumb-bells shaped and tested using the ductility test apparatus. From the three (3) samples, the mean of the data were taken and were evaluated as the ductility value of the bitumen that will be used throughout the study.

4.1.3 Standard Softening Point Test (Ring-and-Ball Test)

Table 4.3: Result of Softening Point Test

Softening Point Test			
Trial	Ball 1 (°C)	Ball 2 (°C)	Mean(°C)
A (Grade 80)	53.8	53.2	53.5
B (Grade 80)	47	47.8	47.4

Softening point value of trial 1: **53.9°C**

Softening point value of trial 2: **47.4°C**

The ring-and-ball softening point test is used to measure the susceptibility of blown asphalt to temperature changes by determining the temperature at which the material will be adequately softened to allow a standard ball to sink through it. From Table 5, two trial of Grade 80 bitumen was made and tested. From the Manual on Pavement Design, the requirement for softening point test of bitumen is it cannot be less than 45°C and cannot exceed 52°C with the temperature differences between ball 1 and ball 2 is not exceeding 1°C. Therefore, this bitumen can be used further for this study.

4.2 Aggregates Testing

4.2.1 Aggregates Specific Gravity

Table 4.4: Result of Specific Gravity for Fine Aggregate

		Test No.	
		1	2
Mass of saturated surface-dry sample in air A	(g)	497	494
Mass of vessel containing sample and filled with water B	(g)	1860	1856
Mass of vessel filled with water only C	(g)	1557	1555
Mass of oven-dry sample in air D	(g)	495.0	491.1

Table 4.5: Result of Specific Gravity for Fine Aggregates.

		Test No.		
		1	2	Average
Particle density on an oven-dried basis	$\frac{D}{A-(B-C)}$	2.55	2.54	2.545
Particle density on a saturated and surface-dried basis	$\frac{A}{A-(B-C)}$	2.56	2.56	2.560
Apparent particle density	$\frac{D}{D-(B-C)}$	2.58	2.58	2.580
Water Absorption (% of dry mass)	$\frac{100(A-D)}{D}$	0.40%	0.59%	0.495%

Table 4.6: Result of Specific Gravity for Coarse Aggregate

		Test No.	
		1	2
Mass of saturated surface-dry sample in air A	(g)	991	1075
Mass of vessel containing sample and filled with water B	(g)	2170	2212
Mass of vessel filled with water only C	(g)	1556	1562
Mass of oven-dry sample in air D	(g)	984	1065

Table 4.7: Result of Specific Gravity for Coarse Aggregates.

		Test No.		
		1	2	Average
Particle density on an oven-dried basis	$\frac{D}{A-(B-C)}$	2.61	2.50	2.55
Particle density on a saturated and surface-dried basis	$\frac{A}{A-(B-C)}$	2.63	2.53	2.58
Apparent particle density	$\frac{D}{D-(B-C)}$	2.66	2.57	2.62
Water Absorption (% of dry mass)	$\frac{100(A-D)}{D}$	0.71%	0.94%	0.83%

4.2.2 Aggregates Sieve analysis

Table 4.8: Result of Coarse Aggregates Sieve Analysis

Sieve Opening	Trial 1	Percentage	Trial 2	Percentage	Average
25 mm	0	100	0	100	100
20 mm	0	100	0	100	100
14 mm	984.50	50.775	518.60	74.07	62.422
10 mm	654.20	18.065	754.30	36.355	27.21
5 mm	311.80	2.475	667.60	2.975	2.725

From table 4.8 above, we can see there are two trials have been done, in those trials, the percentage of passing are different in every trial. This is likely because the uncertainty when preparing the materials. First trial material randomly picked up at the top of the gravel pile and the second trial material randomly picked up at the bottom of the pile. Thus, this is why the result is different. In order to make it even, the average of two trials are selected and the percentage of passing was calculated.

Table 4.9: Result of Fine Aggregates Sieve Analysis

Sieve Opening	Trial 1	Percentage	Trial 2	Percentage	Average
2.36 mm	14.80	97.04	16.00	96.8	96.92
1.18 mm	35.70	89.9	38.40	89.12	89.51
600 μm	96.60	70.58	94.10	70.3	70.44
300 μm	266.00	17.38	267.40	16.82	17.10
150 μm	64.00	4.58	63.10	4.2	4.39
75 μm	6.80	3.22	4.00	3.4	3.31
pan	16.00	1.15	16.60	1.20	1.18

In table 4.9 above, result of fine aggregates sieve analysis is also the same with coarse aggregates sieve analysis, same approach used to counter the problem.

Table 4.10 below, shows the result of rubber crumb analysis. In order to mix the crumb rubber as fine aggregates, sieve analysis has been done to determine the size of crumb rubber.

Table 4.10: Result of Rubber Crumb Sieve Analysis

Sieve Opening	Trial 1	Percentage
2.36 mm	15.48	96.90
1.18 mm	371.80	22.54
600 µm	89.80	4.58
300 µm	15.90	1.40
150 µm	1.90	0.80
75 µm	0.50	0.70
pan	3.50	

4.2.3 Aggregate Flakiness and Elongation

Table 4.11: Flakiness Index (Granite)

Flakiness Index					
Size Fraction	Square Mesh Grading		Mass of fraction to be tested, M_2 (g)	Flakiness Gauge	
	Mass Retained (g)	Percent Passing (%)		Mass retained by gauge (g)	Mass passing gauge (g)
28.0 – 20.0	96	4.84	- (discarded)	- (discarded)	- (discarded)
20.0 – 14.0	1102	55.63	1102	1013	89
14.0 – 10.0	607	30.64	607	564	43
10.0 – 6.30	176	8.88	176	160	16
Total Masses, M_1 (g)	1981	100	ΣM_2 = 1885	1737	ΣM_3 = 148

Table 4.12: Elongation Index (Granite)

Elongation Index					
Size Fraction	Square Mesh Grading		Mass of fraction to be tested, M_2 (g)	Elongation Gauge	
	Mass Retained (g)	Percent Passing (%)		Mass retained by gauge (g)	Mass passing gauge (g)
28.0 – 20.0	96	4.84	- (discarded)	- (discarded)	- (discarded)
20.0 – 14.0	1102	55.63	1102	203	899
14.0 – 10.0	607	30.64	607	156	451
10.0 – 6.30	176	8.88	176	77	99
Total Masses, M_1 (g)	1981	100	ΣM_2 = 1885	ΣM_3 =436	1449

$$Elongation Index = \frac{\Sigma M_3}{\Sigma M_2} x100\%$$

$$= \frac{436}{1885} x100\%$$

$$= 23.1\%$$

4.2.4 Aggregate Abrasion Test (Granite)

Table 4.13: Result of Los Angeles Test

Los Angeles Abrasion Test					
			Test No.		
			1	2	Mean
Mass of aggregate retained on No.4 ASTM sieve	M_1	(kg)	5	5	
Mass of material passing No.12 ASTM sieve	M_2	(kg)	1.261	1.252	
Los Angeles abrasion value	$\frac{M_2}{M_1} \times 100\%$		25.22%	25.04%	25.13%

4.3. Marshall Mix Test

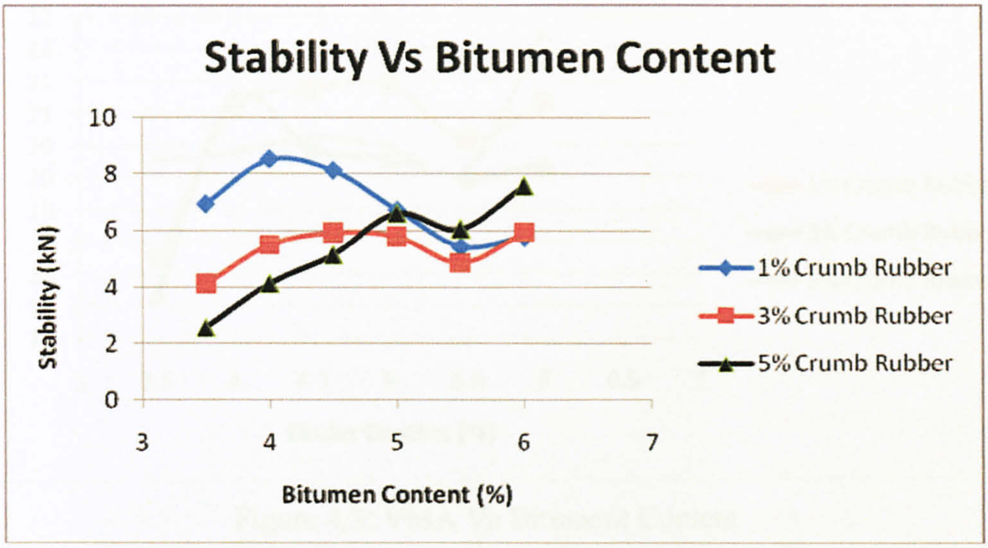


Figure 4.1: Stability Vs Bitumen Content

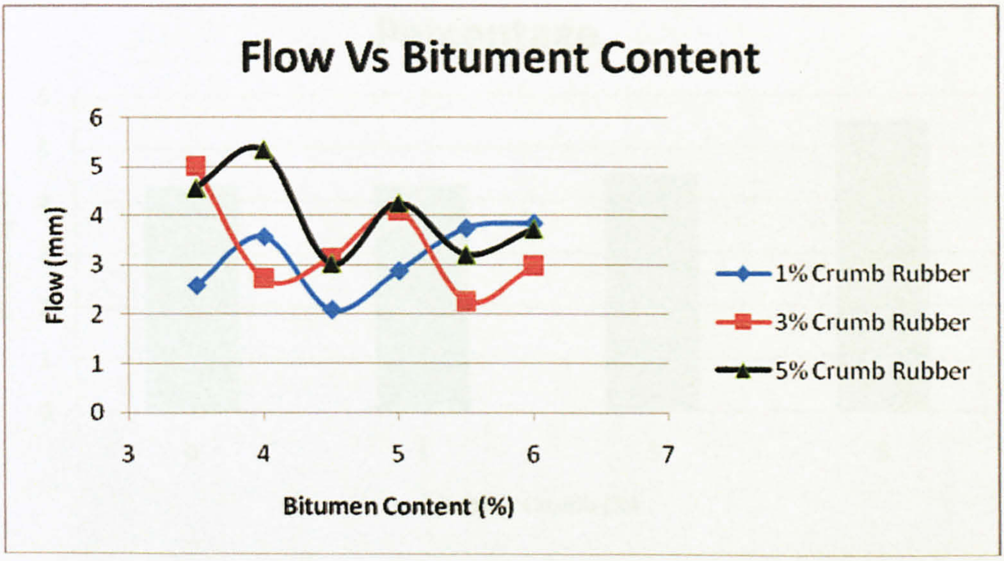


Figure 4.2: Flow Vs Bitumen Content

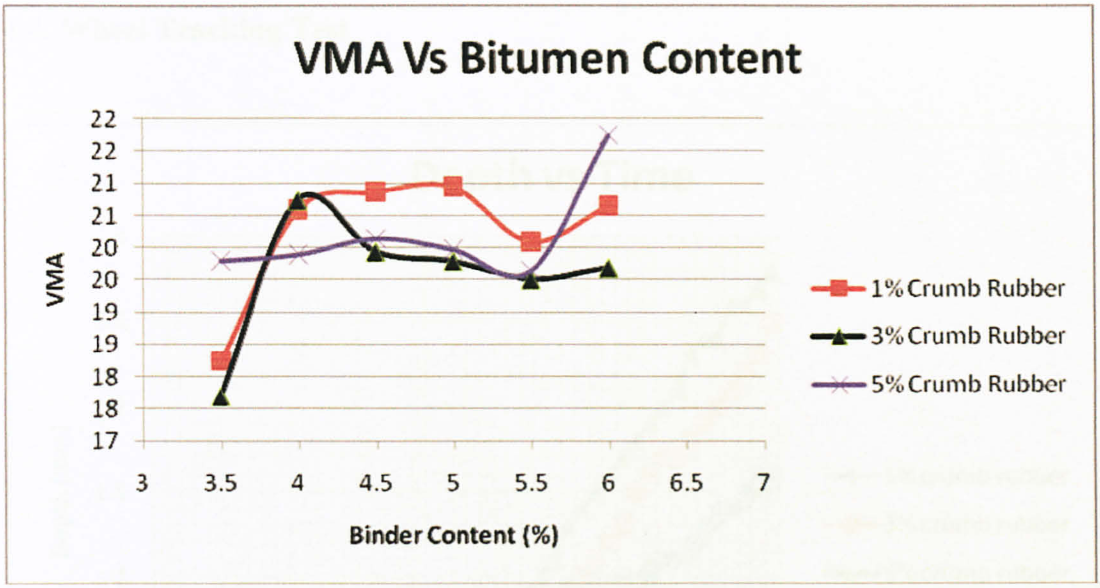


Figure 4.3: VMA Vs Bitument Content

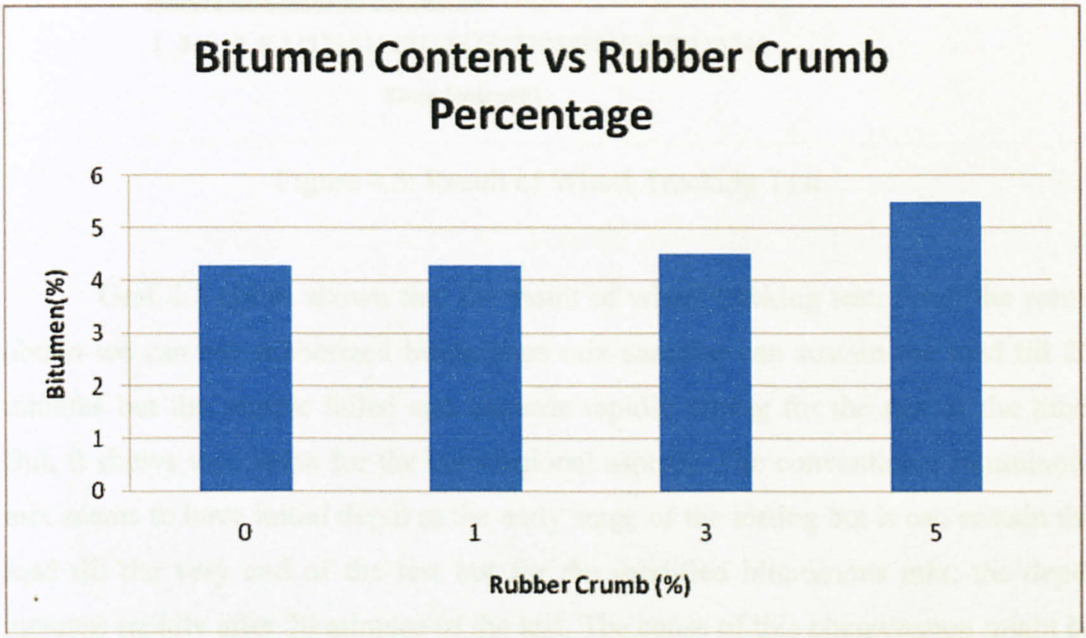


Figure 4.4: Bitumen Content Vs Percentage of Crumb Rubber

From Figure 4.1-4 we can see the result of marshal mix test ploted into graph and using the graph optimum binder content determined. Figure 4.4 shows the bitument content for every percentage of crumb rubber, for zero percent of crumb rubber, the percentage of optimum binder content is 4.3% and also apply for 1% of crumb rubber. For 3% of crumb rubber, 4.5 percent of binder needed and 5.5% of binder needed to bind 5% of crumb rubber.

4.4. Wheel Tracking Test

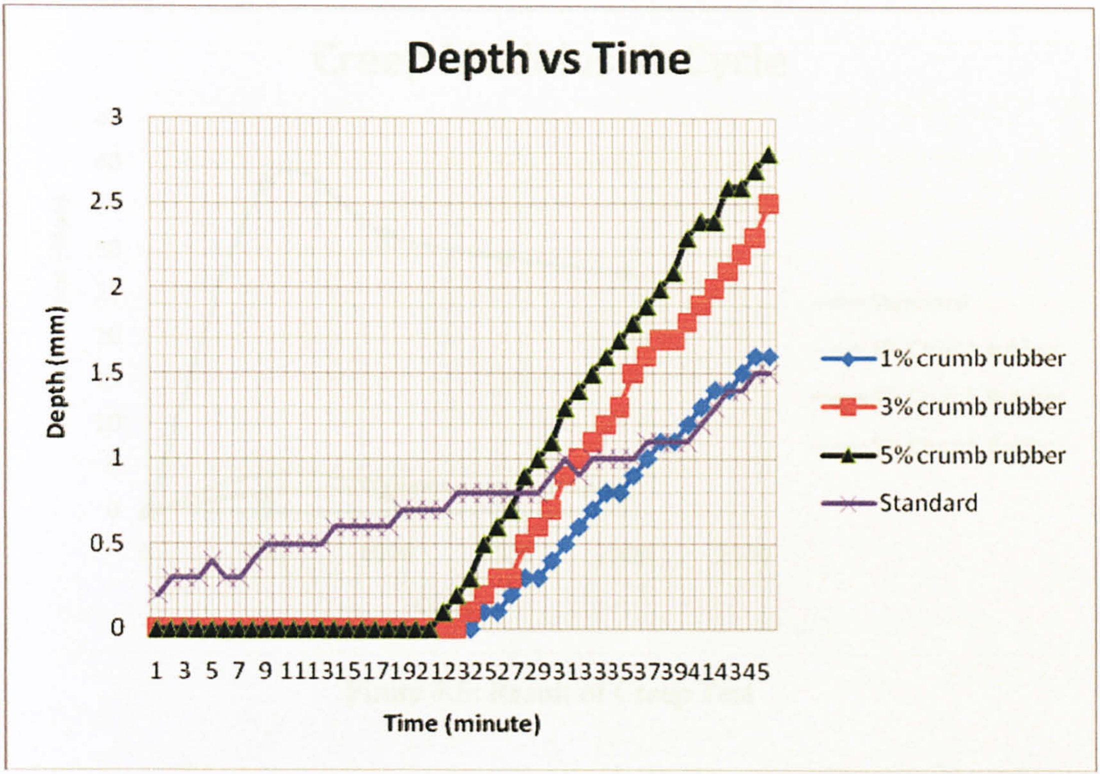
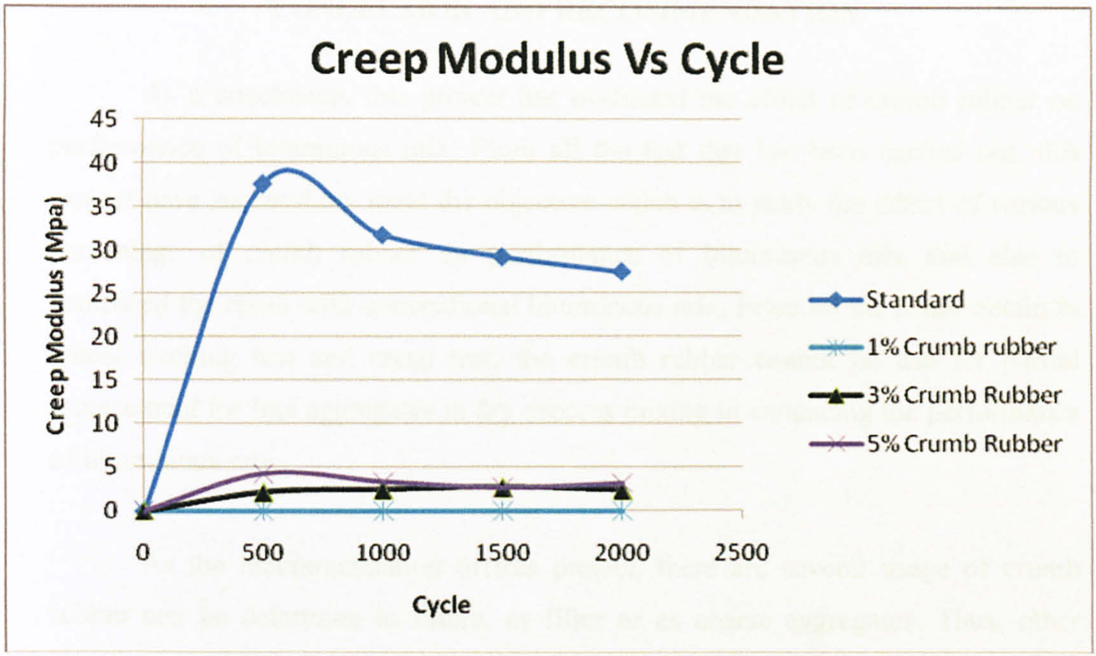


Figure 4.5: Result of Wheel Tracking Test

Graf 4.5 above shown that the result of wheel tracking test. From the result obtain we can see rubberized bituminous mix samples can sustain the load till 20 minutes but the sample failed and increase rapidly during for the rest of the time. But, it shows vice versa for the conventional asphalt. The conventional bituminous mix seems to have initial depth at the early stage of the testing but it can sustain the load till the very end of the test but for the modified bituminous mix, the depth increase rapidly after 20 minutes of the test. The cause of this phenomenon might be for the initial state the rubber can sustain the load but after 20 minutes the bond between the rubber with binder and others aggregates start to deteriorate and this promote to the deformation of the mix and then failed. For the various percentage of the crumb rubber addition, the higher amount of crumb rubber seems to promote the higher depth and deformation of the samples.

4.5 Creep Test



Firure 4.6: Result of Creep Test

Figure 4.6 shown the creep test result of for four samples including the standard sample. The result shown that the samples for rubberize bituminous mix fall far below from the standard samples. This shows that rubberize bituminous mix cannot withstand the constant load under constant temperature. The constant load under the constant temperature will result in deformation and also the sample failed after a certain periods. But for the unmodified bituminous mix, the samples can withstand the constant load till the very end of the testing. This shows that conventional bituminous mix can endure the load from traffic and constant temperature for the longer period of time rather than rubberized bituminous mix.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

As a conclusion, this project has evaluated the effect of crumb rubber on performance of bituminous mix. From all the test that has been carried out, this project have successfully meet the objective which is to study the effect of various percentage of crumb rubber on performance of bituminous mix and also to compared the result with conventional bituminous mix. From all the result obtain in wheel tracking test and creep test, the crumb rubber cannot be use for partial replacement for fine aggregates in dry process mixing in enhancing the performance of bituminous mix.

As the recommendation of this project, there are several usage of crumb rubber can be determine in future, as filler or as coarse aggregates. Thus, other experiment can be done in future to make benefit of crumb rubber in bituminous mix.

REFERENCES

1. Singh B, Tarannum H, Gupta M.J *Appl Polym Sci* 2003;90:1365-77

2. Soon Jae Lee, Serji N. Amirkhanian, Khaldoun Shatanawi 2006, Effect of Crumb Rubber on Aging of Asphalt Binder.

3. Marco Pasetto & Nicola Baldo 2002, Recycling of Tire Rubber in Porous Asphalts Using the Dry Process: Mechanical Characterization and Performance Evaluation of Mixes

4. Herda Yati Katman, Mohd Rehan Karim, Mohd Rasdan Ibrahim, Abdelaziz Mahrez 2005, Effect of mixing type on performance of rubberized porous asphalt

5. M. Hossain, M. Sadeq, L. Funk and R. Maag, a Study of Chunk Rubber from Recycled Tires as A Road Construction Material

6. Roberts, F. L., Kandhal P. S., Brown E. R., and Dunning R. L. (1989). Investigation and Evaluation of Ground Tire Rubber in Hot Mix Asphalt. National Center for Asphalt Technology, NCAT Report No. 89-3.

7. Sikora, M. (no date). Making Better Roads. [Online] Available from: http://www.tireindustry.org/features/better_roads.asp [Accessed 1st January 2009]

8. Samer Hassan Dessouky 2006, Multiscale Approach For Modeling Hot Mix Asphalt

9. Superpave 1997, Performance Grade Asphalt Binder Specification and Testing, 2nd Edition, the Asphalt Institute.

   Superpave Mix Design, Asphalt Institute, Superpave, Series No. 2, 3rd Edition, 2001.

10. Sennov,. V. A., 1987, Theory of use of granulated materials in road construction,

11. Aberg, B., 1996, Void sizes in granular soils , Journal of Geotechnical Engineering, ASCE,Vol. 122, No. 3, pp. 236-239.

12. Fuller, W. B., and Thompson, S. E., 1907. The laws of proportioning concrete, Transactions of ASCE, ASCE, Vol. 59, pp.67-143.

13. Brown Stephen 1990, The Shell Bitumen Handbook, Shell Bitumen UK