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PERFORMANCE OF WET MIX RUBBERISED POROUS ASPHALT

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Abstract: Incorporation of rubber to enhanced the properties of bitumen and bituminous mixes have been utilized extensively in developed countries for many years but its application within Malaysia is relatively recent and few in numbers. It is proven through research that incorporation of rubber to bitumen would improve the properties and strength of the bitumen and bituminous mixtures.

This paper presents the results of laboratory works using rubberized bitumen in porous asphalt. All the bituminous mixes were prepared using a wet process; the rubber additive was blended with bitumen before mixing the resultant rubberized binder with aggregate. Variation in percentages of rubber crumb and binder content were utilized in this investigation. The performances of the porous bituminous mixes were investigated by means of Cantabro Test on air cured samples, Cantabro Test on water soaked samples, Indirect Tension Test (Resilient Modulus), Falling Head Permeability Test on air cured samples and Falling Head Permeability Test on water soaked samples. Results obtained from this study indicate that the rubber content does have a bearing on the resistance to disintegration of the porous mix. Although the rubber component within the modified binder contributes towards aging resistance and increasing the binder viscosity as well as the binder film thickness, there appears to be a limit on the rubber content beyond which the adhesion on the aggregates began to be affected and the resistance to disintegration began to decrease.

Key Words: Porous Asphalt,Rrubberized Bitumen, Wet Mix

1. INTRODUCTION

1.1 Introduction

Based on the literature review, there are many attempts to improve the performance of asphalt pavement. Scientists and engineers are trying to incorporate many types of additives like rubber, polymer, glass fiber, mineral fiber and etc. into asphalt pavement to maximize the performance. One approach can be taken to improve the performance of asphalt pavement is by modification the bituminous binder.

Previous research showed that the inclusion of additives such as mineral fiber resulted in several additional improvements to the mix. Additives are generally used in porous asphalt to stabilize the asphalt cement (AC) film surrounding aggregate particles in order to reduce AC draindown during production and placement. Inclusion of additives permits greater AC contents. A certain interlocking occurred among the additives and between the coated aggregate particles. This phenomenon not only vastly improves bonding, but it significantly strengthens the mix and virtually eliminates AC draindown.

Research study by Texas Transportation Institute showed that rubberized asphalt performed well in construction practices, and that the rubberized asphalt mixes gives a higher durability with better stability than dense-grade mixes.

Fernando *et al.,* 1984, examined the affect of rubberized binder upon densification. Results showed that incorporation of rubber reduced the bleeding of fatting up in the road surface though exposed to high temperatures.

Many research studies showed that incorporation of rubber to asphalt pavement can reduce and mitigate the traffic noise. Mestre Greve Associates, in the report entitled Mixed Roadway Surface Noise, reported that inclusion of rubber to open graded pavement can minimize traffic noise, 3.9 dBA quieter than dense grade asphalt. The Societe des Autoroutes du Nord et de l'Est de la france, Paris conducted a study that showed a noise reduction of 2-3 dBA with rubberized asphalt along the Seine River. Finally, in Bonn, Germany a study showed that using rubberized asphalt as a sound mitigation measure is more cost effective than using sound barriers. Most of this study concluded that rubberized asphalt could reduce noise by 2-3 dBA with few technical problems.

Lundy *et al.,* 1993, wrote three case study using crumb rubber with both the wet process and dry process at Mt. St. Helens Project, Oregon Dot and Portland Oregon. The results showed that crumb rubber product have excellent resistance to thermal cracking and perform very well after nearly 10 years of service.

Rubber asphalt mixtures can be built successfully, but need maintaining quality control. Literature review showed that asphalt rubber mixtures have higher costs rather than conventional asphalt paving materials. This is due of increased binder content, addition of rubber, increased energy requirements due to elevated temperatures and extending mixing time, additional plant personnel/equipment for handling and blending, and additional personnel/equipment at the construction site.

Porous asphalt was appreciated for its improvement in wet weather driving conditions by allowing the water to drain through its porous structure. Porous asphalt is designed to form a pavement mixture with a void content (usually more than 20 percent) that would enable rainwater to evacuate through a system of interconnecting voids. The improved surface drainage reduces hydroplaning, reduces splash and spray behind vehicles, improves wet pavement friction, improved surface reflectivity and reduces traffic noise. Besides the superiority offered by porous asphalt, it also has major problems namely raveling and stripping of the asphalt course. The major causes of raveling are believe to be inadequate asphalt binder film thickness, excessive ageing of binder and loss of asphalt-aggregate adhesion under extreme conditions. Porous asphalt also faces a problem of binder drain down during storage and transportation, also a problem of clogging of voids by deicing materials or other debris.

2. LABORATORY INVESTIGATION

2.1 Materials

The materials used in this research are bitumen with 80/100 penetration, rubberized bitumen, aggregates with porous gradation and Portland cement filler. Porous gradation used in this research is shown in Figure 1.

2.2 Experiments

The performance parameters studied are:

1. The air void content (ASTM D 3203-91)
2. The resilient modulus (ASTM D 4123)
3. The air abrasion loss (BS EN 12697-17:2004)
4. The water abrasion loss (by means of the Cantabro Test on water soaked samples)
5. The permeability on air cured samples (by means of the Falling Head Permeability Test on Air Cured Samples)
6. The permeability on water soaked samples (by means of the Falling Head Permeability Test on Water Cured Samples)

2.3 Sample preparation

Rubberized bitumen was prepared by mixing 80/100 penetration-grade bitumen with various percentages of fine grain rubber crumbs passing 40-mesh sieve. Four levels of rubber content were used, namely 3%, 6%, 9% and 12% by weight of bitumen. The rubber crumbs modified bitumen was prepared using propeller mixer. Mixing was done at temperature of 160^{o}C and speed of 150 rpm. The mixing time was for one hour.

Bituminous mixes were prepared by wet process, in which, rubber additives was blended with bitumen before mixing the resultant rubberized bitumen with aggregate. The hot aggregates (porous graded aggregates) and filler was mixed with rubberized bitumen. The filler content is 2% by weight of mix. The binder content in the mixture was varied between 4.0%, 5.0% and 6.0%.

Specimens were prepared using a Marshall compactor. The number of compaction was 75 blows for each side of the specimens. The temperature for mixing the aggregates with rubberized binder was between 160 to 180°C while the compaction temperature was 140°C.

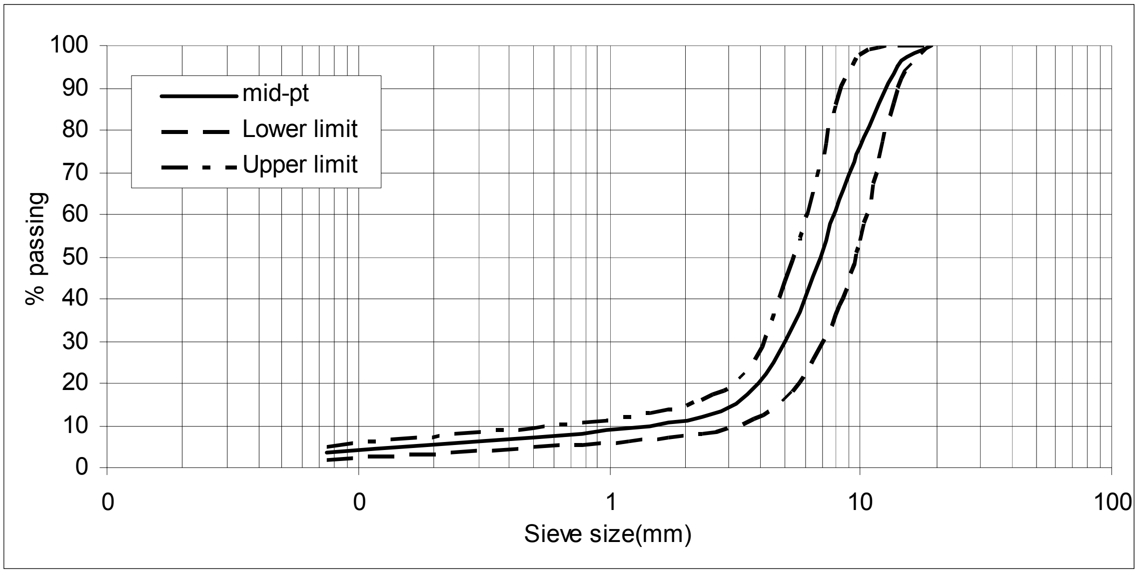

Figure 1. Aggregate Gradation for the Porous Asphalt

2.4 Tests Method

2.4.1 Permeability Test on Air Cured Samples

The specimens were tested before extrusion taking advantage of the tight bond between the bituminous mix and the mould. A water permeability based on the falling head principle was used to quantify the coefficient of permeability.

2.4.2 Permeability Test on Water Soaked Samples

Testing procedure is the same as the Permeability Test on Air cured Samples. However samples were conditioned by immersing in the water at 25°C for 2 hours.

2.4.3 Cantabro Test on Air Cured Samples

Cantabro Test on air-cured samples was used to measure the resistance of the mixes to raveling. The initial weight of the Marshall specimen was recorded. Specimen was placed in a Los Angeles Machine (ASTM Method C131) without the steel balls. The total number of rotations considered in this research was three hundreds. Test performed at temperature of 25°C and speed of 30 to 33 rpm.

2.4.4 Cantabro Test On Water Soaked Samples

Cantabro Test which performed on water soaked samples was to evaluate the resistance to stripping of the mix.

In this test the initial weight of the Marshall specimen was recorded. Then, the samples were placed in a water bath at 49$\pm$1^{o}C for four days. On the fifth day the samples were taken out of the bath and allowed to drain for 18 hours. Using Los Angeles Machine (ASTM Method C131) testing procedure conducted was similar to the Cantabro test on air cured samples.

2.4.5 The Resilient Modulus Test

The resilient modulus was determined for the different rubber-modified asphalt mixes following ASTM D-4123. The test was performed using MATTA equipment at 25^{o}C.

3. RESULTS AND DISCUSSION

3.1 Voids in the Mix (VIM) Results

Figures 2 and Figure 3 show the effects of binder contents and the rubber contents on the VIM. Figure 2 shows the decreasing of VIM as the binder content increases, which is as expected. This is due to the presence of large quantity of binder, which filled the voids between the aggregates. Therefore, the amount of void in the mix decreased.

Figure 3 shows that the VIM increases with the increase of rubber content in the mix. This is because the high amount of rubber absorbs the binder, which is needed to coat the aggregate. This process results in the samples being inadequately coated with binder, thus resulting in voids between the aggregates. This would reduce the contact points between the aggregates and increase the voids. The nature of rubber that can expand when mixed in the bitumen also causes the voids increment in the mix.

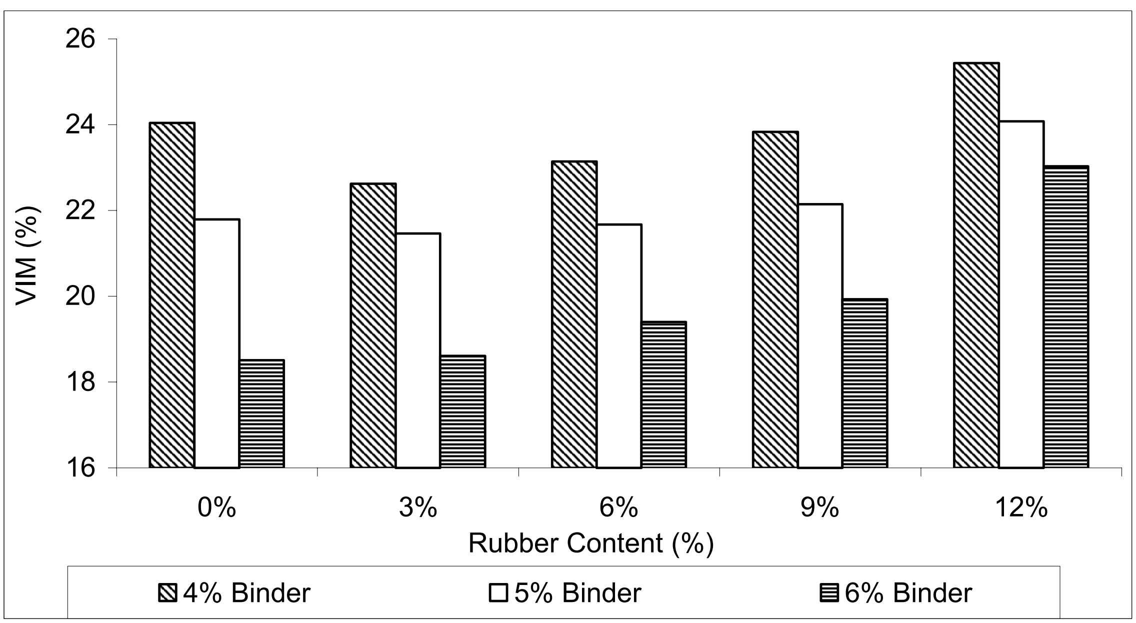

Figure 2. Voids in the Mix for Different Rubber Contents

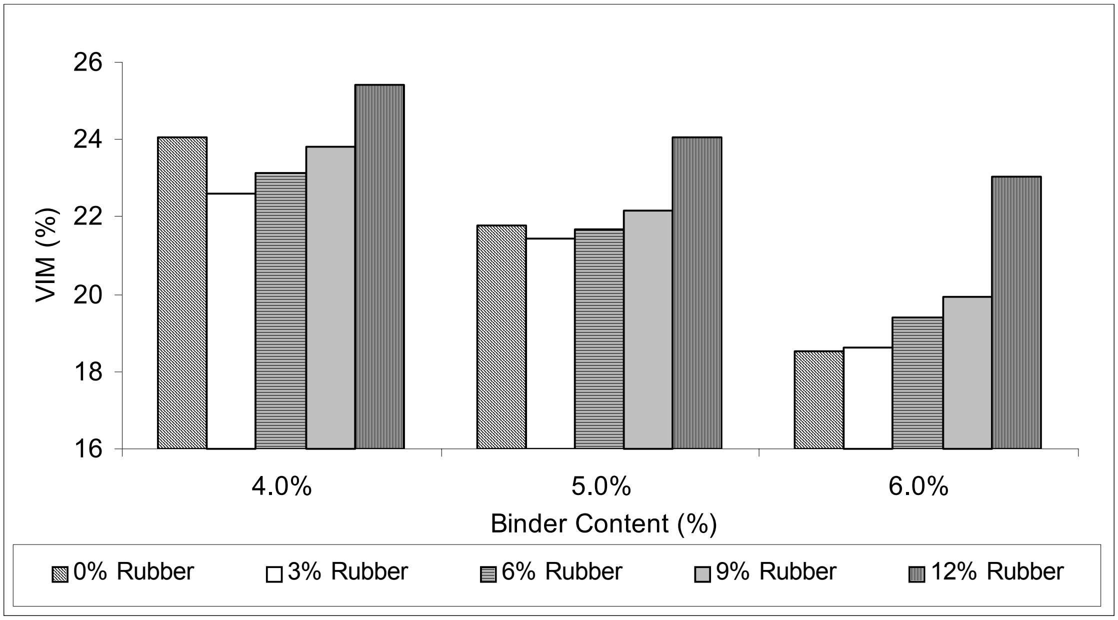

Figure 3. Voids in the Mix Results for Different Binder Content

3.2 Resilient Modulus Results

The results of resilient modulus are shown in figures 4 and 5. Figure 4 shows that for each rubber content the resilient modulus decreases as the binder content increases. On the other hand, Figure 5 shows that at any binder content there is no clear relationship between resilient modulus and rubber content.

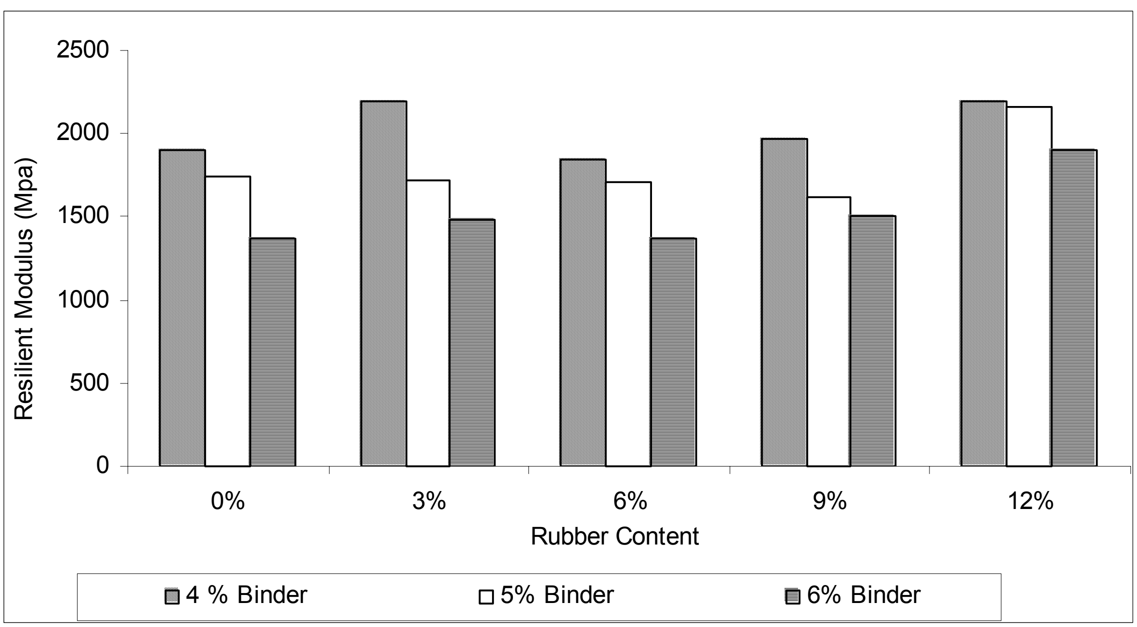

Figure 4. Resilient Modulus Results for Different Rubber Content

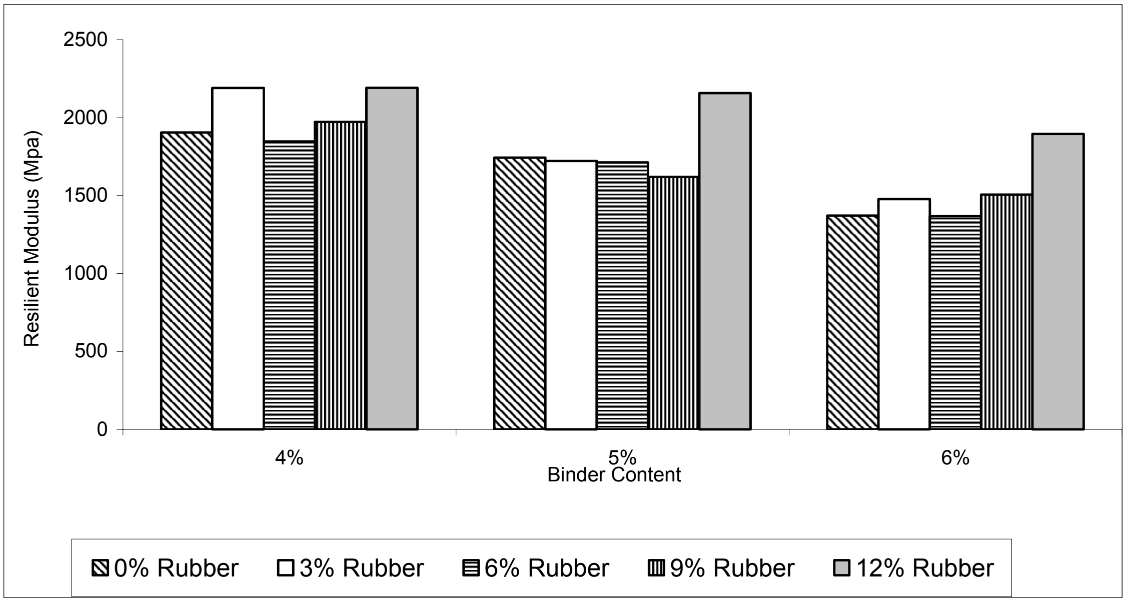

Figure 5. Resilient Modulus Results for Different Binder Content

3.3 Abrasion Loss – Air Cured Samples

The results of the Cantabro Test at 300 revolutions on air cured samples are shown in Figure 6 and Figure 7. Figure 6 shows a decrease of abrasion loss as a binder contents increase. This result was expected because high amount of binder contents improved mix cohesion and hence improves the resistance to tensile stresses.

Figure 7 shows that the abrasion loss increases as the rubber contents increases. Samples with low binder contents (4% binder) shows a high increment of abrasion loss as the rubber contents increase, while samples with high binder contents (5 % and 6%) shows low values of abrasion loss.

According to Flaherty, 2002, the accepted appropriate limit for abrasion loss value for porous asphalt is 25% at 25^{o}C testing temperature. Whereas, the limit value for the abrasion loss suggested in a Spanish study is 30% at 25^{o}C testing temperature (Zoorob *et al.,* 1999).

In this study, the limit value for the abrasion loss is taken as 30%. The result shows, sample with lowest binder content and highest rubber content (4% binder & 12% rubber) was exceed the limit of abrasion loss. This is because the small amount of binder was not enough to coat the aggregates; hence reduce the cohesion between the aggregate. The ability of rubber that can swell and absorb the binder also reduces the amount of binder.

3.4 Abrasion Loss – Water Cured Samples

The results of the Cantabro Test at 300 revolutions on water-cured samples are shown in Figure 8 and Figure 9. Figure 8 shows the abrasion loss decrease when the binder content increases.

Figure 9 shows that the abrasion loss increases as the rubber content increases. All samples with respective percentages of binder contents show the same results.
According to Isabella Skvarka, 1996, the maximum permissible water abrasion loss value is 40%. In this test, many samples exceed the limit. From the results, it shows that water is a serious factor in effecting the performance of the mixes.

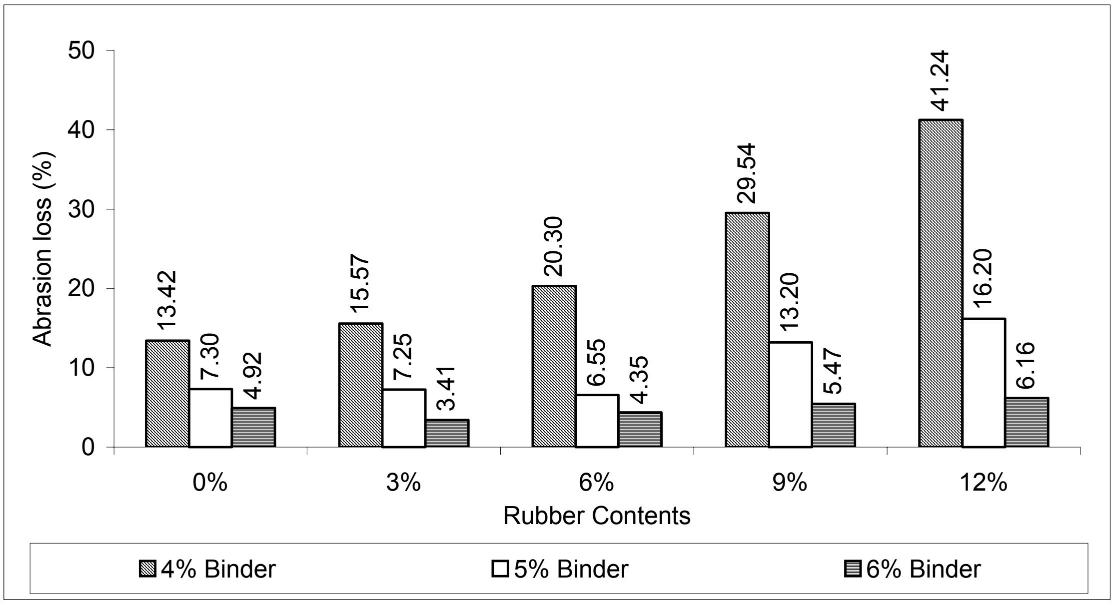

Figure 6. Air Abrasion Loss Result at 300 Revolutions for Different Rubber Contents

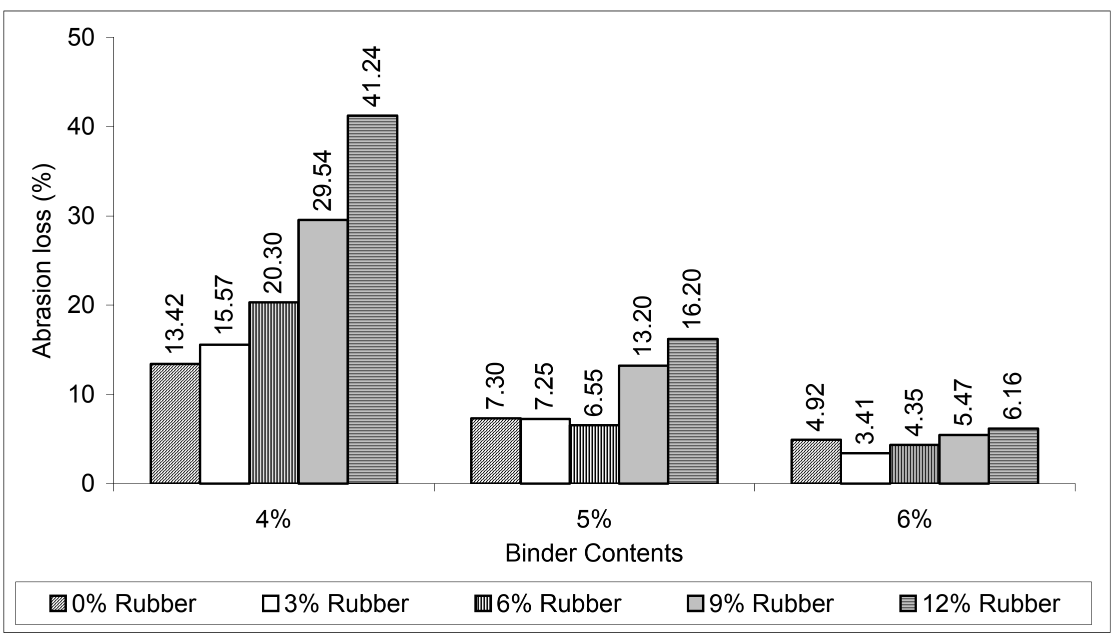

Figure 7. Air Abrasion Loss Result at 300 Revolutions for Different Binder Contents

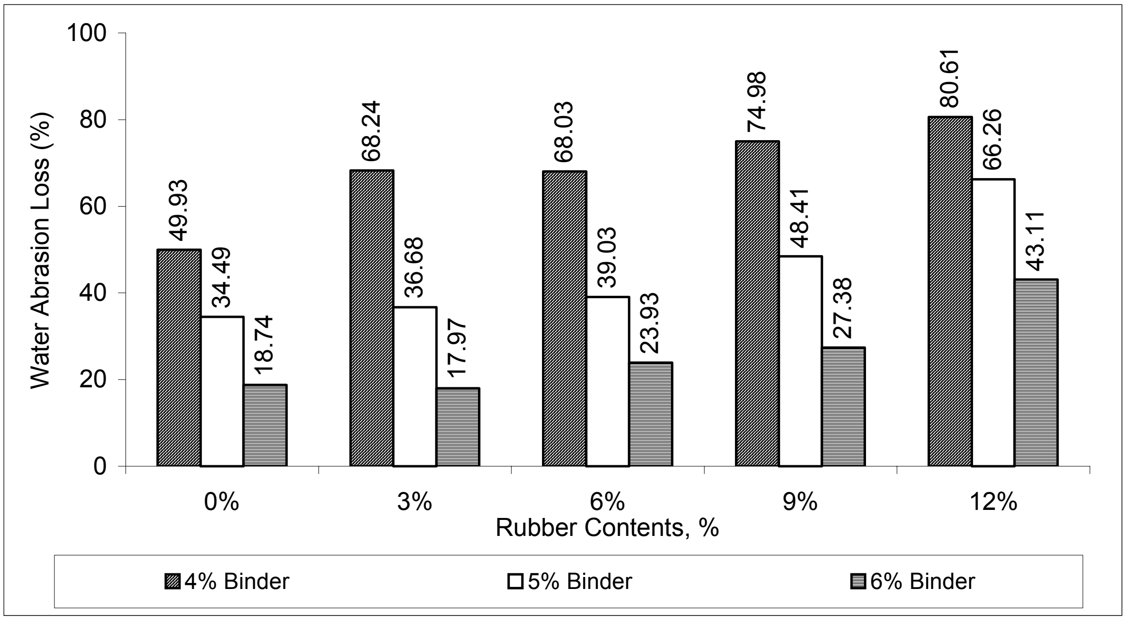

Figure 8. Water Abrasion Loss Result at 300 Revolutions for Different Rubber Contents

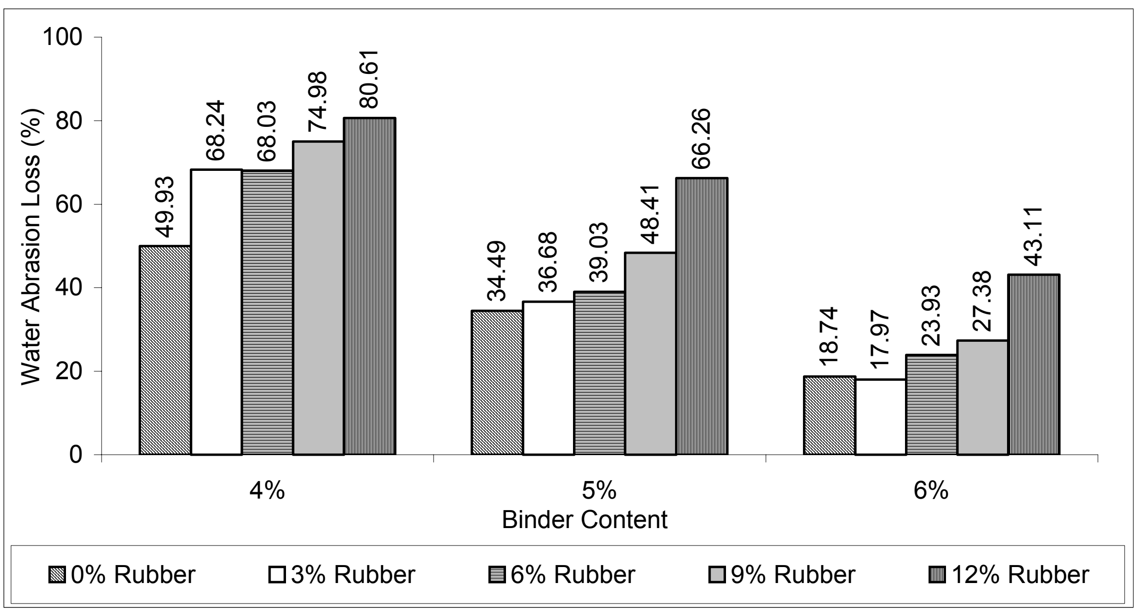

Figure 9. Water Abrasion Loss Result at 300 Revolutions for Different Binder Contents

3.5 Falling Head Permeability Test Result on Water Cured Samples

The permeability coefficients on water-cured samples are shown in Figure 10, 11 and 12. Figure 10 shows that at any specific rubber content in the mix, the permeability coefficient decreased as the binder content increase. This happens due to the excess bitumen filling the air voids and clogging some of the interconnected pores.

The permeability coefficient results in Figure 11 shows inconsistent trend. Therefore, incorporation of rubber into mixes does not affect the permeability. Previous research showed that permeability is a function of voids continuity in the mix.

Figure 12 shows the relationship between permeability coefficients and void contents in the mix. Results show that the permeability coefficient increased as voids contents increase. This confirmed previous research results which shows that water drainage is a function of both the quantity and distribution of voids present in the compacted material (M.O.Hamzah *et al.,* 1997)

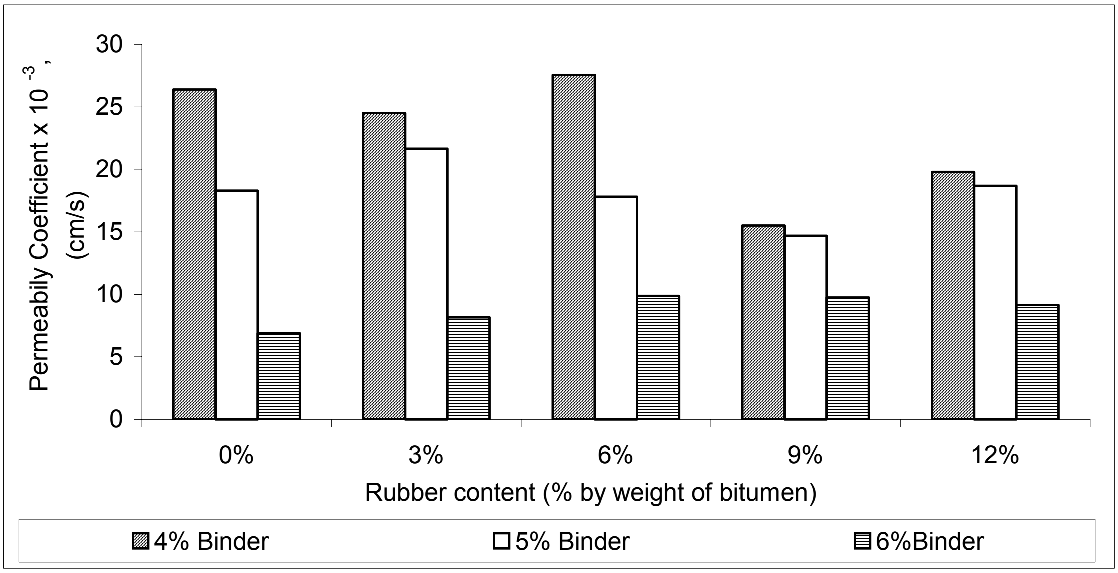

Figure 10. Falling Head Permeability Test Result on Water Cured Samples for Different Rubber Contents

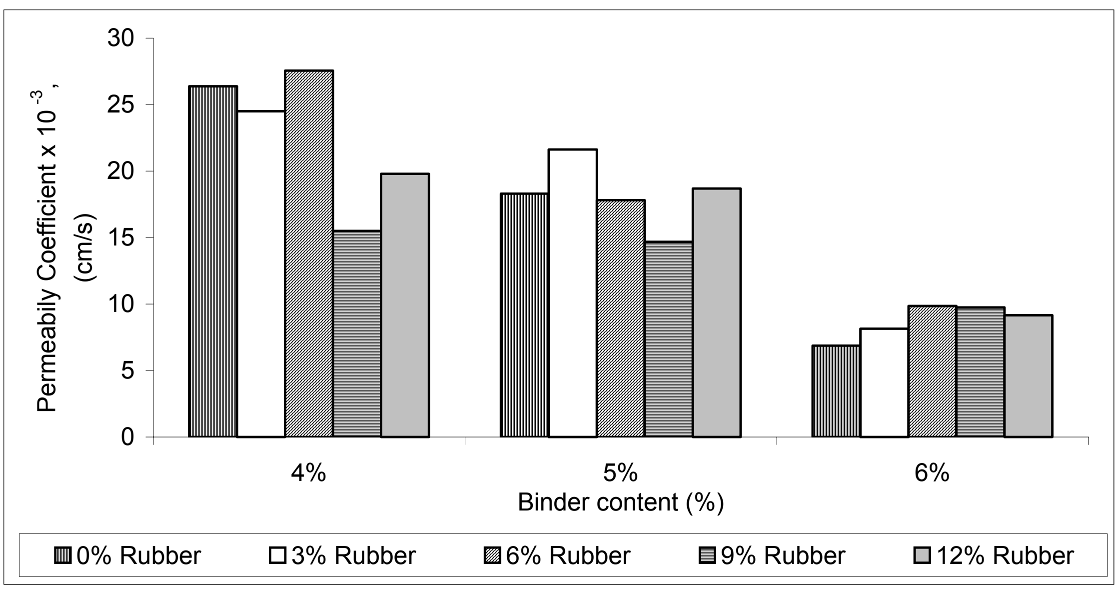

Figure 11. Falling Head Permeability Test Result on Water Cured Samples for Different Binder Contents

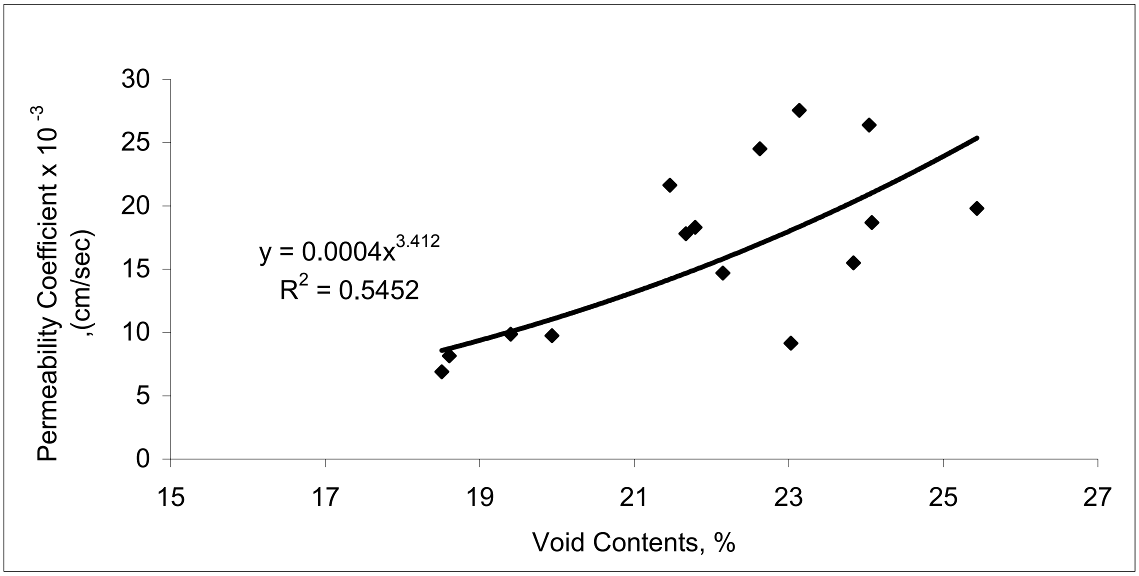

Figure 12. Falling Head Permeability Test Result on Water Cured Samples for Different Voids Content

3.6 Falling Head Permeability Test Result on Air Cured Samples

Results shown in Figure 13 and Figure 15 are almost similar with results on Falling Head Permeability Test on Air Cured Samples. Figure 13 shows a decrease on permeability as the binder contents increases, while Figure 15 shows an increase in permeability coefficient as voids content increases.

Generally, Figure 14 shows that the permeability coefficient decreases as rubber content increases.

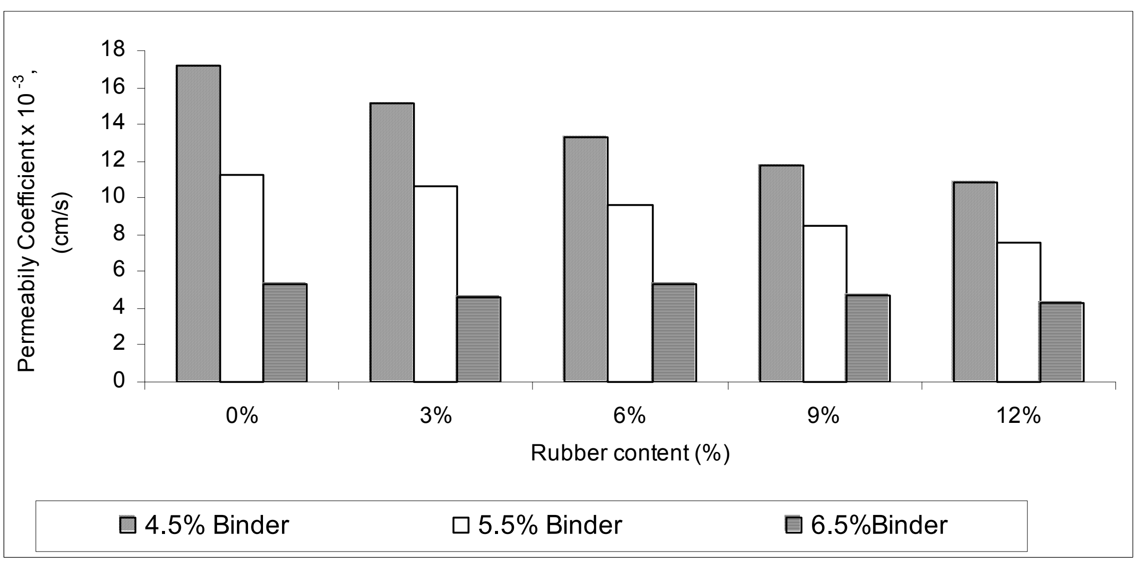

Figure 13. Falling Head Permeability Test Result on Air Cured Samples for Different Rubber Contents

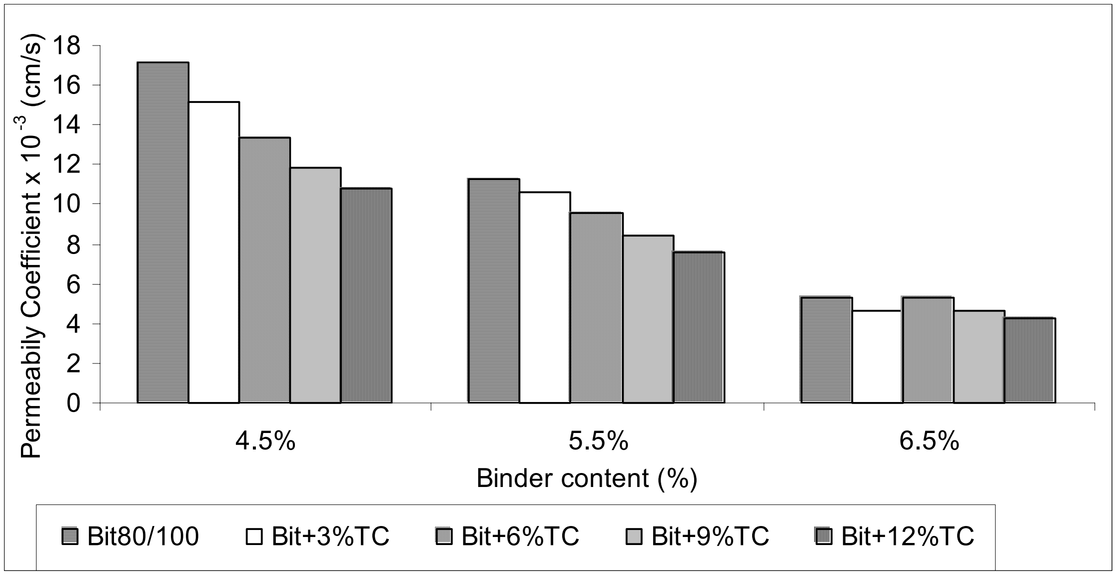

Figure 14. Falling Head Permeability Test Result on Air Cured Samples for Different Binder Contents

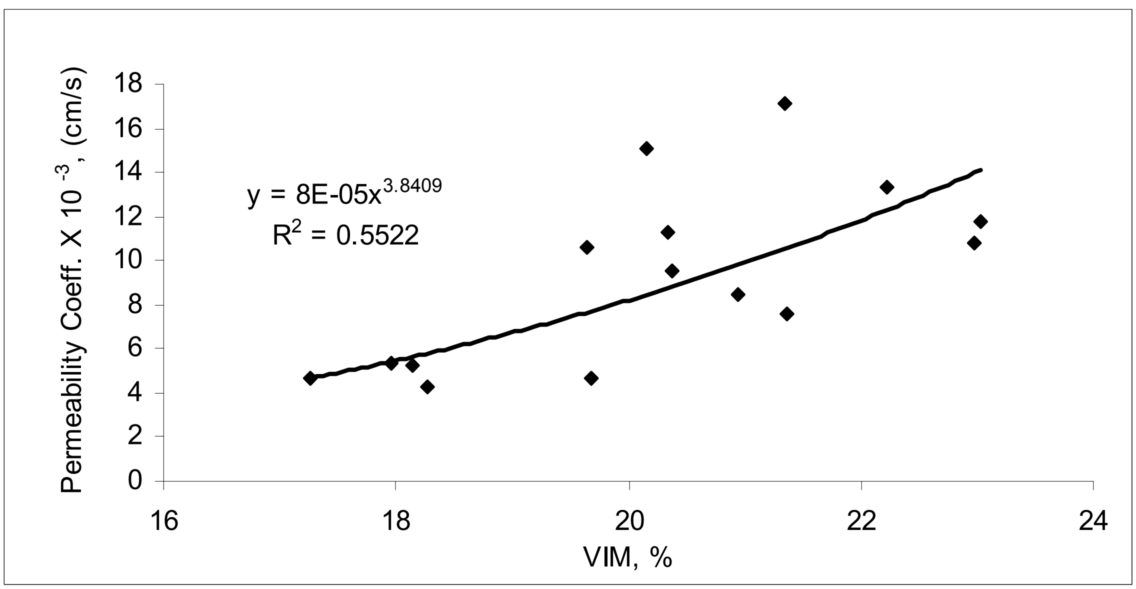

Figure 15. Falling Head Permeability Test Result on Air Cured Samples for Different Void Contents

4. CONCLUSIONS AND FUTURE WORK

The use of rubber shows varies results, some of the results appear to indicate an improvement of the property of the mix and some are not.

This study shows that the incorporation of rubber to bituminous mixes increase the abrasion loss both in air-cured samples and water-cured samples. This is due to the reduction in the

wetted aggregate surface by the bitumen. Rubber absorbs the binder that needed to coat the aggregate. Therefore incorporation of rubber does not improve the raveling resistance and stripping resistance.
Many literature reviews showed that incorporation of rubber to bituminous mixes improved the resilient modulus. However, in this study the resilient modulus results are quite inconsistent and do not show a clear trend.

Results on Falling Head Permeability Test on water-cured samples are also inconsistent. Therefore, the amount of rubber added into the mixes does not necessarily affect the water permeability. This result is expected because previous research shows that water drainage is a function of voids continuity and quantities of voids present in the bituminous mixes. This study shows that the quantity of voids contents affect the permeability; the permeability coefficient increases as a voids contents increases.

Falling Head Permeability Test on air-cured samples results shows the permeability coefficient decreases as rubber content increases. It seems that large amount of rubber present in the mixes fills the airs voids and disturb the voids continuity, thus decrease the water permeability.
Water is a serous factor affecting the performance of porous rubberized mixes, since water increases the stripping process experienced by the binder, the durability of the mixes is reduced. The comparisons between air abrasion loss and water abrasion loss results support this fact.

Although incorporation of rubber into bitumen and bituminous mixes to enhance the properties have been utilized extensively for many years in developed countries, its use in Malaysia is only recent and few in numbers. Therefore, it needs many research works to enhance the potential of employing rubberized asphalt pavement.

The following works can be done to see the effect of rubber both in bitumen and bituminous mixes:

1. Different methods to prepare bituminous mixes can be done for the future works. In the dry process, rubber additives are blended with the hot aggregates before adding the bitumen or the rubber additives are added after the hot aggregates are coated with bitumen. The types of mixing perhaps contribute to the difference of properties of the bituminous mixes since rubber has a different chemical reaction in both processes.

2. Different types of mixer to prepare the rubberized bitumen also perhaps have a potential effect in the bituminous properties. Literature review shows that the properties of rubberized bitumen prepare by high speed shear mixer are better then properties of rubberized bitumen prepare by propeller-type mixer (Karim *et al.,* 1997). Both types of mixer affect the bitumen properties as well as rubber distribution in bituminous mixes.

3. The effect of rubberized asphalt can be tested on different types of aggregate gradations such as SMA and ACW. The effect of rubberized bitumen in coarser porous gradation also can be examined as a future research.
4. An investigation on optimum binder content and the optimum rubber content is needed. Addition of rubber to bituminous mixes requires a slight increase in the

optimum binder content; which is significant to provide an optimum film thickness. Optimum rubber content is needed to provide the strong adhesion on the aggregates thus increased the resistance to disintegration.

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