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Field performance of asphalt pavement maintenance using Cup Lump Rubber Modified Asphalt (CMA)

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Abstract. It was typical in Malaysia that pavement failures at high stressed area were due to the bituminous layer aging subjected to extreme long loading times by the slow moving of heavy commercial vehicles. This scenario causes major structural deteriorations and permanent deformation of the bituminous road surfacing. In order to fix this problem, the used of Polymer Modified Asphalt (PMA) in asphalt mixture to form PMA mixtures was selected as an alternative method to increase the durability and lifespan of the pavement. PMA had been observed for a long time in improving the performance of asphalt pavement and increase the pavement lifespan. Although, it significantly improves the quality of the asphaltic layer and prolongs the life of the pavement, the construction cost was very high. Cup lump rubber was referred to the natural rubber in frozen form and it had been used as an additive in the conventional asphalt to produce cup lump modified binder (CMB). The mixture of cup lump modified binder with aggregates will produce the cup lump modified asphalt (CMA). Recently, Public Work Department of Malaysia and Malaysian Rubber Board recently had been conducted a field study at several locations to identify the benefits and CMA levels of performance as well as the constructability of the CMA pavement in actual field site. The monitoring and testing elements in this research were including mix design, construction methods and performances monitoring. The results have been showed that the performance of CMA was not shown significant improvement as compared to conventional asphalt section after six-month construction. From the result, it was noted that the longer observation period was needed to identify the actual field performance of cup lump asphalt pavement compared to the conventional asphalt pavement.

1. Introduction

There are three modes of asphalt pavement failure which are fracture, distortion and disintegration [1]. Fracture normally occurs in thick bituminous layers in form of cracking due to excessive loading repetition or age hardening. Distortion manifests itself in any of the pavement layers and will normally appear on the bituminous surface as netting or other forms of deformation due to excessive loading creep densification or consolidation moisture change. Disintegration will normally take place on the bituminous surfacing in form of stripping and ravelling due to lack of adhesion chemical aggression or abrasion by traffic degradation of aggregate [1]. Each component of the pavement layers may contribute to failures. The most difficult task is to identify which layer is the cause of primary failures of the road. Extensive research has established the various mechanisms that cause road failures. Some common mechanisms are repeated axle loading, excessive loading, thermal and moisture changes, material



densification, abrasion by traffic and also hardening of the asphalt. Due to this common pavement failure issue, it was noted that the quality of asphalt need to be upgrade to increase the pavement life span.

Most of the Malaysian roads are built using the conventional hot mix asphalt (HMA) technology. The process of producing the HMA involves heating the asphalt to a high temperature of 160/170oC before mixing with the aggregate, the basic hot mix asphalt concrete is composed of two components, asphalt and aggregate [2]. The additional polymer into the asphalt mix may reduce the binder penetration and increase the softening point which also increases the dynamic viscosity of the binder at midrange temperature and decreases the kinematic viscosity at high temperature [3,4].

There are an alternative to of PMA in asphalt mixture to increase the structural strength and durability of the asphalt pavement. PMA was practically effective to improve asphalt performance and increase the pavement lifespan. Although, it has significantly improved the quality of the asphaltic layer and prolongs the life of the pavement, the construction cost was very high. Conventional asphalt modifications with additives could become an alternative way to save asphalt source by improve the quality of asphalt mix so that it can be lasting longer at field. In this respect, there have been some recent natural rubber attempts to expand its applications into more productive way against the limitation on its content through combination with asphalt [5].

Rubber industry in Malaysia has developed through the innovation of rubber used and the application of new exploitation, processing, and manufacturing technologies. Nowadays, the Malaysian rubber industry has evolved through the years and has transformed itself into a more integrated industry where the rapid developments of the mid- and downstream industries have made the industry fast booming. Through innovation, the used of rubber was extended to more complicated usage such as using as an additive in asphaltic mixes.

The use of recycled tire rubber is very common throughout the world. The need to adopt rubber in the construction of the roads are mainly to utilize the recycled rubber, minimizes the environment pollution and diversify the used of rubber in the road construction industry. Rubber modified asphalt is used for the prolongation of asphaltic concrete life. Varies studies are being carried out to improve the quality of bituminous asphalt mixes using polymer additives. One of the alternatives is using rubber either natural rubber, synthetic rubber or crumb rubber in asphalt pavement applications. The first application of rubberised asphalt using crumb rubber in bituminous roads in Malaysia was carried out as part of the 1 km Rembau-Tampin experimental trial in 1993 which also incorporated natural rubber latex and rubber powder from rejected gloves. In 1996, another 3-km trial stretch was carried out at Sg Buloh which only crumb rubber was incorporated. While the controlled sections required resurfacing, this stretch requires only minor repair work after more than eight years in service. However, both the Rembau and Sg Buloh trials lack of systematic long-term performance data and therefore no conclusive inference can be obtained from these trials [6]. In July 2003 Malaysian Rubber Board (MRB), JKR and IKRAM Sdn Bhd jointly carried out a resurfacing work of 4-km stretch Route FT02 near Kuantan where crumb rubber was used in both the dense and porous mixes. In 2010, another stretch of 0.6km was constructed in Bukit Kuantan which only crumb rubber was incorporated. The performance of the road evaluated is satisfactory as no major maintenance has been carried out until now. One of the case studies using waste rubber powder as a asphalt additive was concluded that the waste rubber powder has a high impact on reducing rut depth on asphalt mixtures at different temperatures and stresses. It also showed that asphalt mixtures containing 10% waste rubber powder have better performance at higher temperatures [7]. In those early days, the forms of rubber which were available for incorporation into the binders were [6]; (i) Latex. Extract from rubber trees which was concentrated and stabilised in various ways. Available in two forms, evaporated and centrifuged; (ii) Sheet rubber. Made from coagulated latex; (iii) Rubber powder. Made either by spray-drying the latex or by hammer-milling lightly vulcanised coagulum to form a crumb. Available in several forms such as Pulvatex, Mealorub, Harcrumb or Rodorub; and (iv) Ground tyre-tread. Waste tyres ground into a powder.

In this study, a new evaluation of the use of natural rubber as asphalt modifier will be conducted. The natural rubber modifier is likely to be the crepe rubber which derived from the cup lump rubber. Cup lump rubber was referring to the coagulated material found in the collection cup when the tapper next

visits the tree to tap it again. It arises from latex clinging to the walls of the cup after the latex was last poured into the bucket, and from late-dripping latex exuded before the latex-carrying vessels of the tree become blocked. It is of higher purity and of greater value than the other three types. The cup lump will be used in this study as an alternative to crumb tire and latex as an additive to asphalt mixture which is said to give similar benefits. The rubberized asphalt materials to be used in this research will be as follow:

i. Cup lump rubber

Cup Lump is a blanket crepe rubber from the dries films and lumps of rubber found in the tapping cups at the beginning of the next tapping. Cup Lump is more accessible for the rubber taper as it does not require complicated processing than the rubber sheets and rubber latex [8]. The rubber liquid or latex from the tapped rubber trees will be collected into cups in order to prevent it from flowing into other parts of the tree. The latex in the cups was kept for a certain period of time until itself coagulated or adding formic or acetic acid to quicker turn it to cup lump [9].

ii. Bituminous Cup lump (BC)

Bituminous cup lump is produced by the mixture of cup lump and asphalt in form of rubber master batch at certain rubber and asphalt ratio. Bituminous cup lump will be added into the conventional asphalt as an additive at a certain amount.

iii. Cup lump Modified Binder (CMB)

Asphalt modified by the addition of bituminous cup lump (BC) into the asphalt. The Bituminous cup lump is added into the asphalt at a certain temperature to produce a homogenous and uniform mix of cup lump modified asphalt prior to mixing with the aggregates. The production of CMB is as shown in Figure 1.

iv. Cup lump Modified Asphalt (CMA)

The mixture of cup lump modified binder with aggregates will produce the Cup lump Modified Asphalt or CMA. Yearly, Public Works Department of Malaysia (JKR) spends on average of RM 3.9 billion on works related to state road maintenance of 197,000 km of existing roads throughout Malaysia in 2015 [10]. It is obvious that the government would make a considerable saving if the roads are durable and free from premature defects such as rutting and cracking. It is said that the service life of roads could be increased and their maintenance cost reduced by incorporating rubber in bituminous roads. This economical technique such as adding crumb rubber from a used tire and used glove has been reported to be proven effective and has been used for more than 25 years in the United States.



Figure 1. The procedure of Cup Lump Modified Asphalt (CMA).

The main advantages of incorporating rubber are to increase crack and rutting resistance of the roads and hence prolong their service lives as well as reducing the maintenance cost. A study was found that rubber modified asphalt using crumb rubber in dry process resistance may resulted in cracking and rutting by significant decreasing the penetration values for modified binders, indicating the improvement in temperature susceptibility resistant characteristics. As a result, it also accomplishes the addition of crumb rubber in asphalt mixture using dry process will affect the mix design and its rutting resistance [11]. The Marshall properties obtained has shown that the stability and stiffness of the asphalt mixture are reduced after the addition of the crumb rubber due to its elasticity [12].

JKR is concern about the quality and performance of the roads after the construction. There is the innovative approach adopted to improve the quality of the road by using polymer modified asphalt (PMA) in road construction. It significantly improved the quality of the asphaltic layer and prolongs the life of the pavement but the construction cost may increase. The use of natural source such as rubber is said to be an alternative to reduce the cost of modified asphalt without sacrificing the quality of the road. It is hoped that the result of this research will provide the road authorities with clear reference as to the benefit and limitations of using cup lumps rubber as an additive in road pavement construction. Thus, the objectives for this research are to evaluate the properties of cup lump modified asphalt (CMA), to determine the properties of cup lump modified asphalt (CMA) design mix and to compare the performance of cup lump modified asphalt pavement with the conventional asphalt pavement.

This paper generally discusses the experience of using cup lump rubber as an additive in asphalt mix in the existing roads maintenance project since the conventional asphalt mix was the most typically used in Malaysian road construction and maintenance projects. The initiative of using cup lump rubber as an additive in asphalt mix was initiated by Malaysia Rubber Board (MRB) due to the decreasing of natural rubber price especially cup lump rubber. The proposal was brought to the Public Works Department and the Memorandum of Agreement (MOA) was signed in the year 2015. The main objective of the MOA was the collaboration research using the cup lump rubber in the Malaysian roads. The use of cup lump modified asphalt in road construction was expected to increase the quality and performance of the asphalt pavement due to the conventional asphalt properties improvement. It was mention in previous studies that claimed the addition of rubber into asphalt mixtures may resulted the mixtures more elastic at higher temperature thus enhancing their rutting resistance [13-15].

2. Methodology

The use of cup lump rubber as an additive in asphalt mix was implemented at one of the road maintenance project at Route 4, Jalan Kupang – Gerik, Baling, Kedah. The construction was totally completed by November 2016. This 725-meter length of the pilot project was constructed by recycling an existing pavement structure of road base layer using cold in-place recycling method prior to overlay with the cup lump modified asphalt (CMA) layer as a wearing course while binder course was using conventional AC28 asphalt mix. The construction of the section was divided into two sections which are a conventional section of AC14 aggregate gradation using 60/70 penetration grade asphalt (Control section) and cup lump modified asphalt section using cup lump modified binder and mixed with AC14 aggregate gradation namely (CMA Section). It was noticed that an existing site condition was very poor due to the major road defects such as rutting, cracking and severe pothole patching almost at the overall selected section as showed in Figure 2(a) and 2(b).



Figure 2. The condition of the existing road. (a) conventional asphalt section before construction and (b) cup lump modified asphalt section before construction.

2.1. Field construction

The CMA section and conventional section was constructed continuously as illustrated in Figure 3 and Figure 4. The scope of works for this project included:

- Recycled the existing asphalt surface layer using cold in place recycling method using cement stabiliser up to 200mm thickness throughout the 720m length;
- Overlay the binder course up to 60mm using conventional AC28 asphalt mix throughout the 720m length;
- Overlay the cup lump modified asphalt (CMA) wearing coarse layer up to 50mm at 500-meter length;
- Overlay the conventional AC14 wearing coarse layer up to 50mm at 220-meter length.

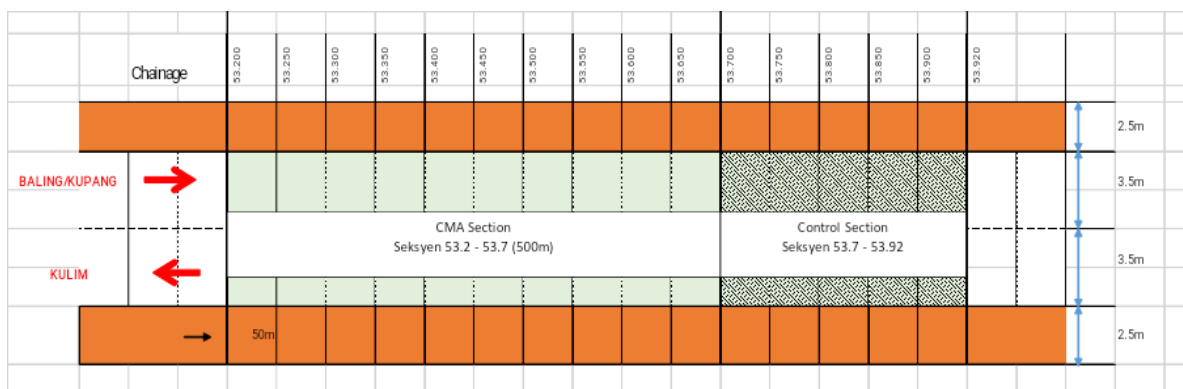


Figure 3. Site plan of CMA and conventional section.



Figure 4. Structure of pavement layer.

2.2. Laboratory work and field testing

Laboratory and field testing was conducted before and after the construction of this maintenance project. Marshall Mix design was carried out for both conventional asphalt and CMA mix before commencing the construction works. Field testing was also conducted before construction to identify the existing road surface condition while post-construction testing was conducted after the construction works completed to identify the performance of the pavement after construction using conventional asphalt and CMA mix.

In this study, cup lump natural rubber was used as an additive in conventional penetration grade asphalt 60/70 to produce cup lump modified binder. The conventional asphalt penetration grade of 60/70 was a control sample. This research was involved the laboratory works and field testing to identify the properties of CMA, construction process and performance on the actual site. The materials and procedure of works were referred to the Malaysian Public Works Department.

This study was used the same combination of aggregate gradation for both conventional control AC14 and CMA design mix as showed in Figure 5. The result of mix design on both asphalt mix of conventional and CMA as showed in Table 1. The result showed that the optimum asphalt content was increased in CMA mix compared to conventional asphalt mix. This result is similar with the previous study done by Hassan et al. [12], where he found that the increase in the rubber content has resulted in higher optimum asphalt content due to the asphalt binder absorption by the rubber particles.

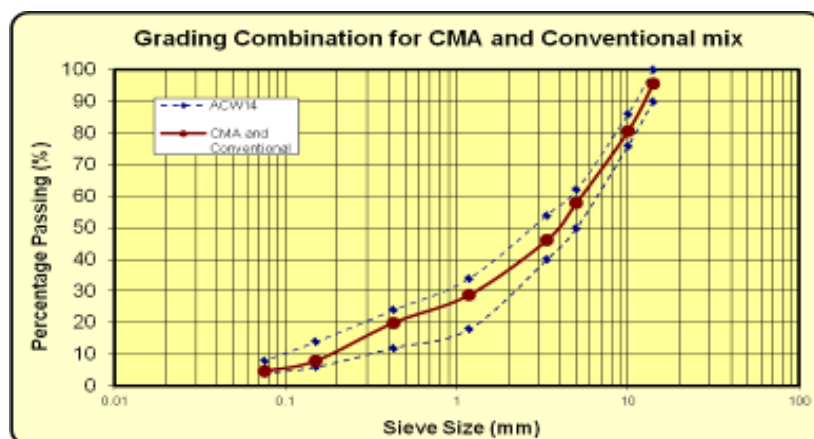


Figure 5. Combined aggregate gradations for both conventional control AC14 and CMA design mix.

It was shown that the mix design for both asphalt mix complies all the design parameter required by the Standard Specification for Road Works JKR/SPJ/2008-Section 4 as shown in Table 1.

Table 1. Test result of mix design for conventional and CMA mix (JKR/SPJ/2008- Section 4) [16].

Parameter	Conventional asphalt		CMA	
	Specification	Result	Specification	Result
Optimum Asphalt Content (%)	4.5 – 6.5	5.20	4.5 – 6.5	5.75
Flow (mm)	2.0 – 4.0	3.00	2.0 – 5.0	2.92
Air voids in mix (%)	3.0 – 5.0	3.80	3.0 – 5.0	3.55
Voids in aggregate filled with asphalt (%)	70 – 80	75.0	70 – 80	78.0
Resilient Modulus (MPa)			> 2500	4200
Dynamic creep modulus (MPa)			> 75	7200
Slope at steady state			< 0.25	0.24

The field testing had been carried out after constructions completed to identify the condition and performance of the road. It is also to compare the performance of conventional asphalt and CMA

pavement surfacing. The testing that had been carried out in this study are determination of structural strength using Falling Weight Deflectometer (FWD), determination of surface condition survey including surface irregularity, rutting and cracking. The performance monitoring had been carried out until six months after construction completed. The performance of site condition was measured and been categorised using the pavement condition indicator as shown in Table 2. The pavement indicator used in this study referred to the Road Asset Management System project report by Public Works Department of Malaysia which it had been used for the road maintenance program [17].

Table 2. Pavement condition indicator [17].

Pavement condition parameter	Key Indicator Category			
	Good	Fair	Poor	Very poor
Roughness/IRI	< 2.5	2.5 - 3.5	3.5 - 5	> 5
All crack area (%)	< 5	5 - 10	10 - 15	>15
Texture (SMTD)	> 0.5	-0.3 - 0.4	< 0.3	< 0.3
Rutting (mm)	< 5mm	-5 - 10	10 - 15	> 15
Pothole (mm)	<25	25 < depth < 35	35 < depth < 50	>50

3. Results

3.1. Rutting

Field monitoring on the rutting was carried out using high-speed road surface profiler. Table 3 showed the result of rutting performance before and after six-month construction. It was shown that the rutting already appeared after six-month construction. However, the result showed that there was no significant difference in the rutting performance for both conventional and CMA section. The construction site was also considered in good condition due to rutting value was below 5mm.

Table 3. Rutting result.

Duration after construction	Rutting (mm)				Indicator
	To Baling		To Kulim		
	Conventional	CMA	Conventional	CMA	
Before	13.02	8.78	11.67	8.40	Good
Month 6	1.80	2.09	3.00	2.40	Good

3.2. Surface roughness (IRI)

The surface roughness was measured using road surface profiler and the performance was indicated by Surface Roughness Index (IRI). The result in Table 4 showed that there is uneven surface has appeared in CMA section and it was obviously higher than the conventional section after six-month construction. However, the overall condition for both sections was still good since the IRI value below than 2.5m/km.

Table 4. Surface roughness result.

Duration after construction	Rutting (mm)				Indicator
	To Baling		To Kulim		
	Conventional	CMA	Conventional	CMA	
Before	3.25	3.46	4.24	3.56	Poor
Month 6	1.60	1.95	2.37	2.18	Good

3.3. Cracking

The surface cracking of the roads was measured using road surface profiler with the attached camera devices. The result showed in Table 5 indicated that the surface cracking on both sections of

conventional and CMA after six-month construction were less than 5% and it indicates the surface was in good condition. Although the percentage of cracking at CMA section was higher than conventional section the different of value was not so significant.

Table 5. Surface cracking result.

Duration after construction	Rutting (mm)				Indicator
	To Baling		To Kulim		
	Conventional	CMA	Conventional	CMA	
Before	48.57	50.46	64.23	42.26	Very poor
Month 6	0.83	1.32	0.84	1.60	Good

4. Conclusion

In nut shell, the study showed that the used of new asphalt mix has improved the quality of asphalt pavement whereby it is able to apply for the road construction works without any major modification in the construction process. The observation and site monitoring testing showed that the performance of CMA section was almost equivalent with conventional section after six-month of completed construction. The result of six-month duration site monitoring is not very convincing as to acknowledge with the site overall performance. To conclude, the extension of performance monitoring is still needed to get a better result.

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