Jurnal
Teknologi

Full paper

Bitumen Emulsion in Malaysia–A Conspectus

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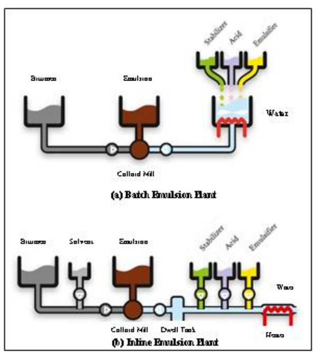
Article history

Received :10 May 2013
Received in revised form :
25 September 2013
Accepted :15 October 2013

Graphical abstract



Abstract

Bitumen emulsion is an important building material, especially in highway pavement construction. It is a mixture of bitumen (asphalt), water and emulsifying agent, dispersed in tiny particles in an aqueous medium. It is an important material widely used in the pavement construction ever since the first introduction in the year 1900's. This paper aims to provide an overview and an understanding among the practitioners on the bitumen emulsion from the manufacturing process, naming and categorizing to its potential application. Bitumen emulsion can be manufactured in a batch plant or in-line plant. Being water based, it is capable to be applied under ambient temperature besides being more environmental friendly. Categorizing the bitumen emulsion is simple but the naming may differs slightly according to local specification. Continuous research also has end up in the modification of conventional bitumen emulsion using polymers to produce polymer modified bitumen (PMB) emulsion which decreases thermal susceptibility and permanent deformation (rutting). It has resulted in even wider application of bitumen emulsion as in microsurfacing, slurry seal and cape seal.

Keywords: Bitumen emulsion; polymer; pavement; cationic; anionic

1.0 INTRODUCTION

The increasingly used of bitumen emulsion in road construction is no longer a new issue ever since the introduction of bitumen emulsion dated back to the early of 20th century. It was first introduced in the 1900's with initial application focused on dust control and later gains interest in farm and market roads paving which experiences relatively low traffic stress [1, 2]. The application of bitumen emulsion later gained more attention in the 1970's following issues related to environmental concern as a result of paving using cutback bitumen [1].

Various researchers have their own definition for emulsion, but normally carry the same meaning. It is generally defined as a stable dispersion of two or more immiscible liquids in the presence of a surfactant [3- 7]. Under normal condition, one of the two liquids will be water. Bitumen emulsion generally consists of asphalt cement, water and a small portion of emulsifiers. The more scientific and precise definition on bitumen emulsion is in accordance with Becher [8] after Baumgardner [9] which define bitumen emulsion as following:

"An emulsion is a thermodynamically unstable heterogeneous system including at least two immiscible liquid phases of which one is dispersed in the other in the form of droplets whose diameter is generally greater than 0.1 micrometers. The minimum stability inherent to this type of system may be increased by adding appropriate agents, such as surfactants or finely divided solids."

As in Malaysian Standard (MS) 161, bitumen emulsion is defined as a liquid product in which a substantial amount of bitumen is entirely suspended in a finely divided condition in an aqueous medium by means of one or more suitable emulsifying agents [10].

There exist three categories of bitumen emulsion, namely oil-in-water (O/W) emulsion, water-in-oil (W/O) emulsion and multiple emulsion, which is normally denoted as W/O/W. The major difference between these three categories of emulsion is the continuous phase within them. The continuous phase refers to the types of base materials in the emulsions itself. In O/W emulsion, the continuous phase is water whereby bitumen is dispersed to form a mixture of 'asphalt in water'. The reverse applies for W/O emulsion, with the continuous phase is an oil and water is the dispersed phase. As for multiple emulsion, it is formed when the dispersed droplets themselves contains another phase which may not have the same composition as the continuous phase. A graphical presentation as shown in Figure 1 gives a clearer view over the types of emulsion taking into the consideration on the continuous phase existed.

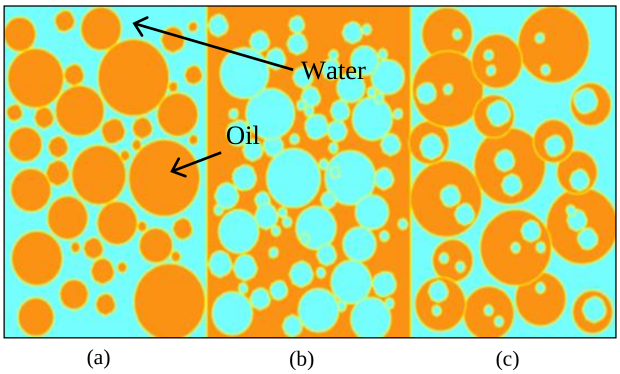


Figure 1 Three categories of bitumen emulsion (a) Oil in Water emulsion (O/W), (b) Water in Oil emulsion (W/O) and (c) multiple emulsion (W/O/W) [11]

Bitumen emulsion is generally categorized as O/W types of emulsion since it is the hot asphalt that is dispersed into small droplets in the continuous phase of water. The size of these suspended droplets normally ranges from 0.1 to 20 microns in diameter [12]. In fact, the particle size distribution should always fulfill the specified range. Larger particle size will end up having a bitumen emulsion with lower viscosity while smaller particle size will increase the spraying performance of bitumen emulsion.

In between the droplets of asphalt binder, there exist similar charges surrounding all the particles. The charge can be anionic or cationic depending on the types of emulsifier used. As it is the nature of the same charges to repel, flocculation of these asphalt particles can thus be avoided. But after a certain period of time, there is a tendency that the dispersed asphalt binder droplets after gaining sufficient energy to overcome the electrostatic charge to re-flocculate since asphalt binder is insoluble in water. This phenomenon may sometimes, but not every time be reversed. It can be done by agitating the flocculate bitumen emulsion gently without causing any turbulence or adding extra emulsifier [12]. Continuous flocculation will eventually result in the coalescence of the bitumen due to the gravitational force, especially if the bitumen emulsion has been stored for a longer period of time. At this stage, the coalescence is irreversible. This is especially true for bitumen emulsion which consisted of more than 75% of asphalt binder [3].

A major advantage possessed in bitumen emulsion compare to asphalt binder is the capability to apply under ambient temperature without any heating required, thus energy saving with no emission of CO_2 and less green house effect. At the same time, being water based, it is environmentally friendly compare to cutback asphalt binder, in which valuable combustible material like kerosene and diesel used to liquefy the bitumen for application is wasted through evaporation process. Due to the above advantages, bitumen emulsion has emerged to gain popularities among the practitioners of road construction.

2.0 MANUFACTURING OF BITUMEN EMULSION

Asphalt binder is generally viscoelastic at ambient temperature. It is normally heated to 160-185^{0}C depending on the grade of bitumen to be able to put in an application which will create potential hazards such as fumes and emissions of CO_2. On the other hand, bitumen emulsion is produced at relatively lower temperature by mixing bitumen and water together with the aid of an emulsifier, either positively charged or negatively charged. Selection of the right type of emulsifier is therefore very important to develop suitable emulsion formulations for different local requirements using the local raw materials and also to stabilize the emulsion by increasing its kinetic stability.

Bitumen emulsion can be produced by mixing hot asphalt binder with water containing emulsifying agent using a colloid mill or other dispersion devices [13]. Manufacturing methods may affect the properties of the final emulsion. Sometimes, polymers are added during the manufacturing process to produce polymer modified bitumen emulsion which possesses better properties compared to the conventional bitumen emulsion. There are several ways to add polymer as for example, pre-blending in the soap solution, co-mill or post addition as indicated in Figure 2.

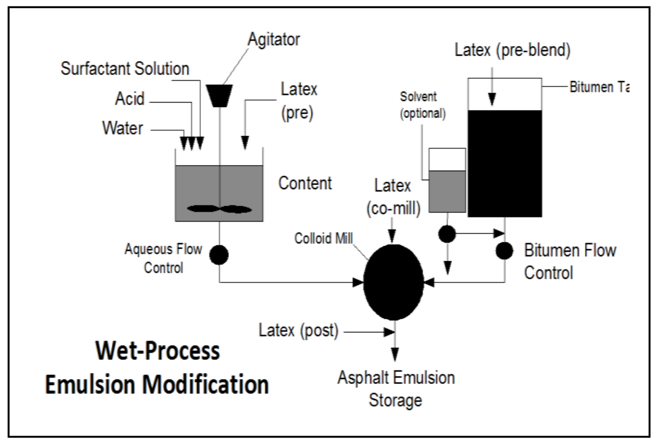


Figure 2 Typical bitumen emulsion modification process in the manufacturing industry [14]

It is stated in the AkzoNobel technical bulletin that bitumen emulsion can be produced either in a batch plant or in-line process plant where both methods have graphically presented in Figure 3 [12]. Both production methods involve a colloid mill, where the energy is applied to the system and water phase between a rotating disc, cone or flywheel and a stator. The first step is to produce the soap in which the preparation is done in a separate tank where the surfactant is activated by chemically reacting it in water. The soap solution includes acid or base, stabilizer and emulsifier. The next step is to deliver the bitumen and soap solution separately into the mill at the predetermined rate and temperature. Bitumen is later heated to 110^{0}C to ease the transferring of the material into the mill while water phase is heated to 30-70^{0}C to dissolve the emulsifiers. However, in colloid mill the temperature is limited to 100-120^{0}C only [12].

The main difference between a batch plant and an in-line plant is the process involved during the production. In batch plant, the emulsion production involves only a few material flows, which allows manual process control, but in the in-line plant, the water heating and all material dosage are carried out continuously using individual dosage pumps for each material. Other ingredients such as latex, polymer, and other additives are introduced into the system to further modify the physical characteristics of the emulsion. It can be added to the soap solution, injected into the system just before the milling process or mixed with the emulsion after milling. Currently, there exist several specifications for bitumen emulsion in use to define the grades and specifications of bituminous emulsions. In Europe, BS EN 13808 [15] and BS 434 [16] are used. In America, the cationic emulsion is specified in ASTM D2397 [17] while in Malaysia, MS161 [10] is used to benchmark the quality of a particular cationic emulsion.

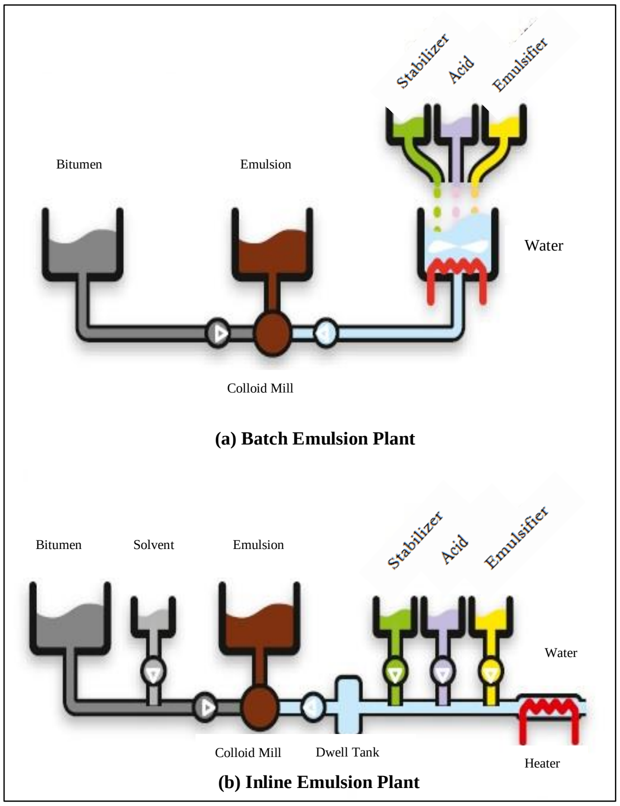


Figure 3 Batch emulsion plant and in-line emulsion plant generally used in manufacturing bitumen emulsion [12]

2.1 The Emulsification Process

In emulsification process, one phase is broken up, dispersed and distributed in a second immiscible or partially miscible phase to produce high interfacial area between two immiscible fluids within a target time. Two types of emulsifier are generally in used, namely anionic emulsifier and cationic emulsifier [18] with an end product shown in Figure 4. These emulsifying agents will form a thin layer of charge around the bitumen droplets that will resist them from forming individual bond [19]. After the water evaporates during the application, a strong bond is formed between asphalt binder cement and emulsifying agent which goes on hardening with the passage of time. These emulsifying agents are similar to soap which allow the particles and water to form a uniform mixture. Stabilization is achieved with the use of surfactants, which consist of polar molecules comprised of a hydrophilic head and hydrophobic tail [20]. Emulsifier is used to provide stability and to prevent coalescence after emulsification, storage and transportation.

Bitumen emulsion is designed to break or revert to asphalt binder and water phases. A great challenge today is to formulate an emulsion that is stable when stored, pumped and mixed. At the same time, development of strength, water resistance and durability when applied to the pavement also need to be considered. Several factors such as chemical properties, particle size, hardness and concentration of the neat asphalt binder may influence the quality and performance of bitumen emulsions [20]. Other factors such as ionic charge, concentration of the surfactant and types of chemical modifiers like polymers will also influence the bitumen emulsions. As the concentration of the emulsifier increases, the particle size of the emulsion is reduced.

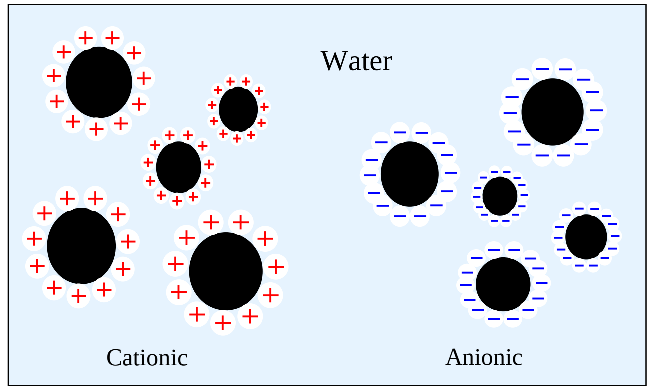


Figure 4 An illustration of cationic and anionic bitumen emulsion

3.0 CATEGORIZING AND NOTATIONS

To categorize bitumen emulsion is easy but may be relatively complex. The charge particles are imparted on the asphalt binder droplets during the emulsification process as discussed earlier. The negatively charged anionic bitumen emulsion is very suitable to positively charged calcareous aggregates like limestone. On the other hand, the positively charged cationic bitumen emulsion should focus on negatively charged siliceous aggregates like granite which occurs abundantly in Malaysia. This explains the fact that cationic bitumen emulsion should normally adopted to be used in the road paving industry in Malaysia.

Besides the particle charge, bitumen emulsion is further categorized according to the rate of setting incorporating rapid setting (RS), medium setting (MS) and slow setting (SS). According to ASTM D977 [21] and ASTM D2397 [17], cationic RS, cationic MS and cationic SS is denoted as CRS, CMS and CSS respectively, where the prefix "C" represents Cationic. As for anionic emulsion, the denotation is in the absence of prefix "C". The bitumen emulsion is later graded with an introduction of numerical value, normally ranges from 1 to 2 to represents the viscosity of the particular emulsion. In the case of modification or polymers added during the bitumen emulsion production, some other suffixes will be added. A typical example of naming and categorizing bitumen emulsion is shown in Table 1.

In Malaysia, the bitumen emulsion used in the road construction industry is specified in the Malaysian Standard (MS) 161 [10]. However, the anionic bitumen emulsion is excluded from the specification as this emulsion is not being used in local road paving works. At the same time, the bitumen emulsion naming and notations also differ slightly. Instead of prefix "C", a suffix "K" is attached to differentiate between anionic and cationic bitumen emulsion, as an example RS-1K. Suffix "K" represents "Kationik", which means cationic in the local language while the remaining alphanumerical characters represent the emulsion types and the viscosity. At the same time, the numerical value shows the information on the viscosity of a particular emulsion ranges from 0 to 3 in the Malaysian bitumen emulsion, which can be considered as significantly different from bitumen emulsion accordingly to ASTM. However, the similarity is that the viscosity of bitumen emulsion increased with the increasing of the value. A brief comparison on the bitumen emulsion in accordance with ASTM D2397 [17] and MS161 [10] is as shown in Table 2.

From Table 2, there exist several similarities and differences between the cationic bitumen emulsion specified in both ASTM D2397 [17] and MS161 [10] which are easily noticeable. There are total seven types of bitumen emulsion specified in MS161 [10] and ASTM D2397 [17]. But, the Malaysian RS-2K, RS-3K, MS-2K and SS-1K is actually identical to the CRS-1, CRS-2, CMS-2 and CSS-1 respectively as stated in ASTM D2397 [17] in term of the percentage of residue. The penetration value of the neat bitumen differs slightly with the Malaysian bitumen is expected to be the harder binder. As for the differences, there are bitumen emulsion specified in ASTM D2397 [17] which are having harder base bitumen like for example CMS-2h and CSS-1h with an extremely low penetration value which does not exist in MS161 [10]. Also, there is a special type bitumen emulsion - quick setting emulsion being specified in the specification which is not available in MS161 [10].

Table 1 The naming of cationic and anionic bitumen emulsion in accordance with ASTM (a, b ,c) and MS (d). [22]

CRS-1 (a)	C	=	Cationic
	RS	=	Rapid Set
	1	=	Low Viscosity
SS-2h (b)	SS	=	Anionic Slow Set
	2	=	High Viscosity
	h	=	Hard asphalt
LMCQS-1h (c)	LM	=	Latex Modified
	CQS	=	Cationic Quick Setting
	1	=	Low Viscosity
	h	=	Hard asphalt
RS-1K (d)	RS	=	Rapid Set
	1	=	Low Viscosity
	K	=	Kationik

4.0 SETTING AND BREAKING OF BITUMEN EMULSIONS

Bitumen emulsion consist of a considerable amount of water, especially the Malaysian RS-1K which is typically used in pavement construction. The water in the bitumen emulsion needs to be get rid of to ensure that only the neat bitumen is left behind. In the presence of water, the degree of adhesiveness will be lessen as the presence of water will provide a barrier for the asphalt binder to coalesce and affecting the development of bond between the asphalt binder particles. Due to that, curing of bitumen emulsion is normally needed to provide a platform for the water to evaporate, leaving behind just a layer of thin asphalt binder that exhibit cohesive properties in nature.

The rate for which bitumen emulsion gain strength is proportional to the rate of water losses from the bitumen emulsion itself. This process is closely related to environmental conditions such as ambient temperature, humidity and the presence of wind movement besides the material properties itself [23]. In another word, under constant environmental conditions, RS bitumen emulsion will gain strength faster compared to MS bitumen emulsion and SS bitumen emulsion.

Curing of bitumen emulsion involves two stages, namely breaking and setting. The breaking stage refers to the initiation of the process whereby water added during the emulsification, starts to separate from the base asphalt binder and begins evaporating [24]. As for setting, it is the stage that the available water has completely evaporated, leaving just a thin, black asphalt binder film at the location of the application [24]. As mentioned earlier that the breaking and setting process is highly dependent on ambient condition, it is normally difficult to determine exactly the time required for a bitumen emulsion to set completely. However, a typical method based on observation of color change is normally adopted on site to determine if the bitumen emulsion has set or not. The color of a fresh bitumen emulsion is generally brownish. As the breaking and setting process continues, a visual color emulsion is said to be set once the black color is observed.

Table 2 A brief comparison of cationic bitumen emulsion in accordance with specifications MS161 and ASTM D2397.

Rapid Setting Emulsion					
MS161			**ASTM D2397**		
Emulsion Type	**Percent Residue**	**Residue PEN**	**Emulsion Type**	**Percent Residue**	**Residue PEN**
RS-0K	38	60-200	-	-	-
RS-1K	50	60-200	-	-	-
RS-2K	60	60-200	CRS-1	60	100-250
RS-3K	65	60-200	CRS-2	65	100-250
Medium Setting Emulsion					
MS161			**ASTM D2397**		
Emulsion Type	**Percent Residue**	**Residue PEN**	**Emulsion Type**	**Percent Residue**	**Residue PEN**
MS-1K	60	60-200	-	-	-
MS-2K	65	60-200	CMS-2	65	100-250
-	-	-	CMS-2h	65	40-90
Slow Setting Emulsion					
MS161			**ASTM D2397**		
Emulsion Type	**Percent Residue**	**Residue PEN**	**Emulsion Type**	**Percent Residue**	**Residue PEN**
SS-1K	57	60-200	CSS-1	57	100-250
-	-	-	CSS-1h	57	40-90
Quick Setting Emulsion					
MS161			**ASTM D2397**		
Emulsion Type	**Percent Residue**	**Residue PEN**	**Emulsion Type**	**Percent Residue**	**Residue PEN**
-	-	-	CQS-1h	57	40-90

The reason for which RS bitumen emulsion set faster than MS bitumen emulsion and eventually SS bitumen emulsion is accounted to the charge particle surrounding the asphalt binder droplets as shown in Figure 5. When the number of charge particle surrounded the asphalt binder droplets is less, the repulsive force between these droplets is also minimize, which ease the flocculation to occur. At the same time, for asphalt binder droplets with lesser surface charge, upon in contact with the surface of the aggregates which contain predominantly the opposite charges will also ease the neutralization of these charges, hence results in faster flocculation and coalescence.

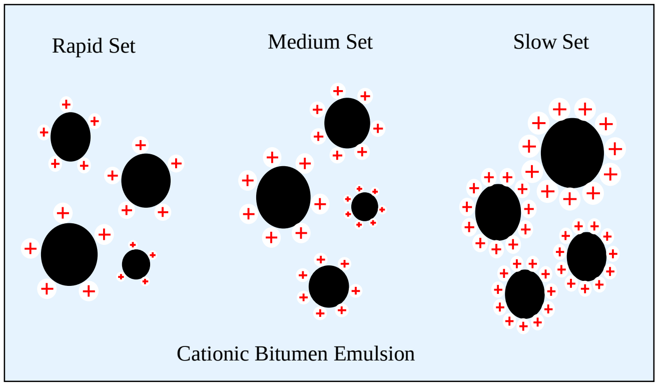


Figure 5 Charge particles surrounded the bitumen droplets decide the setting of the bitumen emulsion

Figure 6 illustrates the breaking and setting of a cationic bitumen emulsion, a typical example which often encounter in Malaysian condition.

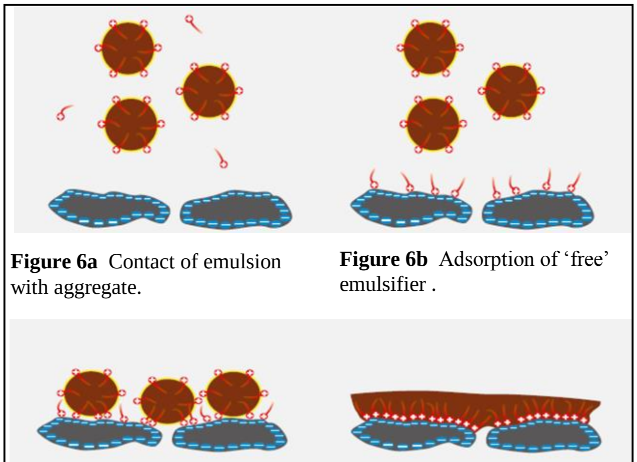


Figure 6a Contact of emulsion with aggregate.

Figure 6b Adsorption of 'free' emulsifier .

Figure 6c Electrophoresis of droplets to surface.

Figure 6d Coagulation/spreading over surface.

Figure 6 The mechanism of breaking and setting of cationic bitumen emulsion. [12]

■5.0 POLYMER MODIFIED BITUMEN EMULSION

A polymer is a chemical compound consists of large molecule that is made up of repeating sub-units connected to each other by chemical bonds. It has unique properties and can be tailored depending on the intended purpose. These properties range from reflective, impact resistant, tough, brittle and translucent to elasticity.

The end product of polymer added into a bitumen emulsion is polymer modified emulsion (PME). PME technology is used to improve the performance of bitumen emulsion especially for cold mixture such as slurry seal and micro-surfacing [13]. Blending bitumen with additives will expand the useful temperature range of the modified bitumen and increases the temperature susceptibility [25]. There are several advantages of PME compared to unmodified bitumen emulsion or conventional hot polymer modified asphalt. It has a better polymer distribution which can improve the properties, develop consistent cohesion strength and have better retention in applications such as chip seals. Improvements in pavement longetivity can be achieved through the reduction of fatigue and thermal cracking and also decreased high temperature susceptibility [20]. The statement is further supported by National Center for Pavement Preservation (NCPP) which states that the performance of PME depends on the types of polymer and compatibility of polymer and asphalt binder [20]. With the right use of PME, it can increase the service life and prevent possible premature failures.

5.1 Types of Polymer Modifiers

There are ample polymers that can be used to modify and enhance the performance of binders used in paving works. Generally, polymer modifiers can be divided into two categories which are elastomers and plastomers, based upon their strain performance characteristics at low temperatures [20]. The elastomers are natural and synthetic rubbers, styrene-butadiene-styrene, reclaimed crumb rubber modifiers harvested from scrap tires and the plastomers include low density polyethylene, ethylene-propylene-diene-monomer and ethyl vinyl acetate. Elastomeric polymers exhibit a low modulus of elasticity which permits the polymer matrix to expand without failure up to 10 times its undeformed dimensions when stretched, but quickly return to its original shape once the load has been removed. For plastomeric polymers, it can attain high strength at a rapid rate, would deform but will not return to their original dimensions when the load was released [26].

Polymers modifiers can create large changes in physical properties of the final product when combined with asphalt binder. The polymers can respond in three ways: 1) elastically; 2) elastomerically (time-dependent elasticity) and; 3) viscously (plastically). It is all depend upon the structure and the conditions of loading in terms of time and temperature. It has been proved that mixtures prepared with styrene-butadiene-styrene (SBS) and ethyl-vinyl-acetate (EVA) can reduced stripping potential and moisture susceptibility than mixtures prepared with base bitumen for all types of aggregate. In another word, PME can increase adhesion between the aggregates and creates a network structure within the base bitumen [27]. The next section will explain briefly about several types of polymers (crumb rubber, SBR, SBS and EVA) normally used in modifying conventional bitumen emulsion.

5.1.1 Crumb Rubber

In the present study, crumb rubber (non-homogenous binders) is used as a modifier to bituminous materials and shown improvement in physical properties of bitumen such as penetration, viscosity, softening point and penetration index [28]. The rheological properties also increase with the increase in temperature and modifier contents. Its contain in excess of 30% carbon black which has been shown to add reinforcing properties to bitumen and antioxidants in the rubber contribute to the durability of bitumen rubber. However, Asphalt Academy mentioned in their technical guideline that there should be some considerations while using crumb rubber as a modifier to ensure that the crumb rubber is dry [29].

5.1.2 Styrene-Butadiene-Rubber (SBR)

SBR is a synthetic latex that has a random structure of copolymers. The usage is more frequent compared to the other polymers. It has simpler modification process which can produce a more stable emulsion that is lower costs. It is normally used rubbers such as in the production of tires, footwear, conveyor, belts and adhesives

[30]. It has been said that SBR modified asphalt can improve the properties of asphalt concrete pavement and seal coats, improved the low-temperature ductility, increased the viscosity, improved the elastic recovery, adhesive and cohesive properties. Previous research shows that bitumen emulsion modified with three percent of SBR latex has a significant effect on the low temperature properties and improvement of aging resistance [31]. SBR also plays an important role to improve storage stability. With an addition of SBR, it will affect the low temperature (5^0C) properties and improves the aging resistance with increasing SBR content up to 4 percent by weight of asphalt binder [32].

5.1.3 Styrene-Butadiene-Styrene (SBS)

Latexes are the most common polymer additives for cement and are dispersions of solid polymer particles in water. It can be either elastomeric and thermoplastics [33]. SBS copolymer is a type of thermoplastic elastomers which confer good elastic properties [34]. SBS has been widely used as an asphalt binder modifier in China and worldwide [35]. The advantage of adding SBS to form a modified bitumen binder exhibit better properties as shown in Table 3 compared to unmodified bitumen binders.

Table 3 Properties of modified and unmodified asphalt binders [35]

Properties	Unit	A-70* Asphalt Binder	SBS Modified Asphalt Binder
Penetration 25°C, 100g, 5s	0.1mm	62	50
Penetration Index, PI	-	-1.35	0.24
Softening Point, $T_{R\&B}$	°C	48.1	70.1
Ductility 5°C, 5cm/min	cm	-	25.2
Ductility 10°C, 5cm/min	cm	27.5	-
Ductility 15°C, 5cm/min	cm	>100	-
Density 15°C	g/cm^3	1.043	-
Solubility (trichloroethylene)	%wt	99.9	99.8
Flash Point (COC)	°C	312	304
Wax Content	%wt	1.86	-
Dynamic Viscosity 60°C	Pa.s	233	-
Elastic Recovery, 25°C	%	-	93.7
Storage Stability: 163°C, 48hr	°C	-	0.4
Viscosity 135°C	Pa.s	0.39	1.78
RTFOT Residue (163°C, 85min, 15rpm, 50psi)			
Quality Change	% wt	-0.02	-0.01
Penetration Ratio: 25°C	%	78.6	80.9
Ductility: 5°C, 5cm/min	cm	-	15.6
Ductility: 10°C, 5cm/min	cm	12.1	-

* A-70 is a Chinese standard asphalt binder grade, with the level of asphalt penetration of 70 and the quality level A

5.1.4 Ethyl Vinyl Acetate (EVA)

Ethylene and vinyl acetate EVA copolymer have revealed as good modifiers to improve the workability and deformation resistance. It has been used as a hot-melt adhesives, coatings and blends to general molding and extrusion [36]. It is widely used because of its solid state properties like flexibility, low temperature properties and tensile strength, and also for its softness and flexibility [37].

In recent research, EVA has been used as a polymer to investigate the structure-property relationships of PME. It has been proved that EVA modification on the bitumen 60/70 (penetration) has improved the rheological properties of neat asphalt binder [38]. The use of EVA polymers in EVA modified binders has improved the rheological properties of the binders. The viscoelastic properties of a 60/70 penetration grade bitumen are improved when EVA is mixed with it [39]. Besides that, the maximum use temperature is also increased and the thermal susceptibility of the elasticity is lowered. Also, EVA modified binders can reduce the risk of cracking at low temperatures and rutting at high temperatures.

6.0 THE CURRENT APPLICATION AND THE FUTURE OF BITUMEN EMULSION IN MALAYSIA

Emulsions are extremely versatile materials. There are a lot of applications (functional or structural) for bitumen emulsions such that it can be used for preventive maintenance and corrective maintenance on both asphalt and concrete pavements, stabilizing and reclaiming bases, and building structural pavements. All these are well presented in Figure 7. The most important rules are putting the right application at the right location at the right time.

As mentioned earlier in Section 3.0, the use of bitumen emulsion depends on the types of aggregate used. In Malaysia, granite aggregate was used for pavement construction. As shown in the Figure 8, granite aggregates are negatively-charged in aqueous media which will work perfectly well with cationic emulsions. This shows that the granite aggregates in Malaysia are compatible with the cationic bitumen emulsions used and the combination of granite aggregate and cationic emulsion will certainly result in better coating during their application.

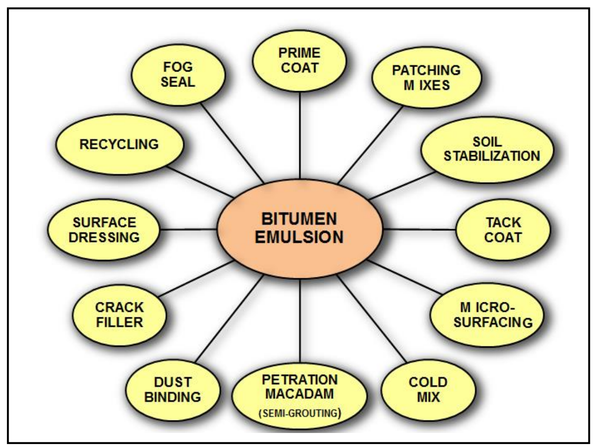


Figure 7 Applications for bitumen emulsion in Malaysia. [40]

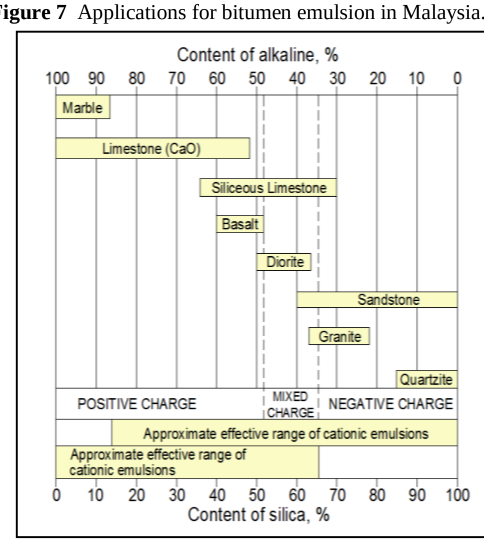


Figure 8 Effective range of cationic emulsions. [40]

The most common usage of bitumen emulsion is to be used as tack coating and prime coating materials. Examples of treatment applications include chip seals, microsurfacing and cape seals [20]. An example of microsurfacing is Novachip construction, which uses PME in the paving works with excellent performance. Besides that, PME is applicable also in non-roadway applications, for example parking areas, hiking trails, or bike paths. It is also classified as a thin surface treatment which in another word, will enhance stone retention, improve low temperature susceptibility, and reduce the effects of high temperature deformation. Besides that, bitumen emulsion is commonly used for cold mix technologies. It can be used as a surface dressing, grouting-penetration macadam, crack sealing, repairing of potholes and depression, sub-base and base courses (sealing) and cold in-place recycling.

At the same time, there are several successful applications of bitumen emulsion in Malaysia. The use of bitumen emulsion to bind together dust particulates away from an aggregate surface has proved to be a successful technical solution for utilizing an otherwise waste aggregate in surface dressing operations. On 6th November 2007, Kemaman Bitumen Company and Bina Masyhur Sdn Bhd have successfully conducted product trial of CRS-2P for chip seal application on the Federal Road Off Jalan Utama Bukit Rokan, Gemencheh, Negeri Sembilan [41]. Also, HCM Engineering Sdn Bhd (HCM), which is a road construction specialist in Malaysia started to introduce and promote cold recycling to replace previous stabilization techniques in the early of 1990s. Initially, cement was used as the stabilizing agent. It was later followed by bituminous emulsion and foamed bitumen. In 1999, HCM undertake a full-scale trial, using the recycling technique, on a section of the Kuala Perlis-Changlun Rehabilitation and Upgrading Highway project, located close to the Thai border. Using both in site and in-plant recycling techniques with cement, foamed bitumen and a special emulsion QS3E, the trial proved to be successful. The QS3E emulsion used is a modified bitumen emulsion which is specially formulated for producing Chipmix, a term for the cold bituminous mix produced by the mobile plant and recycling machines [42]. These two examples of innovation that lead to the commercial success in the emulsion field has characterized the country's approach to understand the global market needs. The drive towards more environmentally friendly and sustainable products makes the future of emulsions increases due to the reduction in the carbon footprint and provides an eco-efficient solution [43]. However, there is still much room for progress, given the technical advantages that emulsion techniques can provide.

■7.0 CONCLUSION

Overall, the use of bitumen emulsion is a feasible alternative to conventional bitumen due to today's harsh environment and economic constraints. Bitumen emulsion offers a reduction in safety and environmental hazards, reduced costs and conservation of energy. Currently, emulsion formulations are under the responsibility of the manufacturers with the proportion of bitumen emulsion is 50-70 percent by weight for the requirements of storage stability and viscosity.

Modification of asphalt binder has been driven by the increase of traffic loads, axle loads and tire pressure besides new technologies and enhancement in polymer technology. The use of polymers in bitumen emulsion can enhance the properties of bituminous road binders in order to get a better rheological behavior at high and low temperatures. The use of polymer can also improve the temperature susceptibility and rutting performance of cold mix asphalt paving. Greater stability of PME also leads to a much wider application in cold mix paving technologies. However, further investigations are needed for the specimen preparation of PME.

Acknowledgment

The authors are grateful to the Ministry of Higher Education (MOHE) and the Universiti Teknologi Malaysia Research grants (GUP Tier 2 Vote 06J52 and Vote 06J98) and Fundamental Research Grant Scheme (FRGS Vote 4F201) for the financial support in this research project. Special thanks dedicated to laboratory technicians and individuals who offered their help directly or indirectly.

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