EFECT OF THE PROPERTIES OF BITUMINOUS EMULSIONS USED FOR SURFACE TREATMENTS IN SRI LANKA

HLDMA Judith and JMSJ Bandara
Department of Civil Engineering, University of Moratuwa
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ABSTRACT

Surface treatment can be used as a successful and economical method to any type of road, from trunk roads to gravel roads. The main objective of surface treatment is seal the existing road pavement thereby arresting disintegration and providing a user-friendly road network.

However premature failures can be observed on surface treatment in many instances. Therefore a research study was carried out in order to find the causes for the unsatisfactory consistency. As the preliminary stage a field investigation was carried out on existing surface treated roads to identify the failures. On going construction sites were also investigated.

Database of the test results on the samples of binder collected at the sites as well as from the manufacturing plant were established. More attention was given to the properties, which are frequently out of the specification limits, and effect of these properties was studied.

The study has found that the properties such as viscosity, storage stability together with the size of the droplets and adhesivity play an important role in surface treatment. Some steps to be taken to improve these properties by carrying out further laboratory testing and also by observing the field performance of the modified bitumen emulsions.

INTRODUCTION

Bitumen Emulsion is a suspension in which finely ground bitumen particles are uniformly dispersed in an aqueous medium. Basically there are three types available; Cationic, Anionic and non-ionic depending on the electric charge that the bitumen globules carry.

In Sri Lanka Cationic emulsions are used as the most of the aggregate locally available are acidic. There are several types of surface dressing which are locally available. Bitumen Emulsions are used as the binder in construction of surface treatments other than in asphalt concreting and bitumen bound macadam cum surfacing.

Surface treatment is used as a well-established economical and highly effective method for maintaining the surface of roads. The object of surface treatment is to seal the existing road surface and to arrest disintegration of the road as well as to provide a comfortable surface to its users.

Although the surface treatment is a simple process, in many instances it is difficult to get the required consistence in performance. The properties of binder and aggregate will effect the obtaining of surface treatments of satisfactory consistency in spite of correct construction techniques.

Therefore this research work carefully studies the factors which will affect to the quality of surface treatments giving more attention on the properties of the binder, bitumen emulsion.
PROPERTIES OF BITUMEN EMULSION.

Properties of bitumen emulsion can be classified in two groups; intrinsic properties and extrinsic properties.

Intrinsic properties are the properties of the bitumen emulsions, which are not dependent on the mineral products with which they are used. Viscosity and the storage stability are examples of this kind of properties. Extrinsic properties are the properties of bitumen emulsion relating to its behavior in various fields of use, i.e. the adhesivity and breaking speed.

Storage Stability

Bitumen emulsions are also thermodynamically unstable dispersions as other emulsions. This instability will force the system to minimise its surface free energy, which in turn to gradual decrease of the soap bitumen interfacial surface area. The ultimate stage of this action is the separation of the components into two immiscible separate phases.

The first visible sign is the settling phenomenon which causes sedimentation, the dispersed phase is collected in the lower part or sometimes in the upper portion, i.e. creaming. The difference in density of the two phases is a determining factor of this phenomenon whose speed is governed by Stokes’ Law. The next step is flocculation. This is a reversible process. At this stage each droplet is still protected by a thin film of emulsifier. The final step is coalescence. The globules of bitumen combine within each other due to breaking of the layer of emulsifier surrounded them. The diagram below shows the steps of settling of emulsions in storage tanks.

![Diagram showing steps of settling of emulsions](image)

Figure 1: Settling of bitumen emulsion (source: Leveque Jean, Bitumen emulsions, 1991)
Normally Cationic Rapid setting 2 type of emulsion is used for the construction of Single Bituminous Surface Treatments (SBST) and Double Bituminous Surface Treatments (DBST). It is very important that CRS-2 emulsion should have sufficient strength to withstand on the surface without flowing and hold the aggregate; as such the bitumen emulsion should be less likely to run or sag. Viscosity is the property of bitumen emulsion, which is responsible for this purpose. Higher the percentage of bitumen gives greater viscosity.

**Breaking of Emulsions**

Breaking of emulsion is a process, which takes place in following steps. These steps are

1. The finely ground bitumen particles separates from the aqueous medium. (Sedimentation)
2. Closing up the bitumen particles (floculation)
3. Formation of a compact mass (coagulation)

The following figure shows the breaking process.

![Fig 2a: Sedimentation](image)

![Fig 2b: Floculation](image)

![Fig 2c: Coagulation](image)

Figure 2: Breaking procedure of bitumen emulsion (Source: Leveque Jean, Bitumen Emulsion, 1991)
Setting of Emulsion

At this stage emulsion is in contact with aggregate. And also water separation takes place at this stage. The higher the zeta potential the faster the globules move, and the higher the ionic characteristics the more the setting tendency is evident. The following diagram shows the setting process.

Figure 3: Setting of bitumen emulsion (Leveque Jean, Bitumen Emulsion, 1991)

Curing of Emulsion

Normally this occurs when the emulsion contains volatile diluents. This normally applies to Cationic Medium Emulsion

Adhesion

The ability of adhesion should be explained with regard to a particular aggregate. The laboratory experiments shows that different aggregate shows different degrees of adhesion. This process takes place in two steps; wetting and resistance to stripping. Poor wetting can be recognized by the presence of uncoated surfaces in mixes and early loss of aggregate from surface dressing. The main reason for stripping is water getting in between the layer of coagulated globules of bitumen and the aggregate surface.

It is necessary for the binder to be in contact with the aggregate. To be good with this property the emulsion should not only be sufficiently liquid, but also there are some properties which are governed by the formulation stage and the properties of the constituents of emulsion. This property is called as the active adhesiveness. Another important quality is once the aggregate is coated the film of binder should not be separated by a foreign agent; water. This quality is known as the passive adhesiveness.

METHODOLOGY

Field investigation was carried out on roads where the surface treatments have been completed and on going construction sites and common failure types were identified.

Samples of binder were collected from the sites and from the manufacturing plant and tested according to the accepted standards, (ASTM D244).
Recent past records of the bitumen emulsion were collected and analysed for the properties.

Few samples of aggregate from different quarries were collected and tested for stripping and coating test, (ASTM D1664).

**OBSERVATIONS**

**Storage Stability**

A sample of 134 nos of Cationic Rapid Setting-2 emulsion which were tested within past two years were considered for the study.

The analysis in relation to storage stability and Saybolt furol viscosity shows that 62% of the values satisfy the specification limit, less than 1. However when the storage value is negative there will be a top layer of bitumen as a result of creaming. This layer sometimes may harden at the top in the storage tanks. Therefore further analysis was carried out to search for the samples of which the storage stability is negative. 28% of the values lie in between 0 and -1 and 10% of the values are out of the specification limit greater than 1.

Diagram below shows the of the results of the tests which were carried out on the samples of CRS-2 emulsion which were considered for the study.

![Stability Chart]

Figure 4: Representation of storage stability

**Viscosity**

The analysis of the database shows that 26% of the results are below the lower bound of the specification limits. Only 74% of the results satisfy the specification limits. However according to some specifications the values of viscosity of emulsion should lie in between 150 and 300 Saybolt Furol Seconds.
Figure below shows the analysis of the results.

**VISCOSITY**

- 26% $s < 100$
- 74% $100 \leq s < 400$

$s = \text{viscosity}$

Figure 5: Representation the analysis of viscosity

**Viscosity & Storage Stability**

- 16% $s > 100$ and $st < 1$
- 84% $s < 100$ or $st > 1$

Figure 6: Representation of viscosity and storage stability

Only 16% satisfy both storage stability and viscosity
Figure 7; Graphical representation of viscosity Vs residue

**Adhesion**

Table 1 shows that the area of the aggregate covered with bitumen emulsion, CRS-2 when the test ASTM D 1664 was carried out. The test was repeated at different temperatures using aggregates of different mineralogical composition.

Table 1; Results of the Coating and Stripping test

<table>
<thead>
<tr>
<th>Binder</th>
<th>Type Color Temp°C</th>
<th>Pink feldspar</th>
<th>Hypers thene</th>
<th>White feldspar</th>
<th>Hyper thene</th>
<th>Green/White</th>
<th>Granite Dark green</th>
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<tr>
<td>Bitumen</td>
<td>30</td>
<td>90</td>
<td>95</td>
<td></td>
<td></td>
<td></td>
<td>100</td>
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<td>75</td>
<td>90</td>
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<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>CRS-2</td>
<td>30</td>
<td>95</td>
<td>100</td>
<td>80</td>
<td>80</td>
<td>92</td>
<td>95</td>
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<td>95</td>
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<td>CRS-2</td>
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**DISCUSSION**

**Emulsion storage**

One advantage of bitumen emulsion is its storability for several months. Therefore what is available presently should be able to store for several months. However results of the tests that have been carried on the samples
collected from sites showed that more than 75% samples are out of the specification. In most of the cases the value of the storage stability is greater than 1 indicating that the settling of emulsion takes place in the tanks, which is undesirable.

Another important advantage is that the emulsion can be manufactured at the time of bitumen is received at the manufacturing plant and stored without storing bitumen at an elevated temperature or reheating at the time of using bitumen. Emulsions can be stored at ambient temperatures and no reheating is required. This is because emulsions are environmentally friendly.

Storing can be done at the manufacturing site or at fixed depots close to the construction sites. The tanks should be sufficiently clean otherwise the contaminants may lead settling. Slight agitation of the tanks of emulsions should be done frequently. Vigorous vibration may lead emulsion to break in the tanks.

The formulation of recipe also affects the storing time. For instance in the presence of the less than the required quantity of emulsifier higher settling takes place. The type of dispersed phase, origin of the bitumen, bitumen classification, quantity and the type of the diluent are also other factors, which will affect the storing of bitumen emulsion. The nature of the continuous phase, type and quantity of emulsifier are also the considerable factors in storability of the same.

In some instances, a bitumen film known as skin is formed at the emulsion surface in contact with air. And also during storage it may possible to have a variation in bitumen content. The amount and speed of settling and creaming increase with storage time. Size of bitumen droplets, greater difference in density between the bitumen and the aqueous phase are also some important factors in this regard. Normally density slightly greater than water density indicates settling and slightly less than water density indicates creaming. However these two phenomena are not that dangerous unless otherwise coagulation does not take place. Slight mixing before applying will recover to a uniform dispersion or make the emulsion homogeneous.

Finally mixing of different types for instance, CSS & CRS emulsions is to be avoided as immediate flocculation may possible. When flocculation occurs in tanks, it is recommended to wash with steam.

**Viscosity**

The prime factor governing viscosity is the concentration of the dispersed phase, bitumen. There is an exponential relationship in between the bitumen content and the viscosity (Fig 7). The type of bitumen, origin of the bitumen, penetration of the bitumen, presence and percentage of solvent will affect the viscosity. The nature of the continuous phase, type and quantity of the emulsifier also affect this property. The particle size distribution, size of the bitumen particles, mill type of the manufacturing process unit also plays an important role in this regard.
Fig 7 shows that when the binder content increases from 55% to around 65% there exists a limited increase in viscosity. However when the binder content increases above 65% there is a considerable increase in viscosity even for a slight increase in binder content. This makes manufacture and use of highly concentrated bitumen emulsion is difficult.

Normally the continuous phase mainly consists of emulsifier and some other inorganic chemicals. As the presence of the chemicals the viscosity of this phase is not that as water. The value is higher than that of water but depends on the type of the soap. Higher viscosities of the emulsifier increases the viscosity of emulsion in turn. Experience in laboratory experiments experienced that certain soaps caused gel formation increasing considerable increase in viscosity and in turn the increase in viscosity of emulsion.

**Cohesiveness**

There is an important property known as the binder internal cohesion, which gives an idea about the shear strength. This property depends on several factors of which the viscosity is the main factor. Cohesiveness has an optimum value corresponding to a given viscosity range which also depends on the temperature. Therefore at a certain temperature the binder becomes hard and at some temperature the binder becomes fluid and soft. Hence resistance to traction forces will be less if it exceeds a certain temperature.

The property which should be obtain is that the binder should be fluid so that it should spread over the aggregate and also should be sufficiently solid to resist the impact load generated by traffic. However this property depends on the road temperature.

**CONCLUSION**

Storage stability, viscosity and adhesivity are the most important properties in relation to surface treatments. Proper storing facilities should be provided at construction sites as to maintain the homogeneity of emulsion without settling in storage tanks. Poor storing will lead to variations in viscosity with perhaps less viscosity and less residue at the top of the tanks leading to high percentage of whipping off aggregate from the road surface.

Adhesiveness of bitumen emulsion varies with the mineral composition of aggregate. It is very practical to get the mixes of aggregates consisting of different mineral composition in construction sites. If there is aggregate having the high rate of stripping the consequence will be the whipping off aggregate. Therefore testing should be done at the laboratory for assessing the stripping considering the temperature as one variable as the rate of stripping varies with temperature. Necessary actions such as adding adhesive promoters should be proposed as required. Modification to bitumen emulsions should be done if necessary.
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