

## Chapter II

### LITERATURE REVIEW

#### 1. Asphalt Emulsion Stabilization

The highway construction industry has used asphalt emulsions extensively for road building and road maintenance for 45 years. Emulsified asphalts offer many advantages over paving-grade asphalts and liquid asphalts. They can be used directly with wet or damp aggregates with much less danger of obtaining a poor coating of asphalt on the aggregate. Usually, they are fluid even at ambient temperatures and, therefore, do not require special equipment to heat them. Because of these factors, emulsified asphalts offer a more economical and convenient means of road construction and maintenance.

Two main categories of emulsion exist. The first is the more commonly used "anionic" emulsion, the development of which took place in the 1930's. The other, more recently developed, is "cationic" emulsion, which was first prepared in Europe and has been used in the United States since 1958. Reviews of the theory of emulsions and asphalt emulsion-aggregate systems as shown in Mertens and Wright (1959) are:

##### 1.1 Theory of Emulsification

An emulsion may be defined as an intimate mixture of two immiscible liquids, one of which is dispersed in the other in the form of very fine droplets.

If a pure oil, such as kerosine, is broken up into droplets and suspended in water, it is clear that this operation markedly increases the area of the interface between the oil and water and

correspondingly increases the total amount of free energy in the mixture. The suspension is, in fact, an oil-in-water emulsion, but tends to separate rapidly into bulk oil and water so that the interfacial area and free energy fall to a minimum. However, if the oil is broken up into droplets in water which contains a suitable emulsifying agent capable of reducing substantially the interfacial energy and interfacial tension and also forming a protective film round the oil droplets, the emulsion will be stable and will not separate into bulk oil and water. Since bitumen can be regarded as a type of highly viscous oil, the same consideration can be applied to bitumen emulsions in which some 30-70 % of bitumen is dispersed as droplets in a continuous water phase containing a suitable emulsifying agent.

An emulsifying agent for the manufacturing of bitumen emulsions must have special solubility characteristics; that is, it must be compatible with both the oil and water phases. This is possible if the molecules of the emulsifier possess both polar and non-polar portions. If upon ionization the nonpolar or organic portion of the molecule, which governs its property as an emulsifying agent, contains the negative charge, the agent is called anionic and the bitumen droplets bear a negative charge. Conversely, if the organic portion of the molecule contains a positive charge, then the emulsifier is cationic and the bitumen droplets bear a positive charge. When the bitumen droplets are formed in water containing an emulsifying agent, the latter forms a layer of surface active molecules at the bitumen interface approximately one molecule in thickness, this

being accompanied by a marked lowering of the interfacial energy and modification of the charge on the interface. The surface active molecules are "absorbed" at the interface where they orientate themselves with the organic portion or hydrophobic-ion wetted by the bitumen and the inorganic portion or hydrophilic-ion of the opposite charge still dissolved in the water. As explained earlier, it is therefore possible to produce anionic or cationic bitumen emulsions by the proper selection of the emulsions.

### 1.2 Emulsion - Aggregate Systems

An electropositive aggregate such as dolomite and some limestones, is known to form a strong bond when used with an anionic emulsion, and an electronegative aggregate such as silica, quartz, and most gravel is good coating and adhesion obtained when used with a cationic emulsion. This can be further clarified as follows: For anionic asphalt emulsions, the emulsified particle carries a negative charge and is attracted to the positively charged surface of the limestone, where the charges neutralize each other. The anionic emulsifier absorbs on the aggregate surface and acts as a bonding agent or "bridge" between the aggregate and the asphalt. As a result, the asphalt plates out on the aggregate surface and a good bond is established even if the aggregate is wet. On the other hand, siliceous aggregates, being negatively charged on the surface, repel the negatively charged particles of anionic emulsions. No charge neutralization takes place, the anionic emulsifier can not function as a bonding agent; and the emulsion drains off the aggregate instead of plating out. Thus, the anionic emulsified asphalt usually work poorly with siliceous aggregates.

By reversing this reasoning, when cationic asphalt emulsions are used with siliceous aggregates, a positively charged particle of cationic emulsion is attracted to the negatively charged surface of silica or quartz and the desired charged neutralization results. In this case the cationic emulsifier functions as the bonding agent and good adhesion is obtained. On the other hand, limestones and dolomite that are strongly positive charged show poor adhesion with cationic emulsions because of like charges.

Either an anionic or a cationic emulsion can be used with some aggregate, such as certain basalts. The cationic emulsions seem to be more versatile, for they can be used over a somewhat broader range of aggregates than the anionic emulsions.

### 1.3 Mixing - Grade Classification

The grades of asphalt emulsion are identified by the Asphalt Institute, USA. (1965) as:

#### Anionic Series

RS-1

RS-2

MS-2

SS-1

SS-1h

#### Cationic Series

RS-2K

RS-3K

SM-K

CM-K

SS-K

SS-Kh

The asphalt residues from the anionic rapid, medium, and slow setting emulsions (RS, MS, SS) have a penetration varying from 100 to 200 with the exception of SS-lh which has a slightly harder asphalt (penetration 40 to 90). The cationic emulsions have residues of similar penetration. The rapid and medium setting cationic emulsions have a residue of penetration ranging from 100-250 while the slow setting (SS-K and SS-Kh) have a residue of penetration ranging from 100-200 and 40-90 respectively. "K" has been added to the cationic emulsion nomenclature to distinguish it from the anionic and the emulsions designated by "h" have a penetration on residue of 40-90.

2. Asphalt Emulsion Systems Used for Base Stabilization

Asphalt emulsion has successfully stabilized a wide variety of aggregate types for use as bases under hot asphaltic concrete pavement. American Road Builders' (1948) reports projects involving approximately 2,743,000 sq. yd. of asphalt emulsion base over widely separated parts in the United States. Chevron Asphalt Company (1967) also report many similar projects. In Thailand, however, emulsified asphalt bases had been successfully used recently (Thai Highway Department, 1973). According to Chevron Asphalt Company (1967), asphalt emulsion systems used for base stabilization are presented as follows:

## 2.1 Asphalt Emulsion - Aggregate Combinations

Four **basic** requirements must be met in order to impart the cementing and water-proofing qualities of asphalt emulsions to the aggregate mixture these are :

- a. Uniform dispersal of the asphalt throughout the mix.
- b. Adequate coating of the aggregate by the emulsified asphalt
- c. Good adhesion of the asphalt to the aggregate so that action of water and traffic will not cause stripping and loss of mix tensile strength.
- d. High tensile strength within the asphalt film.

## 2.2 Coating

It is necessary for the asphalt to adequately coat the aggregate in order to achieve waterproofing and tensile strength. Generally, sands are easily coated with asphalt emulsions. With graded aggregates, it may be difficult to completely coat some of the large particles.

Satisfactory mixes need not be completely coat with asphalt emulsion to achieve the desired performance. Less than a 100 % coating of the coarse particles does not effect the desired end result if the fine matrix of the mix is uniformly coated. During the compaction process, the filler emulsion matrix generally surrounds the large aggregate particles.

### 2.3 Development of Tensile Strength (Rate of cure)

Asphalt emulsions are manufactured with different degrees of mechanical and chemical stability. The rapid development of tensile strength is necessary if the stabilized base is to develop its full support capacities. In most instances the SS type emulsions develop tensile strength at a faster rate than the SM type emulsions.

### 2.4 Selection of the Design Asphalt Emulsions Content

Selection of type and amount of emulsion is made according to the following bases :

- a. Resistance to water absorption.
- b. Resistance to stripping and loss of adhesion in the presence of water vapor.
- c. The stability and tensile strength of the asphalt emulsions treated sample.

The stability and tensile strength of the asphalt emulsions treated sample were determined by using Hveem stabilometer and cohesiometer tests. Method of testing according to Chevron Asphalt Company was known as "Standard" method. In order to determine the resistance to water absorption and resistance to stripping and loss of adhesion in the presence of water vapor, the Mixture Vapor Susceptibility test (M.V.S. test). was used.

### 2.5 Mix Design Criteria

In establishing the MVS R-value for asphalt bases, Chevron Asphalt Company followed the concepts developed by State of California Materials and Research Laboratory. In adapting the test procedures for asphalt treated bases, the following assumptions were made : (FINN, HICKS, KARI and COYNE, 1968)

1. The State of California untreated R-value test used in design of untreated aggregate bases is correlated to field performance. The conditions of MVS design test method on untreated aggregate were set such that the R-value results after MVS were equal or near to the standard State of California R-value. It was assumed that this provide a tie-in between the MVS. R-value Test Method and field performance.

2. HVEEM and DAVITS (1950) suggested that a factor of 0.05 times the Cohesimeter Value (0.05 X C-value) assigned to the tensile strength of the asphalt mix is reasonable. This assumption is not entirely correct since the influence of cohesion will vary, depending upon load, temperature, thickness of the base, and possibly load repetitions. However, use of the C-value factor provides a means for comparison of the asphalt treated base with an untreated base. In this way, it is possible to obtain an indication of the improvement anticipated with asphalt treatment.

Table 1 Design Criteria for Base Course

Requirement from Chevron Asphalt Company

Test property	Method of test	Test requirement
Resistance Rt Value (R+0.05C) after moisture vapor susceptibility (M.V.S.) - for light and medium traffic, DTN under 100* - for heavy and very heavy traffic, DTN over 100*	Chevron Asphalt Company Method 67B - 307	70 min  78 min
Moisture pick up during M.V.S.test,%	Chevron Asphalt Company Method 67B - 307	5.0 max

\* The Asphalt Institute Thickness Design Manual (MS-1), 1963



### 3. Penemulsion Stabilization

Penemulsion, invented in the United States in 1961, is a cationic, low penetration, "SS--Khh" grade, asphalt emulsion. The Penebase or base stock is produced by a special refining process, which removes all oily constituents (commonly known as gas oils) resulting in a very low (maximum 18) penetration asphalt. Penemulsion was especially developed for base stabilization and secondary road construction.

Twin City Testing Laboratory (USA), 1974 tested fine grained sand stabilized with Penemulsion and a similar asphalt emulsion (SS-K) by the Marshall Stability Test Method. The results show that the peak Marshall stability produced by the Penemulsion mixture was approximately six times that of the SS-K mixture after 7 days curing. The optimum asphalt content to produce the maximum Marshall strength was determined to be at a residual asphalt content of 6 % for both emulsion products.

A few laboratory investigations in Penemulsion were designed in the Republic of the Philippines in 1974.

Thailand, Penepime International Inc. sent samples of Penemulsion to Thai Highway Department for field and laboratory testing in 1975.