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CATIONIC SURFACTANTS IN ASPHALT ADHESION

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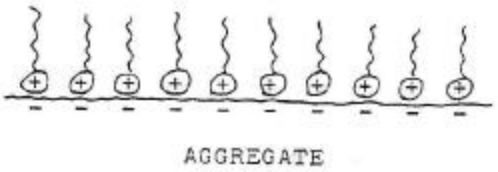
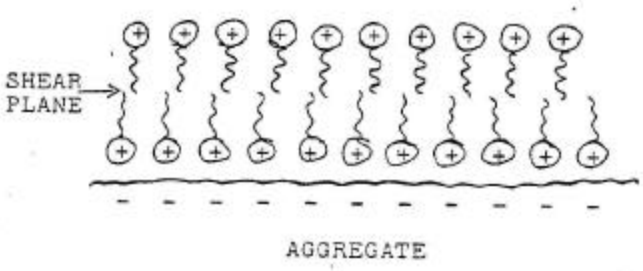
The concept of using cationic surfactants to promote adhesion between asphalts and aggregate is conceptually sound. The mining industry has, for more than fifty years, used and is using the concept of preferential cationic surfactant adsorption by mineral surfaces in flotation ore separation processes. The water treatment industry routinely uses the electrophoretic concept of cationic adsorption by suspended solids in flocculation and filtration methods of water purification. Zeta Potential relationships between the intensity of negative surface charge on the mineral and its surface area and the intensity of positive charge of the cationic surfactant are routinely measured and used as the criteria for pre-selection of the most effective surfactant.

The substantive action of these surfactants is to migrate to the aggregate as the adsorbing cathodic surface. These oil-soluble cationic surfactants, upon migration to and adsorption by an aggregate surface, displace surface water in favor to themselves and render that surface hydrophobic and lipophilic. The degree of hydrophobicity and lipophilicity obtained is proportional to the concentration of chemical surfactant used, the efficiency of migration and the force or strength of the adsorbing bond.



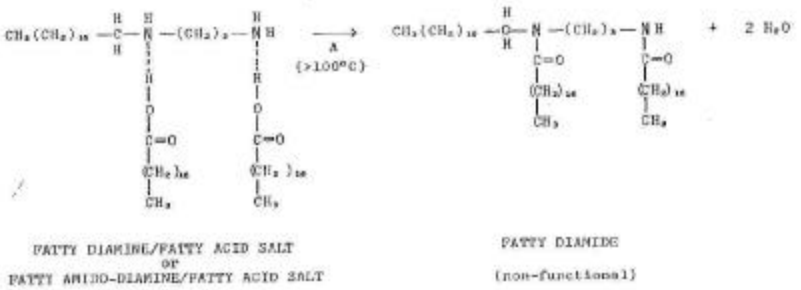
SURFACE CHARGE SATURATION



SURFACE CHARGE OVER-SATURATION

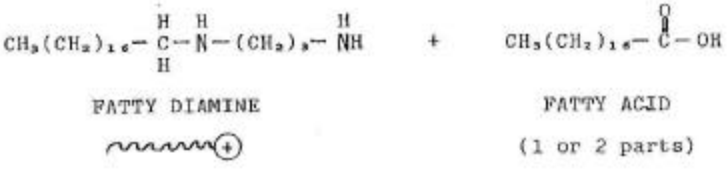
The following chemical structures characterize the two major types of surfactants in current commercial use as adhesion-promoting anti-stripping agents. When their reactive amino

hydrogens are present, these fatty diamine and amido-diamine salts are susceptible to thermal degradation at temperatures of 100C and above to a non-functional fatty amide form. Their reactive amino hydrogens are replaced by chemical substitution reaction with alkyl radicals to engender thermal stability at normal asphalt cement storage temperatures.



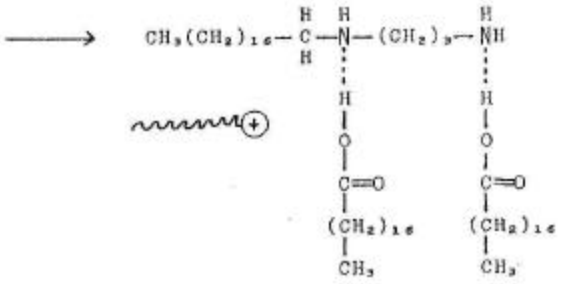
FATTY DIAMINE/FATTY ACID SALT
or
FATTY AMIDO-DIAMINE/FATTY ACID SALT

FATTY DIAMIDE
(non-functional)



FATTY DIAMINE

FATTY ACID
(1 or 2 parts)



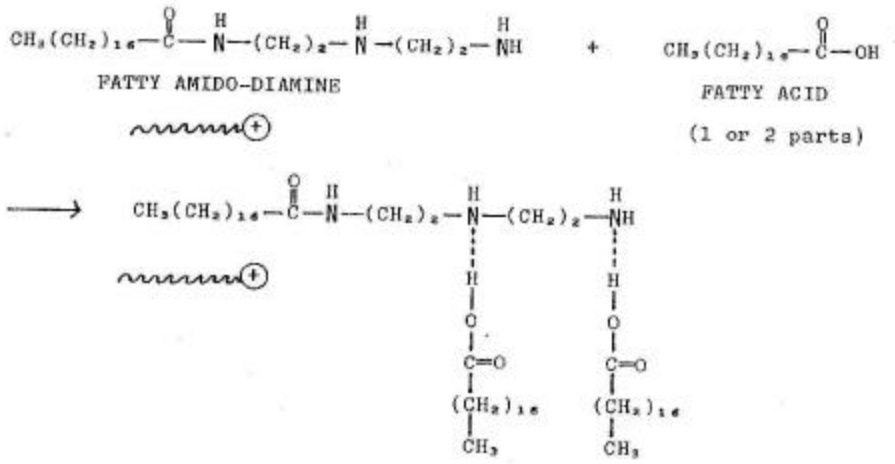
FATTY DIAMINE/FATTY ACID SALT

100% ACTIVE - OIL SOLUBLE

(Functional Anti-Stripping Agent)

$-CH_3$; $-C_2H_4OH$; $-C_3H_6OH$

THERMAL STABILITY SUBSTITUTIONS OF AMINO HYDROGEN



After the hot mixtures are placed as pavement it is conceivable that, with time at sufficiently high pavement temperatures, the dissolved adhesion-promoting anti-stripping agent could continue to migrate to the asphalt/aggregate interface. If the concentration of chemical dissolved in the asphalt is in excess of that needed to satisfy all of the aggregate's adsorption sites, hydrocarbon to hydrocarbon interfacial orientation can occur creating a mechanically weak, water susceptible, shear plane. This potential occurrence emphasizes the need to accurately select that concentration of anti-stripping agent which most effectively and efficiently fulfills the adsorption demands of the job aggregate with time.

The current method of addition of anti-stripping agents to asphalt cement to promote adhesion and prevent the subsequent deleterious effect of water in hot paving mixtures is a very inefficient practice. While sufficiently effective if enough of the agent is used, the majority of anti-stripping agent initially added to the asphalt cement never reaches the asphalt/aggregate interface where it should be to obtain optimum performance. These oil soluble agents, to be effective, must migrate to the asphalt/aggregate interface through the layer of asphalt surrounding the aggregate while the asphalt is at a sufficiently low viscosity to allow such migration. In conventional hot mix practice, the time during which the asphalt is at a sufficiently low viscosity to allow the dissolved anti-stripping agent to migrate to the aggregate interface is while it is still hot. In many instances, this time period is less than three hours. Upon cooling, the increase in asphalt viscosity is of sufficient magnitude to greatly retard and even halt chemical migration. At this point the amount of chemical that reached the aggregate interface while the asphalt viscosity was sufficiently low is just about all that will ever reach that interface. In a typical hot mix, unless the mix is kept hot for a much longer time (ca 12 hours), only approximately 30-40% of the original concentration of anti-stripping agent i~ performing in the proper manner. Elution of additive with hot Isopropyl Alcohol from asphalt cement scraped

from smooth-surface aggregate substantiate the time required at mix temperature for efficient migration to occur. The majority of anti-stripping agent is still in solution in the asphalt layer. By comparison, anti-stripping a-gent added to cutback is much more efficient than in hot mix. The substantially lower viscosity of the cutback can, with time, allow as much as 80-90% of the original concentration to reach the aggregate interface. These rate and efficiency of migration differences, aside from thermal stability factors, can explain why concentrations of anti-stripping additives for cutback range from 0.3% to 0.5% for most uses while their use in hot asphalt cement often exceed 1% basis weight of asphalt.

The most efficient and effective means of improving adhesion of asphalt to aggregate is to apply the adhesion-promoting material directly to the aggregate prior to its being mixed with asphalt cement. This can be done with two materials both of which involve a separate aggregate pre-coating procedure.

One is to apply the anti-stripping agents now being used, dissolved in a suitable solvent, directly to the aggregate by means of a dryer drum with mild heat to volatilize the solvent. A preferable alternative would be to use the more efficient water-soluble cationic homologues that would impart the same pretreatment effect of the oil soluble cationic anti-stripping agents. In this use only water would have to he removed.

GLOSSARY

SURFACTANT - SURFACE ACTIVE AGENT; REDUCES SURFACE TENSION OR INTER-FACIAL TENSION; (e.g., DETERGENTS, WETTING AGENTS, EMULSIFIERS)*

HYDROPHILIC - HAVING AN AFFINITY FOR WATER*

LIPOPHILIC - HAVING AN AFFINITY FOR OIL*

ADSORPTION - TAKING UP OF DISSOLVED MATTER BY THE SURFACE OF A SOLID*

ADHESION - STICKING FAST TO A SURFACE; ASPHALT TO AGGREGATE**

COHESION - STICKING OR HOLDING TOGETHER; ASPHALT TO ASPHALT **

ELECTROPHORETIC MOBILITY -- ELECTROPIHORESIS; RATE OF MIGRATION TOWARD ELECTRODE OF CHARGE OPPOSITE TO THAT OF PARTICLES*

ZETA POTENTIAL - (ELECTROKINETIC POTENTIAL) THE POTENTIAL ACROSS THE INTERFACE OF ALL SOLIDS AND LIQUIDS (CAN BE CALCULATED FROM ELECTROPHORETIC MOBILITIES)*

* Condensed Chemical Dictionary (Tenth Edition - 1981)

** American Heritage Dictionary of the English Language (1971)