

Cationic Mixing-Grade Asphalt Emulsions

M. J. BORGFELDT AND R. L. FERM

Respectively, American Bitumuls and Asphalt Company, Emeryville, Calif., and California Research Corporation, Richmond, Calif.

Cationic asphalt emulsions were introduced in the United States in 1958 for seal coat construction. Their advantages over anionic emulsions gained rapid recognition in the highway construction industry. Recently, mixing-grade cationic asphalt emulsions were made available. The unique properties of these new materials are expected to increase greatly the versatility and usefulness of mixing-grade emulsions in highway base and wearing course construction.

The fundamental physical and chemical properties of aggregate-asphalt emulsion systems are discussed in relation to mixing performance. The advantages in adhesion, dehydration rate, and development of cohesion obtained from cationic emulsifiers in such systems are presented.

Definite field performance advantages of cationic emulsions over anionic emulsions and liquid asphalts include greater permissible variations in aggregate moisture content and mixing temperature and, the ability to compact without excessive reduction of moisture content. These benefits are obtained in all types of emulsion construction and maintenance work. Recommended specifications for two types of cationic mixing-grade emulsions are presented for the first time.

• BEFORE 1958, essentially all asphalt emulsions used for road surfacing and construction in the United States were of the anionic type. The most important characteristic of anionic emulsions is that the emulsified asphalt particles carry negative electrical charges. These charges arise from the ionization of surface active organic acid salts at the asphalt-water interface. The organic acids may occur naturally in the asphalt or may be added as auxiliary emulsifiers. The various types of anionic emulsifiers have been adequately described (1).

Cationic asphalt emulsions are the electrical opposites of anionic emulsions. The emulsified asphalt particles

in cationic emulsions are positively charged. Cationic emulsifiers never occur naturally and must always be added, either to the asphalt or to the water component, before emulsification. Most cationic emulsifiers are acid salts of organic amines or organic quaternary ammonium compounds. Typical cationic emulsifiers suitable for emulsifying asphalt have been reported by Dybalski (2) and in the patent literature (3).

The importance of emulsion particle electrical charge for the adhesion of emulsified asphalt to mineral aggregates has been emphasized by several investigators (4, 5, 6). Most aggregates are either siliceous or contain a large proportion of silicate-

type minerals (7, 8) and, hence, become predominantly negatively charged when moist (4, 5). Cationic emulsions, therefore, adhere considerably better to the majority of construction aggregates than do anionic emulsions (9, 10).

Early in 1958, cationic emulsions, designated as the RS-K grades, were introduced for seal coat construction in the United States. In Europe, the cationics have been used to a minor extent since the early 1950's (11). The field performance of the RS-K emulsions has fulfilled the expectations predicted from their chemical nature (12, 13).

Last year cationic mixing-grade asphalt emulsions were introduced. The benefits of the cationic-type emulsion were thereby extended to a wide variety of highway construction practices. This paper describes field and laboratory data which indicate promise for these new materials in sand, dense-graded, and coarse aggregate mixing.

FACTORS CONTROLLING MIXING PERFORMANCE

The most important characteristics of an asphalt emulsion-aggregate mixture begin to develop when the emulsion starts to set or coalesce. Thus, mixing stability, rate of set or cure, degree and performance of aggregate coating all depend on the relative magnitude and rate of change of two forces that begin operating at that time. These are the force of cohesive strength in the asphalt or coalesced emulsion phase and the adhesive force at the asphalt-aggregate interface. If the emulsion breaks too rapidly and either the cohesive or adhesive forces are very large, the mix will lack stability or mixability. When the cohesive forces are greater than the adhesive forces, the mechanical stresses of mixing cause the asphalt or coalesced emul-

sion phase to assume a minimum surface area and ball up. Thus, if, during the process of mixing, the forces become overbalanced in favor of cohesion, asphalt adhering to the aggregate will be stripped away. Stripping failures of this type can be demonstrated easily by vigorous laboratory mixing tests on certain aggregate-emulsion systems. Therefore, in the initial phases of mixing, it is desirable that the adhesive forces be relatively strong and the cohesive forces remain weak. However, when the mix is placed, the cohesive forces must increase at a fairly rapid rate so that the pavement will cure within a satisfactory time.

Emulsion coalescence or rate of set is mainly caused by two phenomena: attractive forces between the asphalt emulsion droplets and aggregate surface, and the transfer of the emulsifier from the emulsion droplets to the aggregate surface. In the first case, emulsion droplets in Brownian motion strike the aggregate surface and adhere because of ionic forces of attraction. In the second case, emulsifier molecules desorb from the asphalt emulsion droplets to the aqueous phase and to the aggregate surface (14). If the capacity of the aggregate surface for adsorption is large, a sufficient amount of emulsifier may be transferred to destroy the stability of the emulsion. Both emulsion coalescence mechanisms are highly dependent on the type of emulsifier and its concentration. The surface area and chemical composition of the aggregate are also important. Generally, the larger the aggregate surface area, the greater the difficulty of obtaining sufficient emulsion mixing stability. Thus, the porosity of aggregates and percentage of fines influence the mixing performance with asphalt emulsions.

The correlation between aggregate surface area and the ease of coating several different sands with a cationic asphalt emulsion is given in Table 1,

TABLE 1
SURFACE AREA, ELEMENTAL COMPOSITION AND EASE OF COATING
WITH SM-K CATIONIC ASPHALT EMULSION FOR SEVERAL SANDS

Sand	Surface Area (m ² /g)	Major Metallic Constituents (% by wt.)						Ease of Coating
		Na	Mg	Ca	Ti	Fe	Al	
Arizona dune	4.0	3.21	0.48	0.70	0.16	1.99	2.98	Difficult
Ann Arundel	1.2	0.19	0.02	0.08	0.09	0.35	0.47	Difficult
Del Monte	0.21	3.01	0.02	Nil	Nil	0.08	3.11	Easy
Mississippi River	0.03	2.95	0.35	0.35	0.07	1.41	2.84	Easy
Ottawa reference	0.01	0.24	0.02	Nil	Nil	0.14	0.02	Easy

which also gives the amounts of major metallic constituents present in these sands as determined by spectrographic analysis. Surface area rather than variations in chemical composition appears to determine the ease of coating with the emulsion. The surface areas were determined by the nitrogen adsorption method of Brunauer, Emmett, and Teller (15) after the sands were dried to remove moisture.

Cationic asphalt emulsions adhere well to a wider variety of aggregates of different chemical composition than do anionic emulsions. Adhesion results with anionic emulsions are often poor with siliceous aggregates and with some "mixed-type" aggregates; best results are obtained when using highly calcareous or dolomitic aggregates. Cationic emulsions, on the other hand, adhere satisfactorily to all but a few aggregates; *e.g.*, dolomitic materials (10).

Differences in electrophoretic mobilities may explain the differences in the adhesion of anionic and cationic emulsions with "mixed aggregates." Electrophoretic mobilities determined (in unpublished studies by the American Bitumuls and Asphalt Company) for cationic RS-grade emulsions were up to twice as large as for anionic RS-grade emulsions.

Asphalt emulsion adhesion to clay mineral surfaces is particularly important in base stabilization. Aggregates available at the job site for road base construction often contain clay. The swelling tendency of most clays

has, in the past, precluded the use of such aggregates with anionic emulsions. Frequently, suitable aggregates had to be transported long distances to the site. Trouble-causing clays are usually of the montmorillonite type that consists of laminar crystal structures weakly bonded together. Water easily enters the interlaminar spaces and causes swelling (16). Cationic mixing grade emulsions are shown in a later section to be effective agents for stabilizing such aggregates. Presumably, this is because water is prevented from entering the interlaminar spacings.

The nature of the asphalt itself is also an important factor in the adhesive-cohesive force balance. The viscosity of the asphalt has considerable influence on the mix cohesive strength. The softer the asphalt, the less difficulty is encountered in coating aggregates. However, ultimate strength requirements sharply limit the permissible variations of asphalt viscosity.

The cohesive properties of the asphalt or coalesced emulsion phase can, fortunately, be regulated easily by a simple method. Inclusion of small quantities of naphtha cutter stock in the emulsion formula increases mixing stability and improves aggregate coating. After the mix is compacted, this relatively minor amount of cutter stock evaporates readily to give a rapid cure. The considerably larger amount of cutter stock present in cutback asphalts is vaporized only slowly and less com-

pletely under comparable conditions (17).

Water is easily dispersed in the asphalt phase of emulsion-aggregate mixtures and, like cutter stock, also reduces the cohesive strength. Water is, however, sometimes quite difficult to evaporate completely from the final mix. This is particularly noticeable in cool, moist weather. In some instances, extensive blading operations are needed to dehydrate anionic paving mixes satisfactorily before they can be compacted. Cationic emulsions dehydrate and cure at considerably faster rates than do anionics. This is an important advantage when aggregates containing variable and excessive amounts of moisture must be used. Cationic emulsion performance is, therefore, less sensitive to ambient temperature extremes during construction.

MIXING-GRADE CLASSIFICATION

The two types of cationic mixing-grade emulsions described in this paper are designated SM-K and SS-K. The SM-K type was named to indicate its principal use, which is sand mixing; graded aggregate mixing is another important use. The SS-K type is the cationic equivalent of the presently used anionic SS (slow setting) emulsions. The SS-grade emulsions are used principally for slurry seal maintenance, base stabilization, and tack or prime coats.

The specifications recommended for these two new products are given in Tables 2 and 3, respectively. Typical properties for the products now commercially available are also shown. These are the properties of the SM-K and SS-K emulsions used in the present studies. The particle charge test used in the SM-K specification is a relatively new test method described by Mertens, Coyne, and Rogers (10) that is used to indicate the cationic character of the emulsion.

The stability and other properties of the SM-K type emulsion are intermediate between the anionic MS (medium setting) and SS emulsion grades. To a certain extent, SM-K emulsions combine the properties of cutback asphalts and SS emulsions and are designed to replace these two materials in road and central plant mixing. SM-K mixes with and coats satisfactorily either wet or dry aggregates. The presence of a minor amount of cutter stock in SM-K formulations gives workability with dry aggregates. The ability to produce mixes that can be immediately compacted without aeration and which develop high, early cohesion are particularly noteworthy features of SM-K emulsions (18).

The SS-K emulsions meet all existing anionic SS specifications. Certain additional benefits are obtained by virtue of their cationic nature. Adhesion is improved and is 90 percent or better with all currently used emulsion adhesion tests (according to unpublished studies by the American Bitumuls and Asphalt Company). Pumping stability is better than for anionics. Dehydration of the finished mix is more rapid than with anionics.

Both specifications include product performance tests, which acquaint consumers with the performance properties of the new materials.

COMPARISON OF SM AND SM-K EMULSION WITH CUTBACK ASPHALTS

The SM-K emulsions were designed for use in aggregate mixing work, either at the road construction site or in a central plant. They offer many benefits not available with the conventional binders, anionic emulsions, and cutback asphalts (19). These include ease of mixing, ability to coat wet or dry aggregates, faster setting rates, and greater resistance to the deleterious effects of moisture.

TABLE 2
RECOMMENDED SPECIFICATIONS AND TYPICAL INSPECTIONS FOR SM-K EMULSION

Test	Method	Requirement	Typical
Residue (by distillation) (%)	ASTM D 244-60	60 ^a	61.0
Oil distillate (% by wt.)	Calculated ^b	15 ^c	15.0
Viscosity (SSF at 122 F)	ASTM D 244-60	50-500	157.
Sieve (% retained on No. 20 mesh)	ASTM D 244-60 ^d	0.10 ^c	0.01
Particle charge	Described by Mertens et al. (10)	Positive	Positive
Settlement (7 days) (%)	ASTM D 244-60	3.0 ^c	0.2
Sand-coating water resistance (% coated):			
Dry job aggregate	— ^e	80 ^a	95
Wet job aggregate	— ^e	60 ^a	85
Distillation residue:			
Penetration at 77 F, 100 g, 5 sec	ASTM D 5-52	50-250	90
Solubility in CCl ₄ (or C ₂ HCl ₃) (%)	ASTM D 4-52 ^f	98 ^a	99.1
Ductility (cm)	ASTM D 113-44 ^g	80 ^c	140 +

^a Minimum.^b From volume and specific gravity of distillate obtained in residue determination.^c Maximum.^d ASTM Method D 244 procedure modified by replacing sodium oleate solution with distilled water.

^e Aggregate (465 g) and emulsion (35 g) are mixed vigorously for 3 min with spatula in metal pan. After mixture has cured 30 min at room temperature, it is drenched with cold tap water. Mixture then dried by exposure to an electric fan. When surface is dried, percentage of total aggregate surface coated is estimated immediately.

^f Procedure modified by substituting carbon tetrachloride or trichloroethylene for carbon disulfide.^g Run at 77 F for 100 to 200 penetration asphalt and at 60 F for 200 to 250 penetration asphalt.

TABLE 3
RECOMMENDED SPECIFICATIONS AND TYPICAL INSPECTIONS FOR SS-K EMULSION

Test	Method	Requirement	Typical
Residue (by distillation) (%)	ASTM D 244-60	58 ^a	61.2
Viscosity (SSF at 77 F)	ASTM D 244-60	20-100	25
Sieve (% retained on No. 20 Mesh)	ASTM D 244-60 ^b	0.10 ^c	0.01
pH	ASTM E 70-52T	6.5 ^c	3.9
Cement (% broken)	ASTM D 244-60	2 ^c	Trace, < 0.1
Adhesion (% coated)	— ^d	90 ^a	95 +
Settlement (7 days) (%)	ASTM D 244-60	3 ^c	1.0
Coating	— ^e	— ^f	Passes
Distillation residue:			
Penetration at 77 F, 100 g, 5 sec	ASTM D 5-52	40-200	120
Solubility in CCl ₄ (or C ₂ HCl ₃) (%)	ASTM D 4-52 ^g	97 ^a	97.5
Ductility (cm)	ASTM D 113-44 ^h	40 ^a	80

^a Minimum.^b ASTM Method D 244 procedure modified by replacing sodium oleate solution with distilled water.^c Maximum.

^d Job aggregate (100-g sample), properly graded to pass $\frac{3}{8}$ -in. sieve and be retained on No. 4 sieve (for fine aggregates, fraction passing No. 4 sieve and retained on No. 30 sieve is used), and emulsion (10 g), are mixed in 16-oz tin with stirring rod. Mixture held at 200 F for 24 hr and then thoroughly remixed. A 50-g portion of mixture is stirred with 400 cc of boiling distilled water in 600-cc beaker for 1 min. Mixture then air dried on absorbent paper. Percentage of total aggregate surface area coated is estimated immediately.

^e Sample of the job aggregate passing No. 4 sieve placed in the mixing bowl of mechanical mixer of planetary type (Readco Model P-12 or equivalent). Sufficient water, if necessary, added to darken aggregate. Desired amount of emulsion added and mixture stirred until uniform coating is obtained.

^f Must mix with dense graded job aggregates without breaking, balling, or segregation.^g Procedure modified by substituting carbon tetrachloride or trichloroethylene for carbon disulfide.^h Run at 77 F for 100 to 200 penetration asphalt and at 60 F for 200 to 250 penetration asphalt.

Anionic asphalt emulsions present several problems that have hindered their use in central plant mixing. They will not coat most dry, graded aggregates, and the amount of water needed is usually greater than de-

sired at compaction. Long periods of curing at the road site are, therefore, required. Cutbacks, even in the presence of adhesion agents, will not coat wet, graded aggregates very well. The SM-K emulsions overcome both

these difficulties and coat either wet or dry aggregates equally well. Aeration is greatly reduced or entirely eliminated. Because no heat is required for drying aggregates, higher pugmill production rates are possible.

The advantages of SM-K emulsions over an RC-3 cutback containing an adhesion agent for graded-aggregate mixing are illustrated by the following tests with an aggregate from Josephine County, Ore. Two series of mixes were made without the addition of water and with equivalent amounts of SM-K emulsion or RC-3 cutback to furnish 4 and 5 percent binder content by weight. After compaction, all the samples were cured for 15 hr at 140 F. *S*-values were then determined in the Hveem stabilometer (20). The *S*-value is a measure of the stability or supporting power of asphalt-aggregate mixtures and of their ability to resist deformation under load. The *S*-values for the SM-K emulsions were 36 and 27, respectively, and the RC-3 mixes gave values of only 12 and 14. Two more mixes were then made, each containing 4.8 weight percent water and an amount of SM-K or RC-3 equivalent to 7 weight percent binder. The *S*-value of the SM-K mix was 22, but the RC-3 mix disintegrated before the test could be run. The aggregate used in these tests had a sand equivalent (21) of 56 and the following grading:

Sieve Size	Weight Percent Passing
1-in.	100
¾-in.	98
½-in.	77
⅜-in.	64
No. 4	44
No. 10	34
No. 40	16
No. 80	8
No. 200	4

A series of Hubbard-Field stability tests (22) was run comparing the rate of cohesion development in RC-1, MC-1, and SM-K mixes. The aggregate used was a sandy silt from San Diego County, Calif. It had a sand equivalent of 28 and the following grading:

Sieve Size	Weight Percent Passing
¾-in.	100
No. 4	98
No. 8	95
No. 16	87
No. 30	77
No. 50	50
No. 100	25
No. 200	13

The specimens were prepared and tested after various periods of curing. The results are shown in Figure 1. Even though the combined percentage of water and solvent volatiles in these three mixes was equal, the SM-K mixes developed cohesion at a much faster rate than the other systems. The strength obtained after 175 hr was also much better.

Figure 2 shows road construction near Salinas, Calif., using SM-K emulsion applied with a Wood's mixer. Because the SM-K emulsion was able to function with less water present in the aggregate than when using SS emulsions, the mix could be compacted immediately after spreading. SM-K emulsions, therefore, permit mixes to be made at optimum moisture content. In addition, much less mixing was required to give a satisfactory composition with SM-K on this project than with a comparison test section made with a cutback asphalt. A further advantage was obtained in that the emulsion was successfully applied at ambient temperatures while the cutback had to be applied hot. Also, the mixing chamber in the Wood's machine had

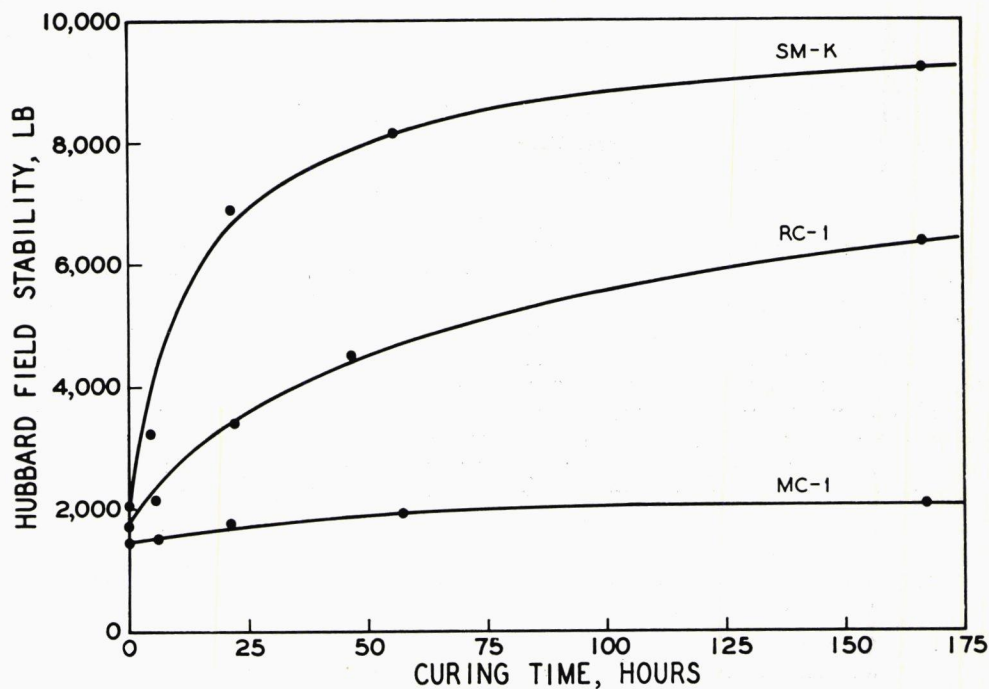


Figure 1. Hubbard-Field stability tests comparing rate of cohesion development in three mixes.

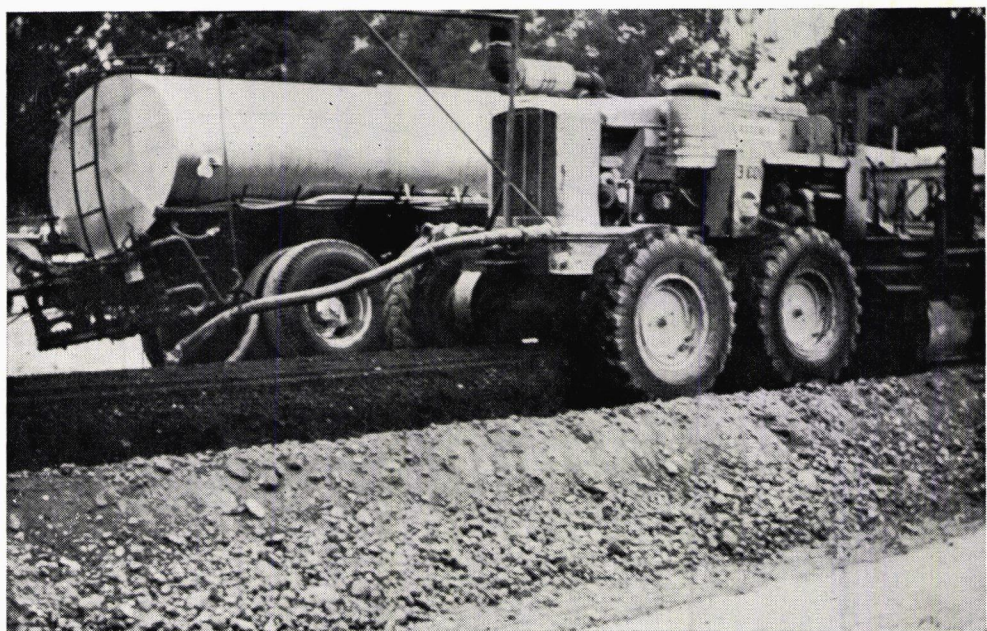


Figure 2. Road construction using SM-K emulsion applied with a Wood's mixer.

to be heated during the use of the cutback. Because an open flame was used, this created a fire hazard.

The incorporation of adhesion agents, some of which are high molecular weight organic amines, in anionic emulsions improves their adhesive properties. However, it does not appear possible to achieve by this means the high level of performance obtainable with cationic emulsions. This is undoubtedly because of the differences in polarity of the amines and the anionic emulsifying agents. In particular, the organic amines are less effective in highly alkaline emulsions, because their greater solubility in asphalt under such conditions

tends to remove them from the aggregate-asphalt interface.

The improvement in resistance to deformation under load and in cohesive strength obtained when a cationic emulsion is used in making mixes with clay sand is shown in Figure 3. Comparison is made with anionic emulsion mixes, both with and without an adhesion agent. The results are given in terms of the *R*- and *C*-values obtained in the Hveem stability and cohesion tests, which are measures of the foregoing properties, respectively (20). The adhesion agent improved the performance of the anionic emulsion, but failed to give the degree of improvement possible

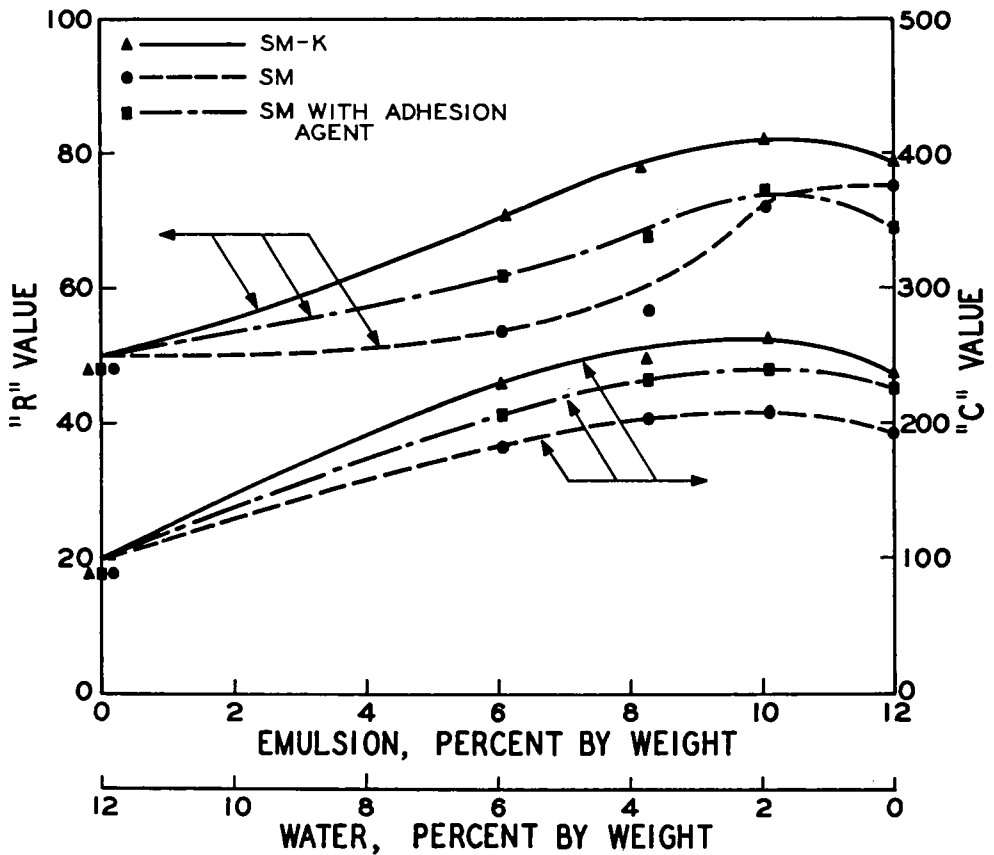


Figure 3. Hveem stability and cohesion values for clayey sand mixes.

with the cationic emulsion. The adhesion agent was used in these tests in an amount equal to the concentration of the cationic emulsifier. The aggregate was obtained from the Coates Pit in Contra Costa County, Calif. It has a sand equivalent of 18 and the following grading:

Sieve Size	Weight Percent Passing
No. 16	100
No. 30	99
No. 50	92
No. 100	32
No. 200	16

The use of amine-type adhesion agents is subject to another disadvantage. Acidic constituents present in most asphalts slowly combine with the amine additives and nullify their effectiveness as adhesion agents. This is true for both cutback and paving-grade asphalts. The low pH of cationic emulsions suppresses the ionization of the asphaltic acids and prevents this reaction.

COMPARISON OF SS AND SS-K EMULSIONS

Slurry sealing is an important maintenance operation for the highway engineer. This type of construction requires aggregates that conform to the following grading (23):

Sieve Size	Weight Percent Passing
No. 4	100
No. 8	70-100
No. 16	40-80
No. 30	30-60
No. 50	20-50
No. 100	10-25
No. 200	5-15

Aggregates retained on a No. 4 sieve or larger cause streaking during ap-

plication. An insufficient quantity of fines results in segregation during application and raveling of the cured mix. An excessive amount of fines makes the mixes brittle. The aggregate should have a minimum sand equivalent of 40.

A seldom recognized cause of slurry seal failure is the use of powered brooms for street sweeping. This equipment, in combination with water, exerts a very severe abrading force. Slurry seals made with cationic emulsions resist this force very well.

The practical value of cationics in resisting the stripping forces of mechanical action and water is shown by the wet track abrasion tests in Figure 4. Slurry seal mixes were made with typical anionic and cationic SS emulsions and tested in accordance with the procedure recommended for this test (23). The cationic emulsion gave excellent results, particularly in the range of emulsion concentrations normally employed. With this particular aggregate, chosen for the comparison because of its borderline quality, satisfactory performance could not be obtained with the anionic emulsion under any conditions.

Slurry seal mixes must be fluid enough to fill cracks and small depressions and to be applied in thin lifts; *i.e.*, usually less than $\frac{1}{4}$ in. deep. This fluidity is a disadvantage in that the water required to obtain this condition must be evaporated before subsection to vehicular traffic. Depending on weather conditions, 4 to 24 hr are required for the water to evaporate from anionic slurry seals. On some construction projects, it is difficult to hold traffic off for such periods of time.

Cationic slurry seals dehydrate at much faster rates than do anionic slurry seals. This is shown by the curing rate curves for anionic and

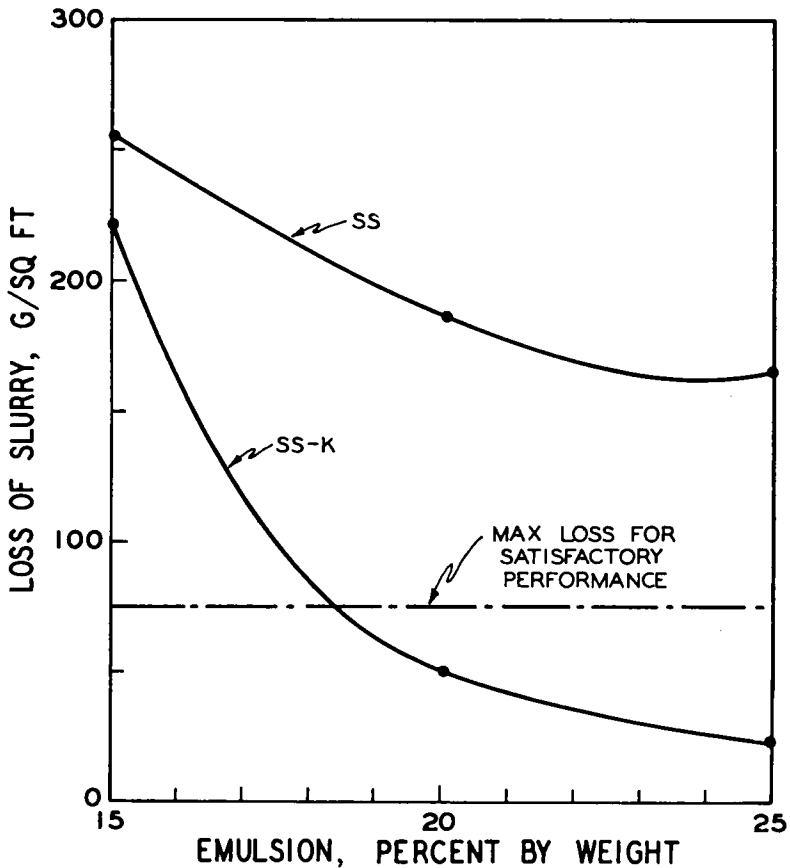


Figure 4. Wet track abrasion test.

cationic slurry seal mixes in Figure 5. Two hours or less was sufficient to set the cationic mix, while all of the anionic specimens required much longer times. Cationic emulsion slurry seals are reasonably resistant to traffic when the residual water content is as high as 2 percent; anionic emulsion slurries must contain less than 0.5 percent water before they are satisfactorily resistant to abrasion.

Another difficulty occasionally experienced with anionic emulsion mixes is "wash-off" due to rainfall before the time the emulsion sets. Unless the water content of such

mixes is below a certain low level, addition of more water causes restoration of the partially coalesced emulsion to its original condition. Unexpected rainfall can thereby have disastrous effects on anionic slurry seals.

Cationic slurry seals are essentially immune to this difficulty after initial coalescence has started. This is shown in Figure 6, which was taken after a sudden, heavy rainstorm struck a small-scale slurry seal test section at Richmond, Calif., about one-half hour after completion. The cationic section is in the background, and the anionic section is in the fore-

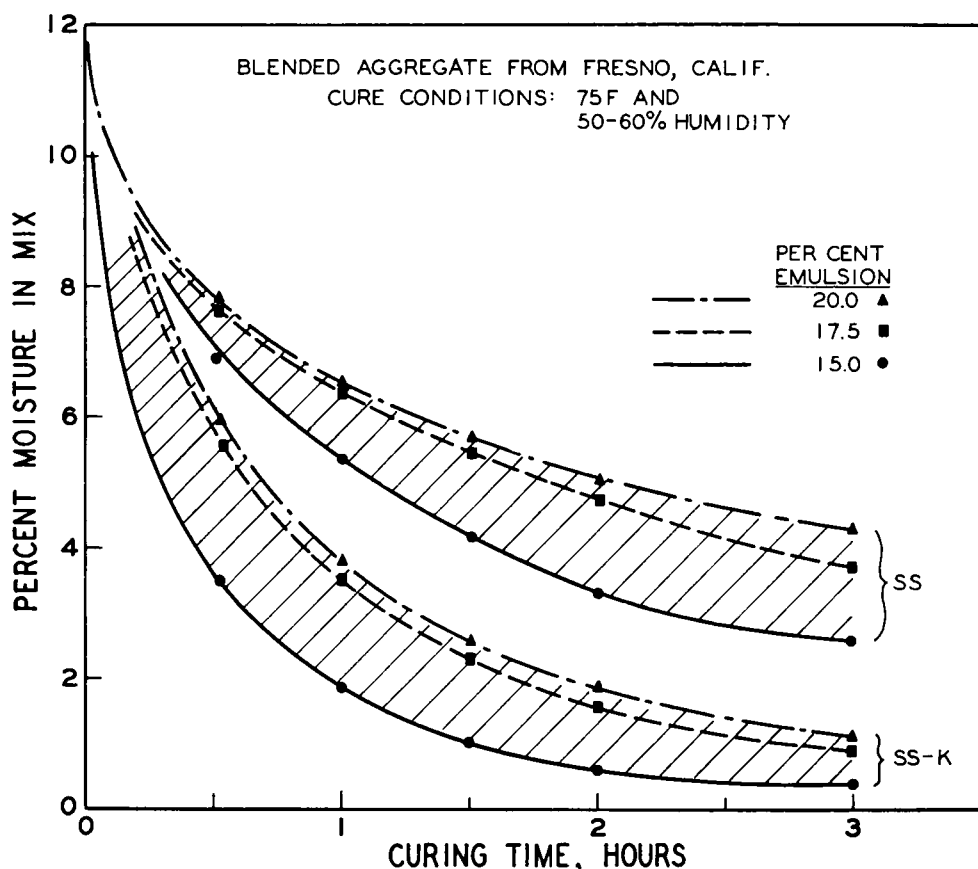


Figure 5. Curing rate curves for anionic and cationic slurry seal mixes.

ground, with a heavy runoff on the roadside from the anionic section. Runoff from the cationic section was slight and would have been entirely absent if the mix could have cured for about another half hour before the rain started. The anionic section would have been susceptible to heavy damage for many additional hours.

The superiority of cationic emulsions for base stabilization is shown in Figure 7. Cationic and anionic SS-grade emulsions were mixed in laboratory tests with a graded aggregate containing a considerable amount of clay. The aggregate had the following grading:

Sieve Size	Weight Percent Passing
$\frac{3}{4}$ -in.	100
$\frac{1}{2}$ -in.	88
$\frac{3}{8}$ -in.	75
No. 4	60
No. 8	51
No. 16	40
No. 30	31
No. 50	23
No. 100	15
No. 200	8

The sand equivalent of the aggregate was 21. The coarse fractions were crusher run gravel from Fairfield,



Figure 6. Small-scale slurry seal test section after sudden, heavy rainstorm.

Calif. The 8 percent fraction passing the No. 200 sieve contained the following:

Material	Weight Percent
Bentonite clay	5.0
Limestone dust	0.8
Fairfield nonplastic crusher fines	2.2

Bentonite clay is one of the most plastic types of silicates and was purposely added to make the stability critical.

The mixes were prepared with 7 percent emulsion, compacted at optimum moisture content, and cured at 100 F to one-fourth the compaction moisture. The specimens were then buried in moisture-saturated Ottawa sand for two months before the stability determinations to obtain equilibrium conditions.

PROSPECTUS FOR CATIONIC MIXING-GRADE EMULSIONS

SM-K and SS-K cationic asphalt emulsions are now commercially available in some areas. Their availability is being extended rapidly to all areas where the aggregates available are particularly suited to the use of these new products.

Particularly noteworthy among the properties of the new materials are the ability to coat and adhere to a wide variety of dry or moist aggregates, superior resistance to mechanical stripping action and moisture, and rapid setting tendencies.

These properties mean that contractors will be able to use a wider range of aggregate types and will have greater flexibility in their choice of construction practices. It appears likely that mixing-grade cationics will speed highway construction procedures. The amount of mixing or blading is in some cases much less

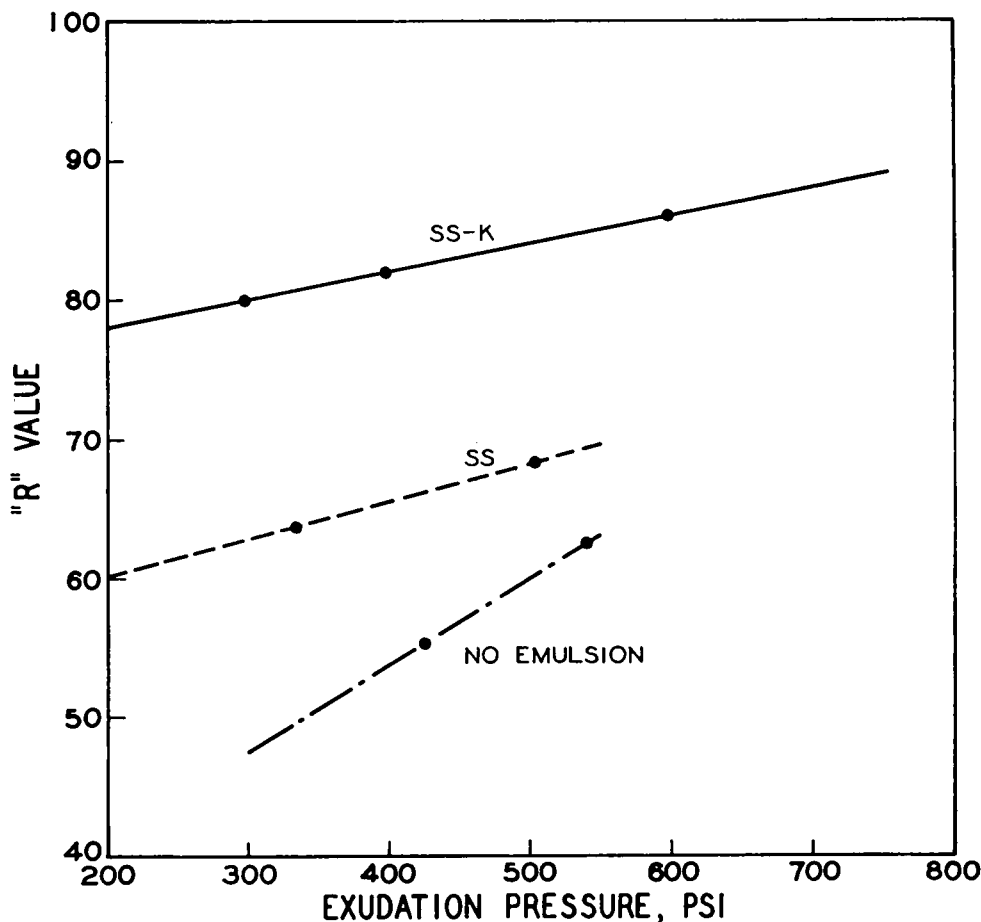


Figure 7. Hveem stability of graded aggregate containing clay.

than that required with anionic emulsions or cutback asphalts.

The mixing-grade cationic emulsions are expected to be successful in applications where anionics have given marginal results in the past. The future demand for these new emulsions will not develop, however, entirely at the expense of the anionics. Anionics, which are inherently somewhat less costly than cationics, will continue to be used where application conditions are favorable. The properties of the cationics are such that their use will expand into appli-

cations now employing nonasphaltic materials.

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DISCUSSION

K. E. McCONNAUGHAY, *K. E. McConnaughay, Inc.*—As a manufacturer of asphalt emulsions whose experience with these materials dates back some 35 years, K. E. McConnaughay, Inc., is much interested in research designed to develop the full potential of these materials. A continuing research program is maintained for this purpose and in this light the research efforts that have produced this paper have been supported. However, some aspects of the presentation require comment.

Throughout the paper the authors refer to anionic emulsions and compare the properties of these with cationic materials. If in so doing, test results, experience, and opinions of the American Bitumuls and Asphalt Company is being cited with respect to the materials of their own manufacture, the paper should be written so as to make this limitation clear. On the other hand, the writer objects to the inference that all anionic emulsions are inferior to cationic ones. The performance advantages claimed by the authors for the cationic materials over the anionic ones they tested are just as valid for certain anionic emulsions over other anionic ones. Specifically, the weatherproof type of anionic MS materials which the writer's organization long has favored have many of these performance advantages as compared to SS and MS anionic types which are subject to washing by rain.

An SS-K emulsion is presented as a cationic material and the slurry seal made from it is referred to as cationic. The SM-K cationic material is characterized as cationic in the proposed specification for this material by requiring a positive charge result in the particle charge test, but the proposed specification for the SS-K material does not include this

requirement. Therefore, it may be that the SS-K emulsion is truly cationic. Certainly it could meet the requirements of the specification and not be cationic.

In the introduction to the paper the statement is made, "The most important characteristic of anionic emulsions is that the emulsified asphalt particles carry negative electrical charges." Contrary to this statement, the writer considers that the most important characteristic of any asphalt emulsion is its performance in use. He agrees that asphalt emulsions should coat aggregate readily in a wet or dry condition and should produce mixtures with good workability that are not water susceptible, do not require the addition of water for mixing, and compact readily without excessive reduction of moisture content. For these reasons his organization has not generally recommended the use of SS types of emulsions or of MS materials that are susceptible to washing with water. However, he believes that these properties are achieved in emulsions of his manufacture which fall into the anionic class.

The writer does not wish to leave the impression that he does not recognize that cationic asphalt emulsions can be satisfactory road-building materials. His experience to date with the cationic materials of his manufacture has been entirely satisfactory, and some projects of this type are more than four years old. However, satisfactory performance of pavements he has constructed with anionic emulsions that are over 30 years old can be cited. Also, where both cationic and anionic emulsions of his manufacture were used in a comparative way in the same project, superiority of cationic emulsions has not been demonstrated. Such projects

have included siliceous as well as carbonate aggregates. Therefore, particle charge of the asphalt emulsion is not the controlling factor in performance.

M. J. BORGFELDT AND R. L. FERM, *Closure*.—The authors have evaluated in their laboratory cationic and anionic emulsions made by a number of manufacturers. It was not intended to infer that anionic emulsions are inferior or that they are unsatisfactory for highway construction and maintenance. The superiority of cationic asphalt emulsions is best demonstrated by their rapid acceptance by consumers, and tests run by unbiased groups. For example, the Highway Department of North Carolina used some 100,000 gal of cationic emulsion in 1958, in 1959 they used 4,000,000 gal, and in 1960, 8,500,000 gal. The Montana Highway Department has run adhesion tests on some one hundred different aggregates. Anionic emulsions reacted more favorably than cationic emulsions on only 2.8 percent of these aggregates, which include both siliceous and calcereous types. Cationics were superior on some 64 percent of the aggregates. The Department of Highways of Ontario, Canada, conducted coating tests with various limestone aggregates, all showed a preference for cationic emulsion. In a paper presented at the Sixth Annual Conference of the Canadian Technical Asphalt Association at Victoria, B.C., November 1961, A. E. Holberg stated:

In the meantime, I obtained comments from Dr. Ing Letters and according to his experience in Western Germany, cationic emulsions do just as well with dolomite carbonates as with any other aggregates as far as field performance is concerned.

Mr. G. Bertlet of Esso-Standard-France, commented on this as follows. "To date we never came across a material giving better results when using anionic emulsions than when using cationic emulsions."

Cationic emulsions have been used in France since 1953, and in 1960 accounted for 38 percent of the total emulsion market.

Mr. McConaughay asked if the SS-K emulsion is cationic, as the specification does not include a particle charge test requirement. The SS-K emulsion will not migrate under the conditions of the particle charge test. Using microelectrophoresis techniques, the cationic nature of this emulsion can be demonstrated. This method however is not suitable for specification purposes, as it requires equipment not usually available to control laboratories. More definitive tests are being investigated.

The authors agree with Mr. McConaughay that the most important characteristic of an asphalt emulsion is its performance in use and feel that the essential chemical difference between anionic and cationic emulsions is the sign of the charge on the asphalt particle. Inasmuch as a majority of road building aggregates have a negative charge, the value of a binder bearing a positive charge is apparent.