Emulsified Petroleum Oils and Resins in Reconstituting Asphalts in Pavements

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Asphalts in paving mixtures change in composition, or age, with time. The rate and degree of change depends on their chemical composition, environmental conditions, and length of exposure.

In the case of hot-plant mixes, the aging process starts even before pavement construction because of exposure to air at high temperatures in thin films during the hot-mix cycle. Sooner or later the asphalt will reach a state of brittleness which manifests itself in the form of pitting and raveling of the surface or shrinkage and brittleness cracking, with eventual spalling.

Addition of suitable asphalt components at the appropriate time during the aging process can stop aging by reconstitution of the weathered asphalts. Appropriate treatment of pavements returns the weathered asphalt to its original condition. In many instances, the properties of the asphalts are so improved that they surpass those in the asphalt prior to mixing with the aggregate.

Laboratory data illustrate the manner of aging of asphalts and the concept of restoring properties by use of selected fractions of petroleum oils and resins. Reasons are cited for the selection of an emulsion system for bringing together the aged asphalt and the particular oils and resins.

The engineering properties of the preparation required for obtaining the desired results are described, together with a summary of 3 years' field experience. Test data from pavements subjected to treatment under various conditions are also presented, including evaluations and measurements of such physical properties of the pavement as permeability, texture, stability, and skid resistance.

• IT IS characteristic of asphalts, in asphalt paving mixtures of all types, to change in composition with time. After construction and during service on the road, this process (referred to as aging in this report) is generally a gradual one with the rate and degree of change dependent on the original chemical composition of the asphalt, its environmental conditions, and length of exposure to weathering. In the case of hot-plant mixes, the aging process starts even before pavement construction because the asphalts are exposed in thin films to air at high temperatures during the hot-mix cycle. The rate of change is often influenced by the catalytic action of the aggregate surface on which the asphalt film is deposited.

Many studies on both the causes and effects of asphalt aging have been reported in the literature (1, 2, 3) with general agreement on the nature of the problem but with some differences of opinion on the mechanics of the aging process within the asphalt itself. The interpretations range from the assumption that asphalt hardening or brittleness is purely an evaporation phenomenon to the more complex explanations predicated

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on the correlation of asphalt composition, determined by fractional chemical analysis, to long-term performance on the road. The fact remains, however, that sooner or later the asphalt will reach a state of brittleness which is manifested in the form of pitting and raveling of the surface, or shrinkage and brittleness cracking, or spalling, or combinations thereof, with eventual deterioration of the pavement (4, 5).

It would be of considerable advantage, therefore, to asphalt users if it were possible to retard, stop, or reverse the aging of asphalt, in situ, by the addition of suitable asphalt components at some appropriate time during the aging process. Such a treatment would require a material that would effectively rejuvenate the aged asphalt with minimum interference with the serviceability of the pavement, and yet be economically feasible. This paper describes the results obtained with a material especially formulated as such a reclaiming agent by combining with and reconstituting aged asphalt, in situ, thereby restoring its plasticity.

FUNDAMENTALS OF COMPOSITION OF RECLAIMING AGENT

Disregarding the details and minor differences of opinion regarding the chemical composition of asphalts, it is generally accepted that asphalt consists of two main fractions, asphaltenes (insoluble in pentane) and maltenes (soluble in pentane), and that the maltenes consist of subfractions of various oils and resins. The Rostler analysis (3) determines the following four principal fractions of maltenes: nitrogen bases (N), first acidaffins (A_1), second acidaffins (A_2), and paraffins (P). The influence of maltenes on the durability of asphalts as cementing agents has been shown to depend on the ratio of the four fractions of the maltenes. The parameter $(N + A_1) / (P + A_2)$, expressive of the ratio of the more reactive to the less reactive fractions, is a useful guide for predicting performance of an asphalt as a binder (3).

The reclaiming agent used in the present work is an emulsion of maltenes designed to change the resins/oils ratio (expressed by the preceding parameter) in the asphalt to increase durability. It is a cationic emulsion of specific properties tailored to facilitate and assure the desired incorporation of the added maltenes.

THE CATIONIC OIL-RESIN EMULSION

A number of products could be designed to serve as an asphalt replasticizer. The reclaiming agent used in the work described in this paper is the product "Reclamite" developed by the Golden Bear Oil Co. Reclamite is described in detail in pending patent applications. The principal general requirements for this type preparation are as follows:

1. Facilitate penetration of the emulsion into the asphalt pavement surface.
2. Effect preferential wetting of the asphalt by the added maltenes.
3. Accelerate penetration of the emulsion into the interstices of the asphalt structure itself.

TABLE 1

SIGNIFICANT PROPERTIES OF RECLAIMING AGENT

Intrinsic properties of maltenes emulsion:	
Avg. particle size, 1:4 dilution (μ)	1.8
Polarity, by electrophoresis	Cationic
Stability, in 1:7 dilution	--[1]
Maltenes content (%)	60 ± 3
Typical properties of maltenes:	
Specific gravity	0.95
Viscosity at 90° C (cP)	25
Flash point, COC (°F)	400
Loss on heating, 3 hr at 325° F (%)	1

[1] No irreversible stratification; no coagulation on contact with sea water.

The essential function of the emulsion after penetration into an asphalt pavement is to deposit the oil and resin components on the films of aged asphalt without disturbing the existing structure of the asphalt-aggregate mix with respect to adhesion, cohesion or stability. Subsequently, the deposited oils and resins flux with and replasticize the aged asphalt and "reclaim" or "rejuvenate" it. The degree of improvement by such treatment depends on the asphalt's state of embrittlement and the composition and quantity of the maltenes comprising the oil-resin blend. Proper design of the reclaiming agent can make the replasticized asphalt more chemically stable than the original because the added components are more durable and in better balance than those generally encountered in asphalts. Table 1 summarizes the significant properties of the product used.

SELECTION OF EMULSION SYSTEM

Laboratory tests were conducted to determine the best manner of adding the reclaiming material. Ease of handling and application were significant factors in deciding that the product should be in the form of an emulsion. However, the most important factor favoring emulsification was the need for a preparation which would penetrate rapidly into the pores of the asphalt paving, without displacing the asphalt films from the aggregate or destroying the existing structure of the asphalt-aggregate mixture.

Table 2 summarizes test results obtained on uniformly prepared laboratory specimens to determine both the rate and depth of penetration of the maltenes applied in various forms, together with test results on kerosene, MC-70 liquid asphalt, and tap water for comparative purposes. The specimens were briquets, 2.5 in. in diameter, 1.6 in. high, with a 2-in. diameter, 0.318-in. deep reservoir pressed into the top side. The briquet mixture consisted of 90 parts by weight of 20-30 mesh Ottawa sand (ASTM C-109), 10 parts portland cement and 7.5 parts asphalt of 48 penetration. Appendix A is the standard procedure used to blend, mix and mold the briquets.

It is evident (Table 2) that a relatively rapid rate of penetration was obtained with all forms of emulsion systems, except the asphalt emulsion (grade SS-1, diluted 2:1 with water) which did not penetrate but formed an asphalt skin at the surface when the water phase evaporated. When applied directly, without a carrier, the oils and resins penetrated very slowly over a 24-hr period. However, the oils and resins, when dissolved in kerosene, also penetrated rapidly.

The briquets were relatively impervious to plain tap water, but with the wetting agent added water penetrated readily. The water with wetting agent even penetrated the treated briquets, but at a much slower rate. This serves as a measure of the relative effect on pavement permeability of these various treatments. The last column (Table 2) indicates that all emulsion systems tested are more effective in decreasing the permeability of an asphalt-aggregate mixture than are the kerosene cutbacks. Moreover, although the SS-1 asphalt emulsion formed a membrane, water still managed to permeate through.

Figures 1 through 12 show the briquets in ultraviolet light used to determine the penetration depth of the fluorescent oils and resins. The procedure was to split one of duplicate briquets and measure depth of penetration to the nearest 0.01 in. As is evident from Table 2, the average depth of penetration for the maltenes in any form of application was virtually the same. The only anomaly was the anionic emulsion that ran through the briquet and out the bottom. This was anticipated, however, because of the repellent nature of the asphalt-coated surfaces to negatively charged particles.

An improvised load-penetration test was run on the same type of briquet to evaluate the effect of the cationic emulsion of maltenes on the cohesiveness of asphalt as compared to other dilution systems and materials. An apparatus applied load to the treated end of the briquet through a 1.128-in. diameter (1.0 sq in.) piston at a strain rate of 0.25 in. per min to a total deformation of 0.250 in. The data obtained from this test are relative but valid for the series of briquets tested. The apparatus and the test are described in Appendix B. Resulting load-deformation diagrams are shown in Figure 13. A refinement of this test is under development.

To establish reference points, two load-deformation curves are shown for freshly-mixed briquets made with 7½ percent by weight of 48-penetration and 200- to

TABLE 2

RATE AND DEPTH OF PENETRATION INTO UNIFORMLY-PREPARED ASPHALT-SAND LABORATORY BRIQUETS

Test Figure No.	Treating Fluid	Penetration: Time, 10 Ml Vol.	Penetration: Depth[1] (in.)	Penetration: Time[2] into Treated Briquets
1	Control	--	--	12 sec
2	Cationic maltenes emulsion, concentrated	4 min 35 sec	0.89	18 min
3	Cationic maltenes emulsion, diluted 2:1	45 sec	0.88	16 min
4	Cationic maltenes emulsion, diluted 1:1	30 sec	0.89	18 min
5	Anionic maltenes emulsion, diluted 2:1	2 min 8 sec	1.30[3]	19 min
6	Nonionic maltenes emulsion, diluted 2:1	51 sec	0.90	22 min
7	SS-1 asphalt emulsion, diluted 2:1	--[4]	0	48 min
8	MC-70 asphalt cutback	--[5]	0.45	--[6]
9	Straight oil-resin	24 hr	0.83	8 min[7]
10	Kerosene	32 sec	0.97	2 min
11	Oil-resin in kerosene	2 min 3 sec	0.84	4 min
12	Tap water	16 hr	--[8]	21 sec

1 Observed in ultraviolet light.
2 For 10 ml of 0.375% Aersol OT sol.
3 Ran through briquet and out bottom.
4 Dried at surface forming membrane.
5 Collapsed briquet in 11 to 12 hr without penetrating completely.
6 Specimen damaged.
7 Lifts surface.
8 Not measurable.

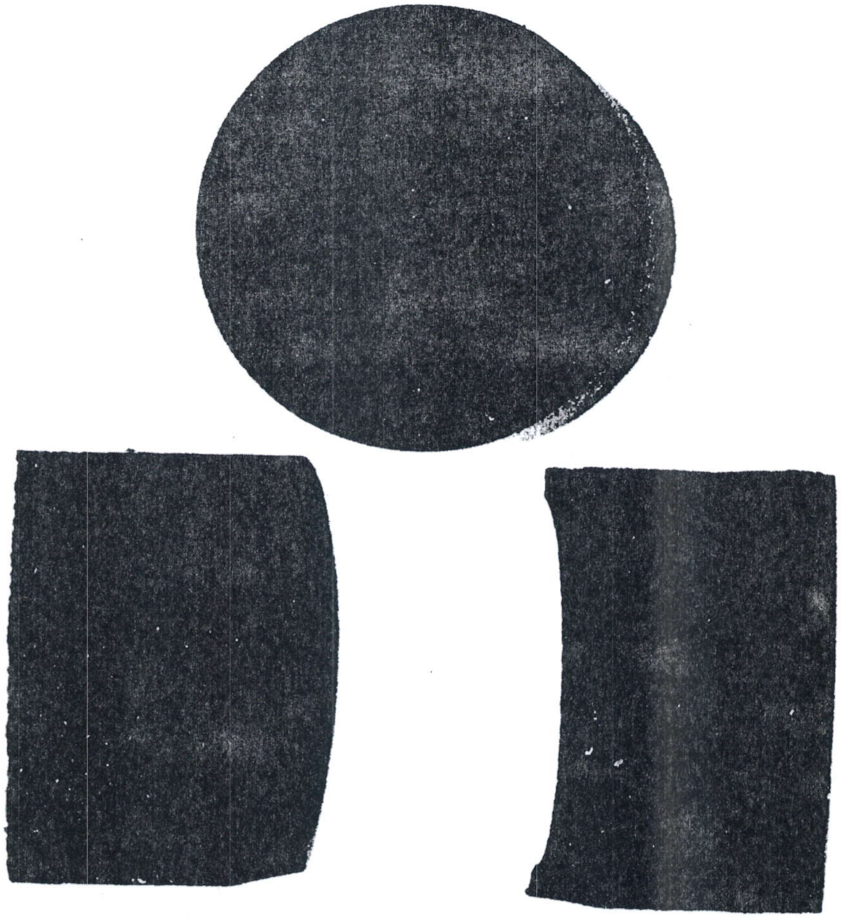

Figure 1. Untreated control.

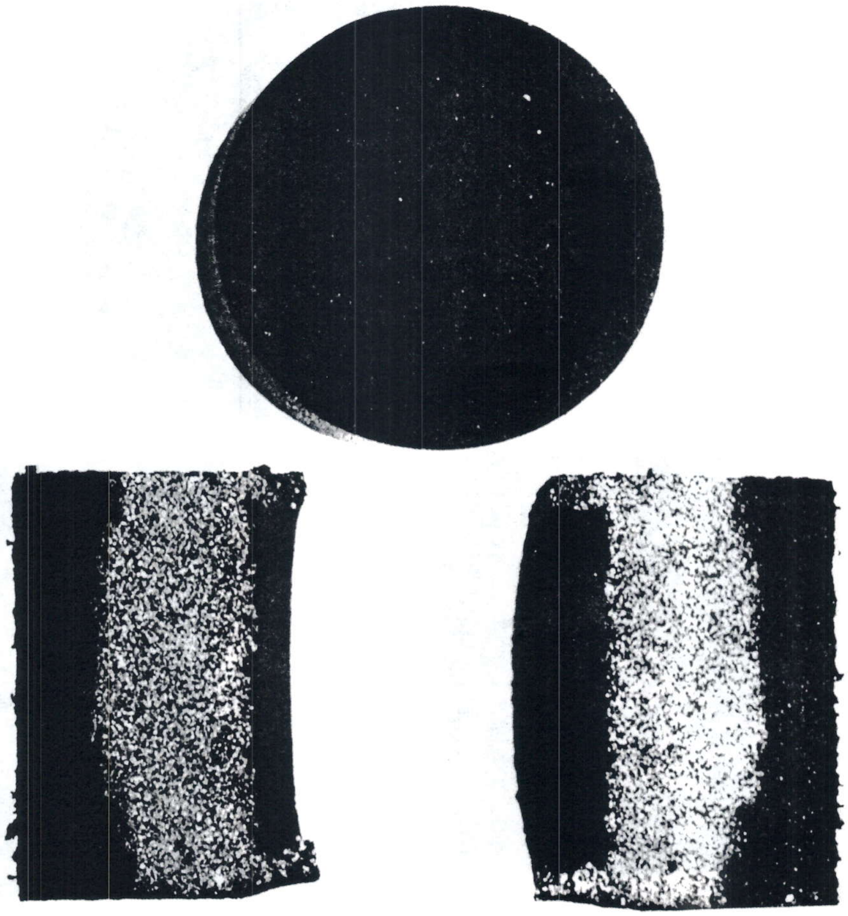

Figure 2. Cationic maltenes emulsion, concentrated.

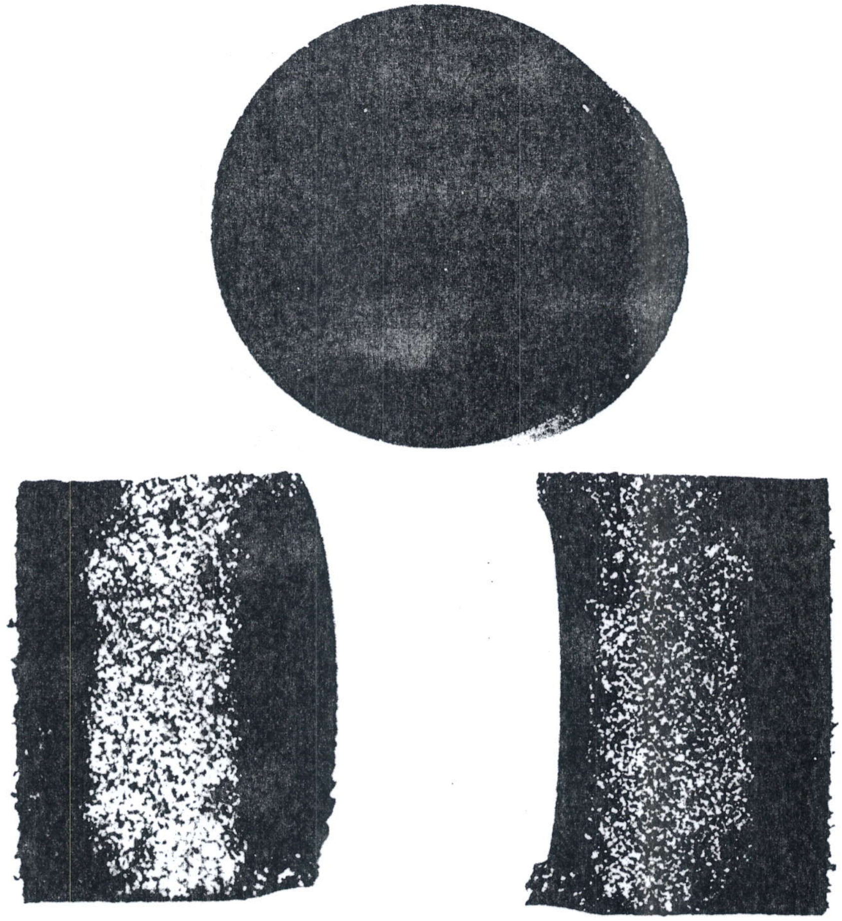

Figure 3. Cationic maltenes emulsion, diluted 2:1.

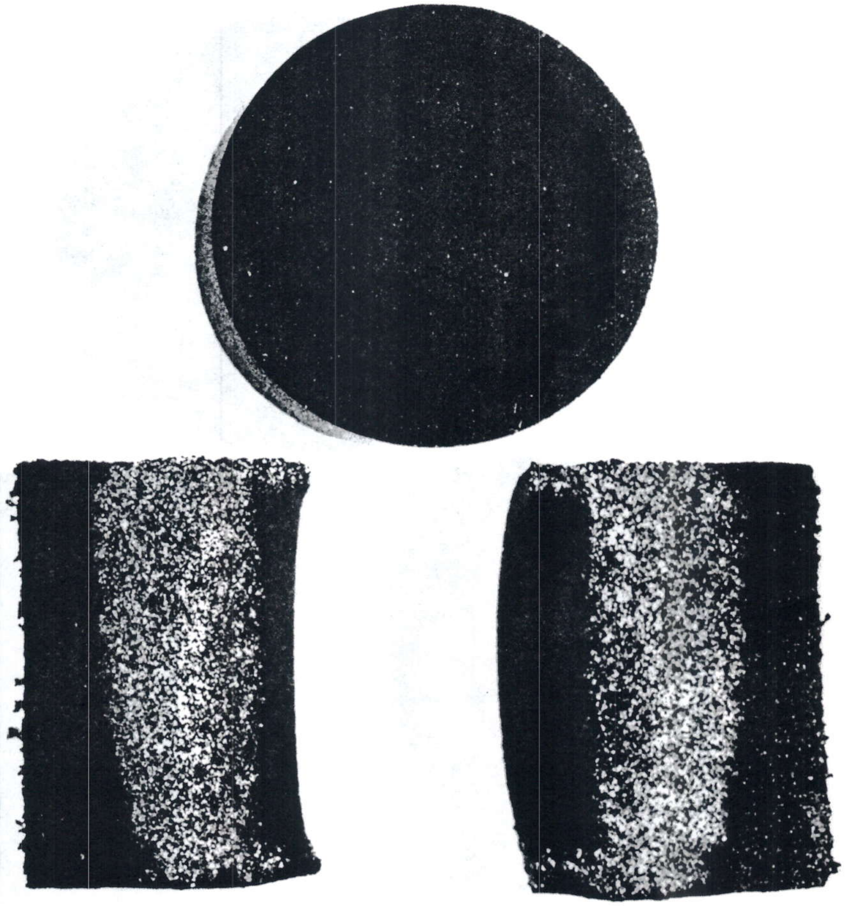

Figure 4. Cationic maltenes emulsion, diluted 1:1.

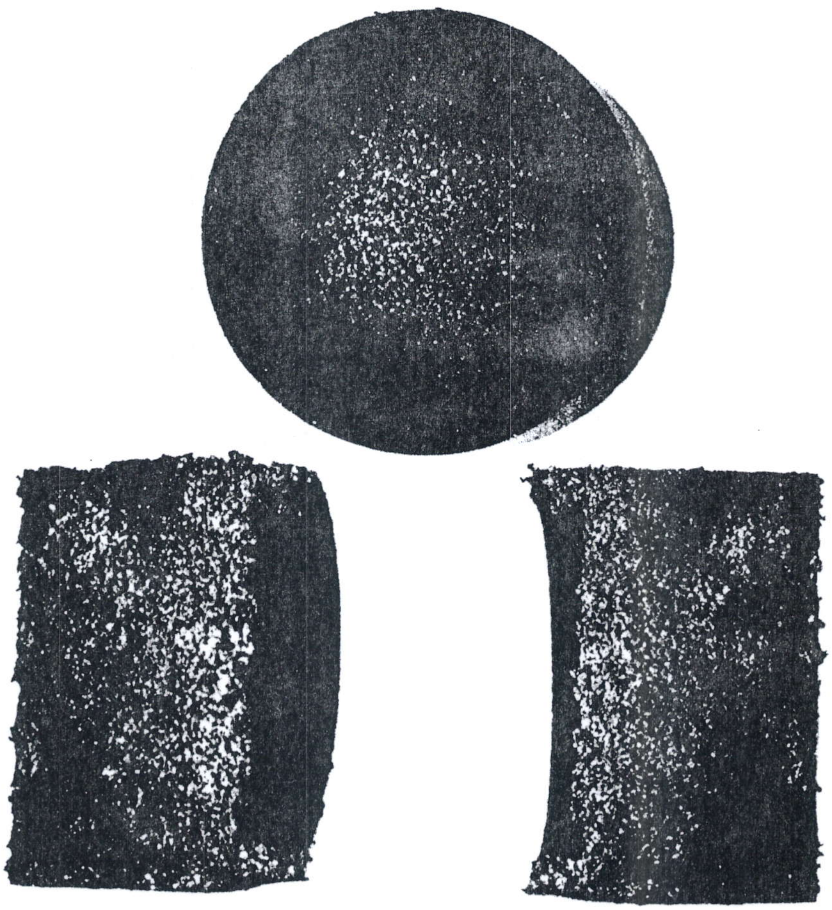

Figure 5. Anionic maltenes emulsion, diluted 2:1.

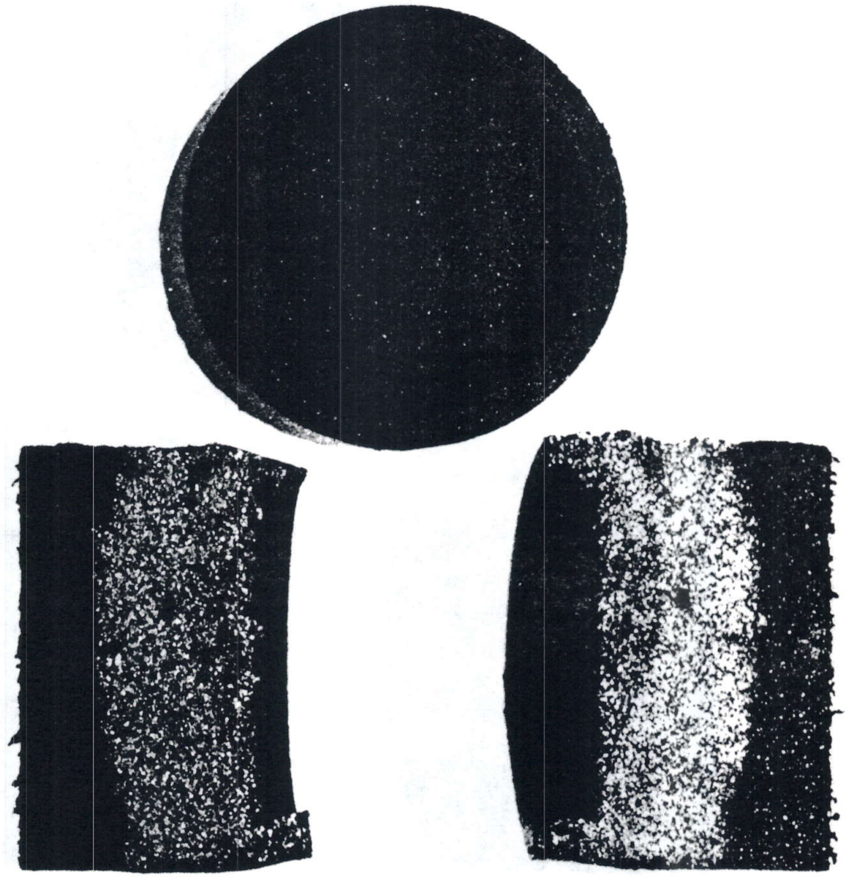

Figure 6. Nonionic maltenes emulsion, diluted 2:1.

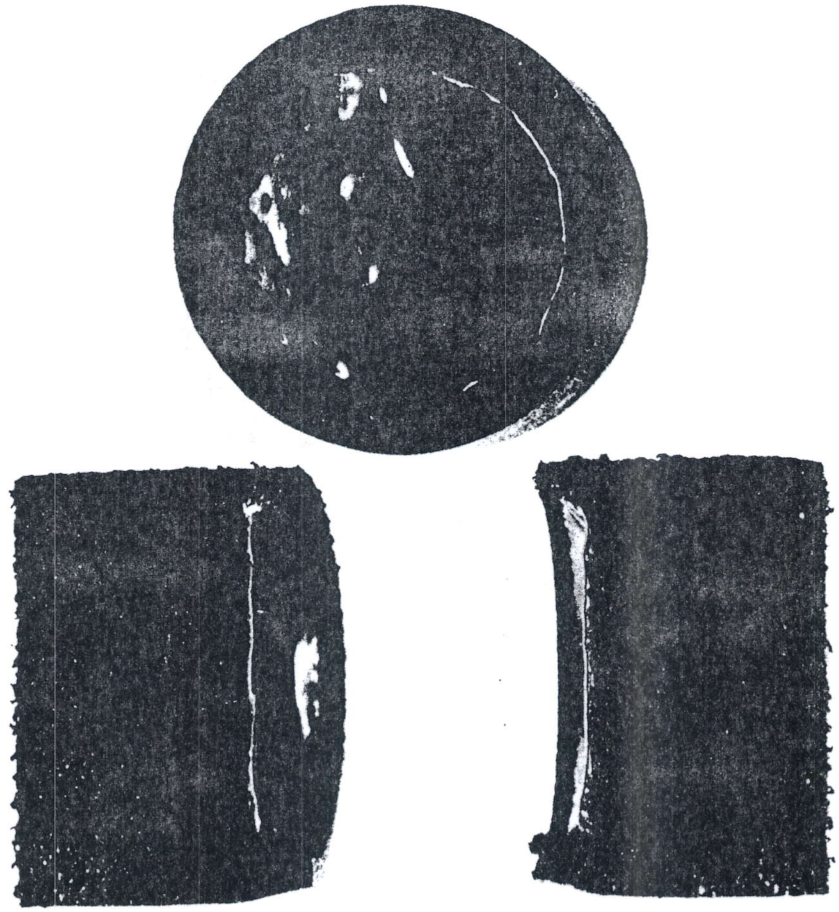

Figure 7. Asphalt emulsion (SS-1h), diluted 2:1.

Figure 8. Asphalt cutback (MC-70).

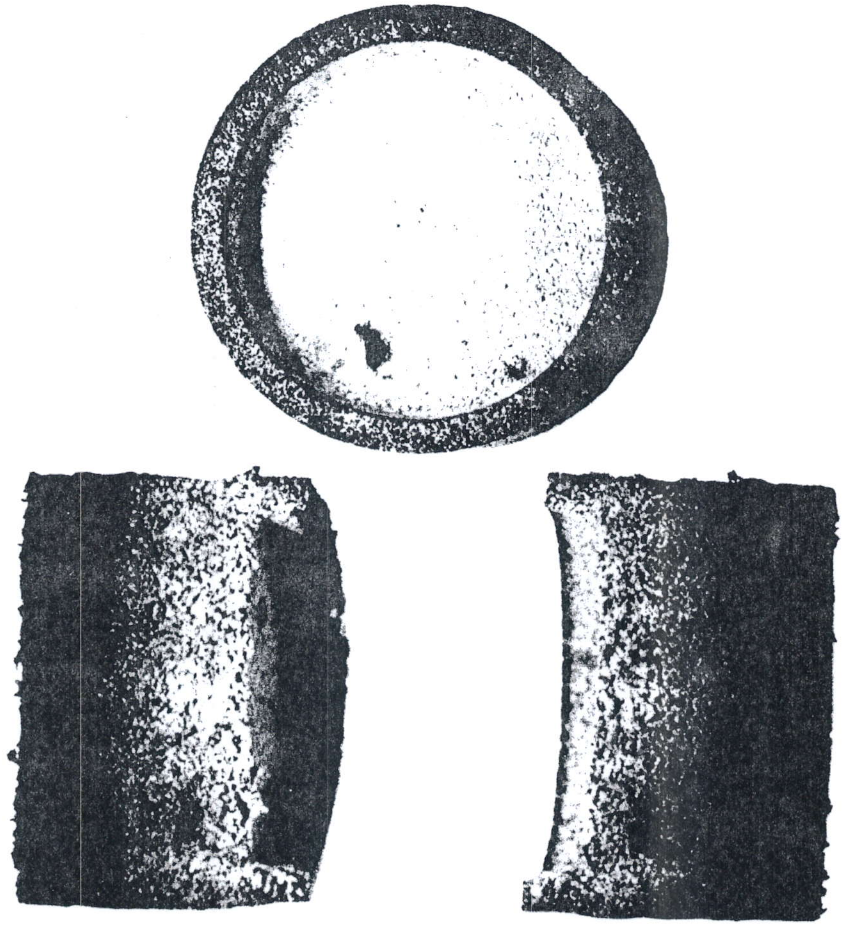

Figure 9. Maltenes without carrier.

Figure 10. Kerosene.

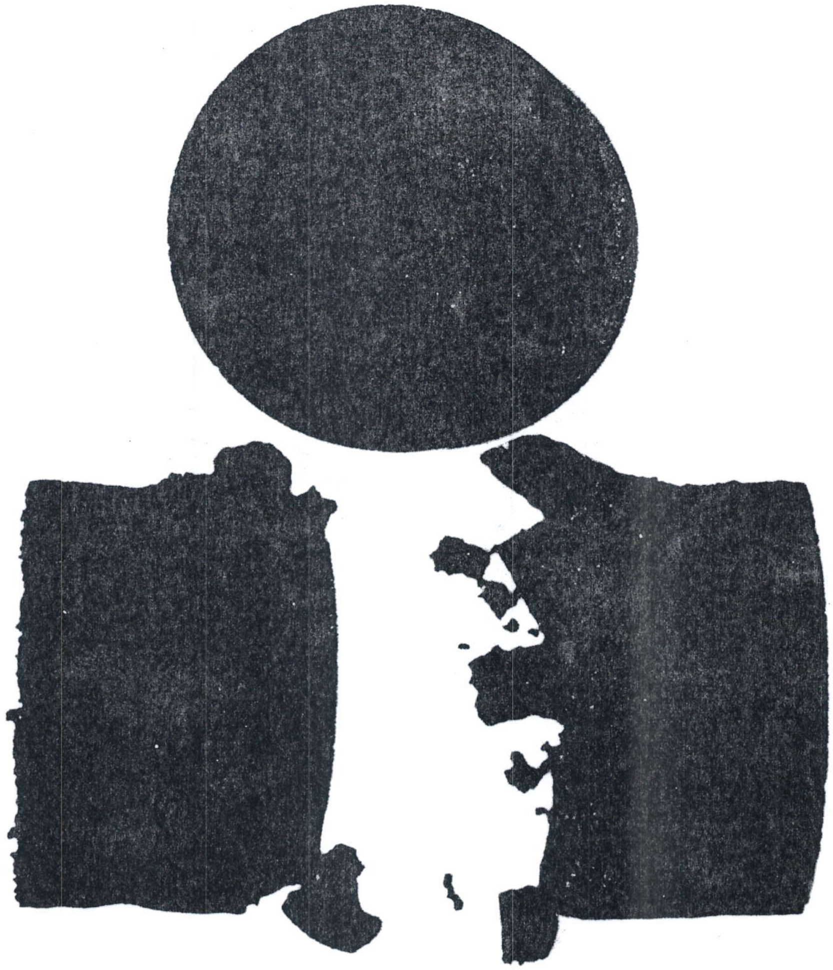

Figure 11. Maltenes solution in kerosene.

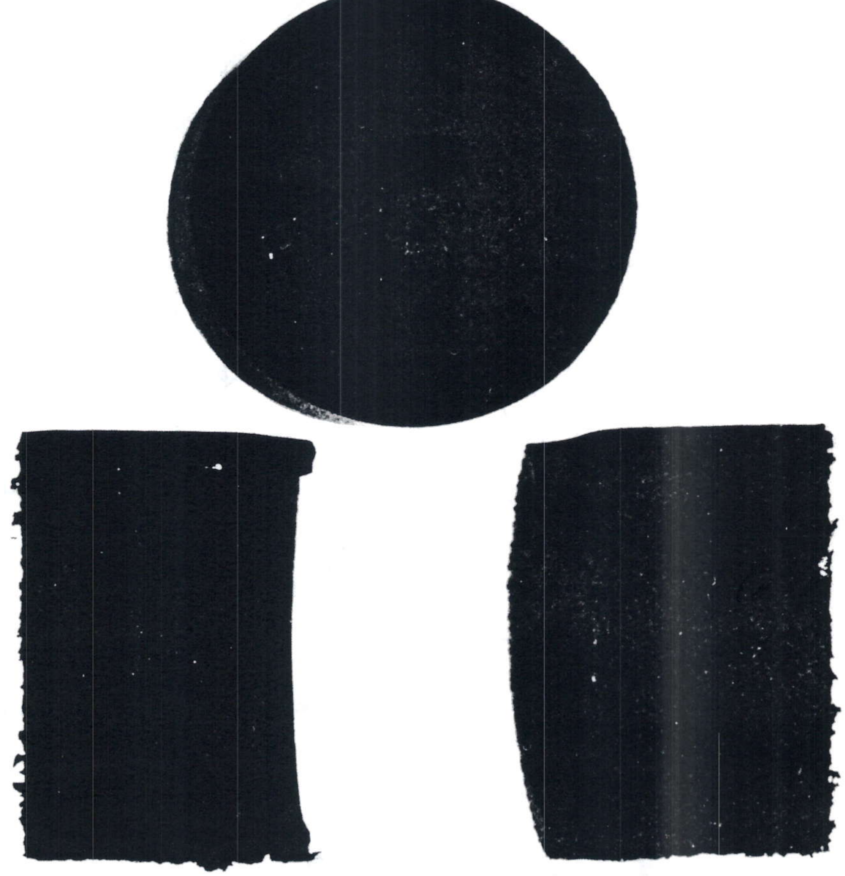

Figure 12. Tap water.

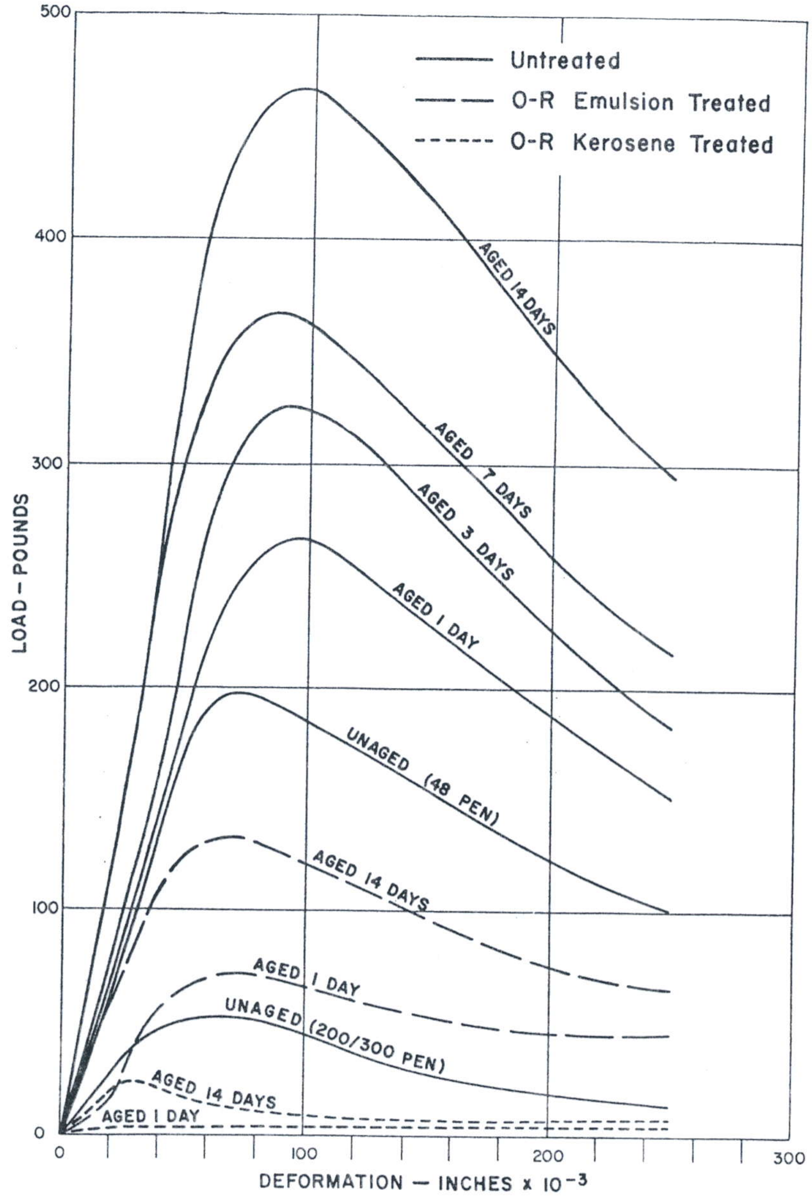

Figure 13. Effect of cationic maltenes emulsion and maltenes solution in kerosene on load-penetration test at various agings in infrared oven.

300-penetration asphalts. All other curves represent various treatments of a reference briquet made with 48-penetration asphalt at various ages. The briquets were aged in the infrared oven described elsewhere (2, App. III). The oven is automatically controlled so that the temperature within the briquets is maintained at 140 F during the specified aging time.

Figure 13 indicates that kerosene as a carrier destroys the cohesiveness of asphalt binder and that proper cohesion cannot be regained even after 14-day exposure at 140 F in the infrared oven because the kerosene has dislocated the asphalt-cement between the points of aggregate contact. In contrast, the emulsion system for introducing the maltenes does not displace the asphalt bonding the aggregate particles; in all cases, the briquets resist load penetration exceeding that of 200- to 300-penetration asphalt, although the consistency of the binder has been lowered. Figures 17 and 20 show the difference in behavior.

From similar laboratory studies and from 5 years' field experience in applying various emulsions to pavements, it has been concluded that the best method for incorporating the maltenes into the asphalt, in situ, is in the form of a fine particle, cationic emulsion as described. Although a dilution rate of two parts of emulsion concentrate to one part of water is generally used to get the best combination of penetration rate and economy, the dilution rate for a particular job should be chosen on the basis of job conditions.

LABORATORY EVALUATION OF EFFECTIVENESS

In the early stages of development, fractional chemical analysis of asphalt was used to tie in the effect of various asphalt components to performance of asphalts on the road (2, 3). This was followed by tailor-making asphalts using components from various base asphalts. It was found that certain fractions of petroleum oils and resins could not only be used to restore the original properties to aged asphalts but the same components could also make the reconstituted asphalt superior to the original asphalt in aging resistance. Figure 14 shows the improvement made in the aging resistance of a typical 200- to 300-penetration asphalt as measured by resistance to abrasion. Further laboratory tests were made to ascertain the effect of exposure of asphalt-aggregate mixes to treatment.

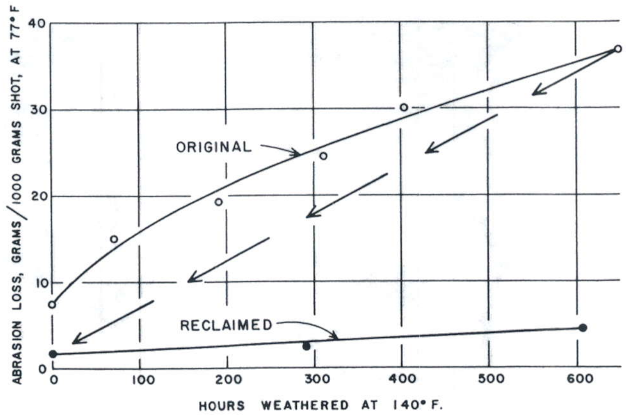

Figure 14. Durability of a 200- to 300-penetration asphalt before and after reclaiming with selected maltenes fraction (2).

Importance of Particle Charge

A series of tests was designed to determine the importance of particle charge, as related to the adhesion characteristics of the asphalt-aggregate system. The test consisted of placing 2-g pellets (made by mixing 100 parts Ottawa sand and two parts 85- to 100-penetration asphalt, and aging 7 days in the infrared oven at 140 F) into beakers containing 50 ml distilled water and heating the water to the boiling point. Several pellets were prepared and tested after treatment with 0.06 g of the oil-resin blend. The blend was applied as a cationic emulsion, as a nonionic emulsion, in an undiluted form, and as a solution in kerosene. The stripping effect was evaluated by observing the

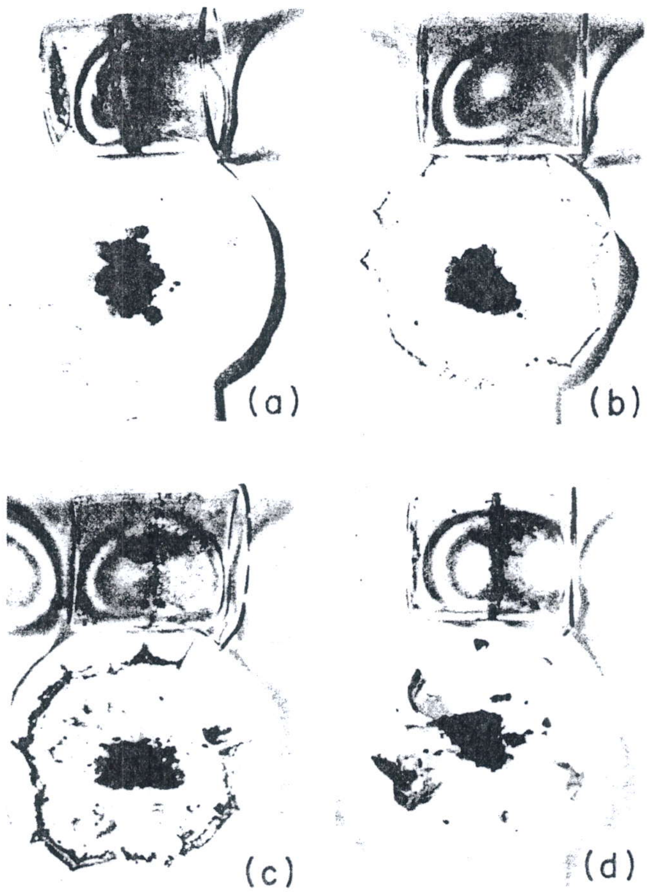

Figure 15. Effect of treatments on stripping resistance of sand-asphalt mixture when exposed to water at boiling point: (a) control, untreated; (b) cationic maltenes emulsion; (c) nonionic maltenes emulsion; and (d) maltenes solution in kerosene.

amount of asphalt floating at the water surface and clinging to the beaker walls, as well as by noting the area of exposed aggregate surfaces on the Ottawa sand at the bottom of the beaker. The contents of the beakers were then filtered through No. 1 Whatman filters.

Figure 15 shows that most of the asphalt was stripped off the sand grains in the untreated control pellet and all of the treated pellets, except the one treated with the cationic emulsion of the maltenes. Although little stripping was noted in the cationic sample, that which occurred came from asphalt at the bottom of the pellet where the treatment did not reach.

Fragments of the treated pellets were examined under a microscope to observe the effect of the treatment and aging procedure on the asphalt cementing the sand grains in the pellets. Figures 16 to 20 are photomicrographs of the specimens. The control (Fig. 16) shows the type of bond prevailing in such mixes after aging. Improvement in the bonding accomplished by the cationic emulsification system, which causes the maltenes to wet preferentially the asphalt portion of the asphalt-sand mixture, is shown in Figure 17.

Figure 18 shows that the nonionic emulsion system does little to increase the bond because there is no preferential wetting of the asphalt portion. The straight application of the oils and resins resulted in droplets of uncombined oil-resin material becoming attached to the sand grains (Fig. 19). With kerosene as a carrier for the oil-resin (Fig. 20), the asphalt films washed from the sand grains and accumulated in the voids between them, resulting in loss of bond at the points of contact.

Effect on Asphalt Durability

Another laboratory investigation was designed to ascertain the effect of the addition of the maltenes on asphalt durability and to gain some insight as to the length of time required for the oils and resins to mix completely with the asphalt. Abrasion test pellets were prepared in accordance with the procedure given elsewhere (2, App. II), using a 48-penetration asphalt and 20- to 30-mesh Ottawa sand. A set of 4 pellets was then treated with the oil-resin blend in each of the several forms under study. Two pellets were then aged in the infrared cabinet for 24 hr and the other two pellets for 7 days. Afterwards, the aged pellets were subjected to an abrasion test by tumbling them in a 16-oz French square bottle for 500 revolutions according to a procedure

Figure 16. Photomicrograph before stripping test of untreated sand-asphalt mix (see Fig. 15a).

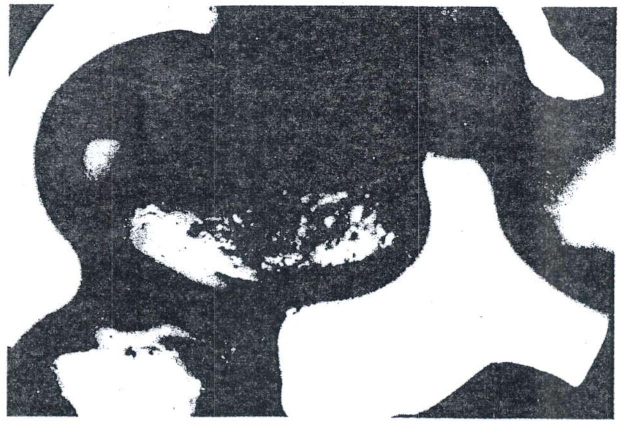

Figure 17. Photomicrograph before stripping test of cationic maltenes emulsion treated sand-asphalt mix (see Fig. 15b).

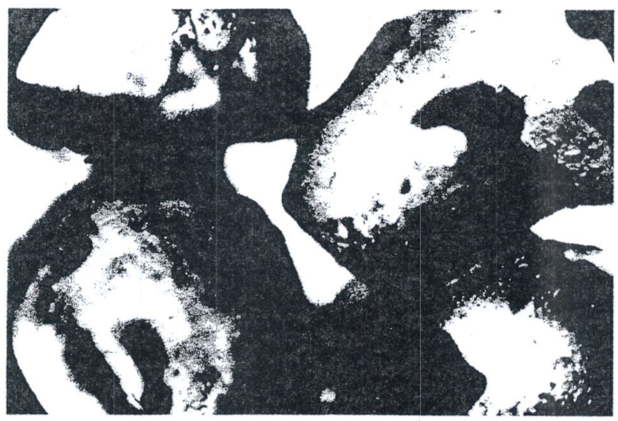

Figure 18. Photomicrograph before stripping test of nonionic maltenes emulsion treated sand-asphalt mix (see Fig. 15c).

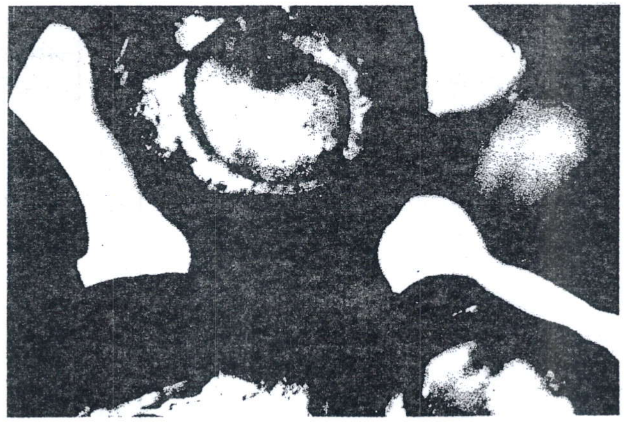

Figure 19. Photomicrograph before stripping test of sand-asphalt mix treated directly with maltenes without a carrier.

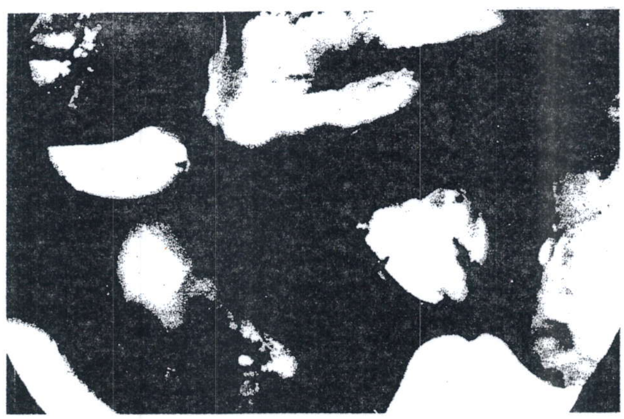

Figure 20. Photomicrograph before stripping test of sand-asphalt mix treated with maltenes solution in kerosene (see Fig. 15d).

described elsewhere (2, App. I). Table 3 summarizes the results. The selected blend of resins and oils effects an improvement in abrasion resistance irrespective of how it is carried to the asphalt. Again, the oil-resin emulsion with the cationic emulsifier shows the best long-term improvement in abrasion resistance.

TABLE 3

PELLET ABRASION TEST

Treatment	Abrasion Loss[1] (%)	
	24-Hr Aging	7-Day Aging
Untreated control	27	34
Oil-resin emulsion:		
Cationic	17	13
Nonionic	18	19
Anionic	20	21

[1] Average of duplicate specimens.

As the second part of this investigation, 8 sand-asphalt briquets, 2 ½ in. in diameter and 1.6 in. high (with the 2-in. diameter, 0.318-in. deep reservoir at the top) were molded using 48-penetration asphalt in accordance with the procedure given in Appendix A. All briquets were then weathered for 7 days in the infrared oven at 140 F.

After cooling to room temperature, one specimen was tested for load-penetration resistance as described in Appendix B. The remaining seven were then treated by pouring into the reservoir 10 ml of a dilution of two parts cationic oil-resin emulsion, and one part water. The seven specimens were again placed in the infrared oven at 140 F and withdrawn one at a time at 3-hr, 8-hr, 1-day, 2-day, 4-day, 7-day and 14-day weathering intervals. After cooling to room temperature, each briquet was tested for penetration resistance in the same manner as the untreated control specimen. Figure 21 plots the maximum resistance to penetration of the briquets vs interval of weathering after treatment.

At least 20-hr exposure in the infrared weathering oven at 140 F was needed in this case for the full effect of the cationic emulsion treatment to take place. In terms of field conditions, this would be roughly equivalent to a two-month period under average weathering conditions for the year. Accordingly, the time interval should be considerably less during the hot summer months (1 to 3 days) and somewhat longer in the

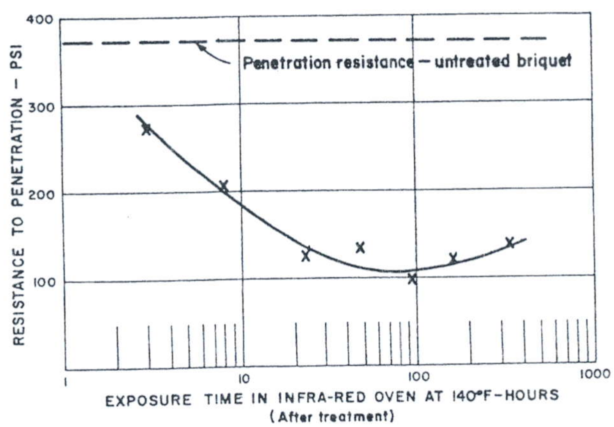

Figure 21. Load-penetration vs aging time as measure of time required for fluxing of maltenes with aged asphalt.

winter. Generally, it would be desirable to apply the emulsion when pavement temperature exceeds 80 F, even though the ambient temperature might be as low as 50 F.

OUTLINE OF USES

Although the primary function of the cationic maltene emulsion is to combine with and reconstitute aged asphalt, thereby restoring its plasticity, it acts as a "seal in depth" because after penetration it combines with and expands the asphalt. Permeability of the pavement to both air and water is reduced. In some instances, where initial shrinkage cracks had already developed, the treatment actually reversed the shrinkage process and closed the cracks. Moreover, when placed between successive layers of asphalt pavement, it provides an excellent bond by promoting a fusing of the asphalt at the interface.

Because of its ability to act as an asphalt replasticizer, a seal in depth, and a bonding agent, the oil-resin emulsion can be used on all types of asphalt paved surfaces not only in preventive and corrective maintenance but also in construction and reconstruction operations.

Preventive Maintenance

In preventive maintenance, the emulsion is applied to a structurally-sound asphalt pavement as soon as it begins to show signs of aging or brittleness through the symptoms of dryness, surface pitting, raveling or shrinkage cracking. Generally, these conditions develop in a 2- to 10-yr period after construction, depending on such factors as mix design, asphalt durability, pavement permeability and climatic conditions. The object is to penetrate the asphalt pavement and replasticize the asphalt before deterioration of the pavement has progressed too far (6).

Because asphalt pavements weather from the surface downward and it has been found that the permeability of the pavement usually increases with age, it follows that a spray treatment is, in a sense, self-regulating. The process of causing it to penetrate into the surface is, therefore, quite simple as the desired treatment consists essentially in applying that quantity of material, as determined by test, which will be absorbed by the pavement.

Exceptions to the self-regulating principle are asphalt pavements that have received surface treatments or seals which will inhibit penetration and pavements that have developed a "glaze" from high-density traffic and grease drippings. In such cases, removal of this seal is generally required to permit penetration, but this is no longer a preventive maintenance measure (7).

Corrective Maintenance

In corrective maintenance, the oil-resin emulsion is used with other procedures to improve a structurally sound asphalt pavement that is already extensively pitted or badly cracked. Usually the surface must be scraped or loosened and the loose material sprayed and recompacted or discarded. It may also be desirable to incorporate a new mixture of sand and asphalt in the loosened surface to provide a proper balance of aggregate and asphalt. If the existing surface requires a chip seal or a slurry seal, or even a thin asphalt concrete overlay, the oil-resin emulsion can be used as a spray treatment to prime the old surface and to provide a tack coat simultaneously.

The procedure to be used in corrective maintenance depends on the particular situation which determines what equipment and techniques will prove most effective. In general, combinations of heater-planing, blading, scarifying, mixing and rolling may be used, with the emulsion added at the most appropriate time.

Reconstruction

In reconstruction, the product may be used as a prime to replasticize existing asphalt-paved surfaces before a resurfacing operation or as an aid in breaking up and reworking an old, weathered asphalt paving while simultaneously replasticizing the asphalt in the mix. In the latter case, the treatment may be sufficiently effective to make the mix reusable as a surfacing.

New Construction

In new construction, the object of the treatment is to insure plasticity and improve the durability characteristics of the freshly-placed mix, while providing a construction seal to reduce permeability. This treatment applied after the asphalt paving has been spread and compacted serves two purposes: (a) it penetrates the surface and combines with the asphalt to restore the durability lost in the mixing cycle at the hot plant; and (b) it combines with the asphalt and causes the asphalt to expand and block the pores of the pavement, thereby sealing the pavement to the depth of penetration (Fig. 22).

A light spray of the oil-resin emulsion between lifts of asphalt during construction also serves as an excellent tack coat. By fusing with the asphalt on both sides of the interface, a positive joining of asphalt layers is developed.

APPLICATION QUANTITIES AND METHODS

The simplest method of bringing together the oil-resin blend and the aged asphalt is by spraying a predetermined quantity on the pavement surface and allowing it to soak in. This procedure is always effective in preventive maintenance, in new construction seals, and in priming and tack coating operations. Conventional asphalt spreader trucks may be used but they must be free of leaks and well calibrated to give a measured and uniform spread.

In the case of preventive maintenance and prime coating, the rate of spread is determined by the "grease ring" permeability test procedure (Fig. 23) described in Appendix C, using the criterion that the minimum spread rate is that quantity which soaks into the pavement in a 15-min period. In new construction seals, a spread rate of 0.2 is generally used for a 2-in. lift or more, and about 0.05 gal per sq yd is used in tack coating.

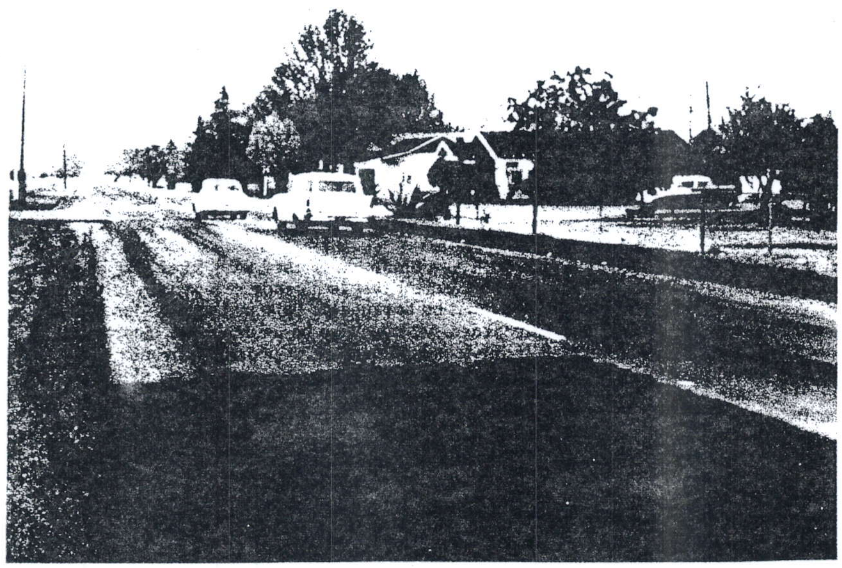

Figure 22. Asphalt section treated with cationic maltenes emulsion as construction seal: after rainstorm treated section dried quickly (background); untreated portion retains water in pores (foreground).

Figure 23. "Grease ring" permeability test.

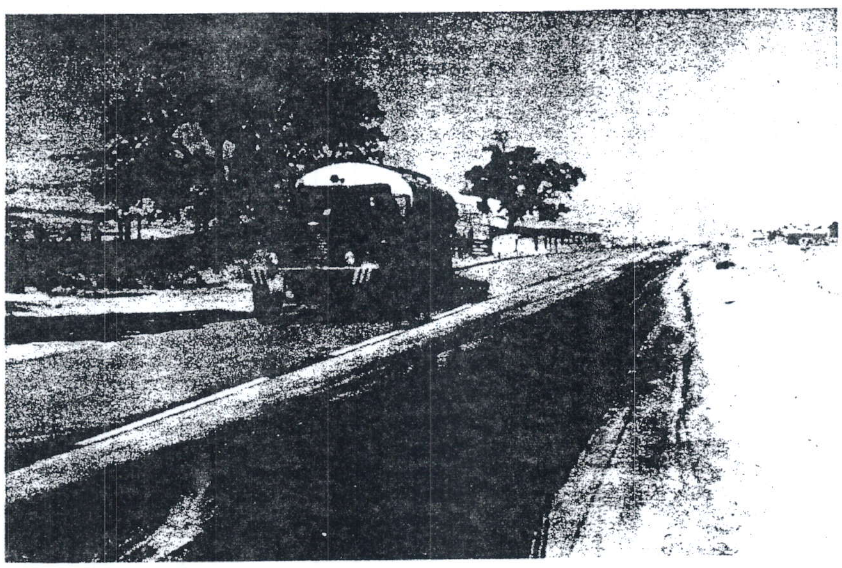

Figure 24. Spraying cationic maltenes emulsion in preventive maintenance; right lane lightly sanded.

It has been found that all newly-laid asphalt paving and the majority of weathered asphalt pavements are sufficiently permeable to respond to this simple spray-and-penetrate approach, provided a seal coat has not been applied.

If the pavement has had a so-called "fog" seal of asphalt emulsion or RC cutback, there is usually no difficulty in getting penetration, as this type of seal weathers rapidly and wears off in a short time. However, the fog seal does present a problem calling for special precautions as its weathered remnants will combine with and hold a certain amount of oil-resin residue at the surface — causing a slippery condition. In such instances, a light sanding is necessary (about 1 to 2 lb of fine, dry sand per sq yd) before traffic can be allowed on the pavement. In no case, however, should this sanding be done before the emulsion has had at least 15 min (preferably 45 min) to penetrate.

The sanding procedure is also appropriate when it is difficult to control traffic speed or when traffic must use the treated surface before complete penetration. It should be used on all areas where grease drippings have accumulated, such as at intersections, steep up-grades or sharp turns. Where light sanding is required over the entire area and when time is of the essence, sanding should begin from 15 to 45 min after the oil-resin emulsion is applied and follow the path of the application at the same speed (Fig. 24). The sand must be dry and gritty.

Where chip seals and slurry seals have been applied, penetration is often not possible in a reasonable time period unless the seals have largely worn away or are burned or otherwise removed by a heater-planer or similar operation. However, sometimes it is desirable to treat a chip seal, itself, in order to rejuvenate its asphalt. This is not only possible but readily accomplished, provided the rates of spread are predicated on existing conditions. Slurry seals as a rule do not respond well to treatment, particularly if they are extremely dense. Moreover, slurry seals are often overly rich in asphalt and present a skidding hazard when treated.

Where the maltenes emulsion is used in reconstruction as an aid in breaking up an existing pavement so that it can be reworked, respread and recompacted, a successful procedure (Tulare County, Calif., 1961-62) was to shoot the road mix, one lane at a time, with 0.1 gal per sq yd of a 2:1 dilution of the emulsion and water a few days before discing. The oil-resin blend replasticized the hard ¾-in. thick crust on the old road mix enough to speed up the discing and to facilitate break-up of the fragments of crust into a workable mixture, free of dry balls of material, by simple blade mixing. Over 100 lane-miles of road mix were reconstructed in this fashion with considerable savings in time, labor and equipment. The work crew was able to cover about twice the area in a given period of time and the discs required sharpening less frequently. The finished pavement was superior in serviceability, appearance, and smoothness as there were no hard lumps of unbroken material protruding from the surface.

EVALUATION OF FIELD TEST SECTIONS

Many field test sections are under observation to ascertain both the short- and long-range effects of various methods of treatments using this particular emulsion. Provisions were made for comparisons of treated and untreated areas subjected to the same loading and weathering conditions.

In examining and evaluating these test areas, the important consideration is to judge the relative overall performance of the treated vs untreated pavement, rather than to rely solely on visual appearance. Evidence of changes in surface texture, or cracking, or other signs of embrittlement should be sought and verified by digging into the pavement to compare effects beneath the surface. Actual field measurements of relative pavement permeability and laboratory test data on asphalts recovered from cores taken from field test sections can provide the relative numbers for a true assessment.

The most notable example of preventive maintenance is a test section on a taxiway at Edwards Air Force Base, Calif. In June 1959, the asphalt concrete paving was beginning to show signs of surface pitting but no shrinkage cracks had developed. Spread rates of 0.15 and 0.30 gal per sq yd of a four part emulsion to one part water dilution were applied on both ends of an untreated control section.

In the last $3\frac{1}{2}$ years, the surface of the untreated control section has pitted severely, the asphalt has been stripped from the aggregate at the surface and large shrinkage cracks have gradually developed and expanded. A recent survey found that the sides of the shrinkage cracks are breaking off and spalling badly because of extreme brittleness. These cracks meander over to the boundary of the treated area and gradually fade out (Fig. 25). To date, no cracking has started in the treated test areas.

Preventive maintenance test areas are also located on the asphalt concrete apron at Meadows Field (the Bakersfield airport), on the asphalt concrete resurfacing of the White Wolf Grade section of the California State Highway System east of Arvin (Fig. 26), on some asphalt concrete paved shoulders of highway US 99 just north of Lodi, on a road mix on Kern County's Comanche Road just north of US 466 (Fig. 27), and many other locations representing various types of asphalt surfaces.

There are also several test sections employing the cationic maltenes emulsion as a construction seal, including Kern County's Panama Lane project.

Lodi Test Section

In August 1961, the 8-ft wide asphalt concrete outer shoulder of US 99 north of Lodi was treated with the emulsion. The emulsion concentrate, as delivered to the jobsite, was diluted 2:1 with water and applied with a conventional asphalt distributor. Rates of spread of 0.06 and 0.14 gal per sq yd and an excess quantity (approximately 0.25) were used for this test. For comparison, a section of the shoulder was sprayed with 0.1 gal per sq yd of a conventional asphalt emulsion (SS-1), diluted in the proportion of 60 percent emulsion and 40 percent water.

It was apparent that the diluted oil-resin emulsion penetrated into the five-year-old pavement quite readily — complete penetration within 5 to 20 min depending on the rate of spread. Because the pavement had not previously been sealed and there were no

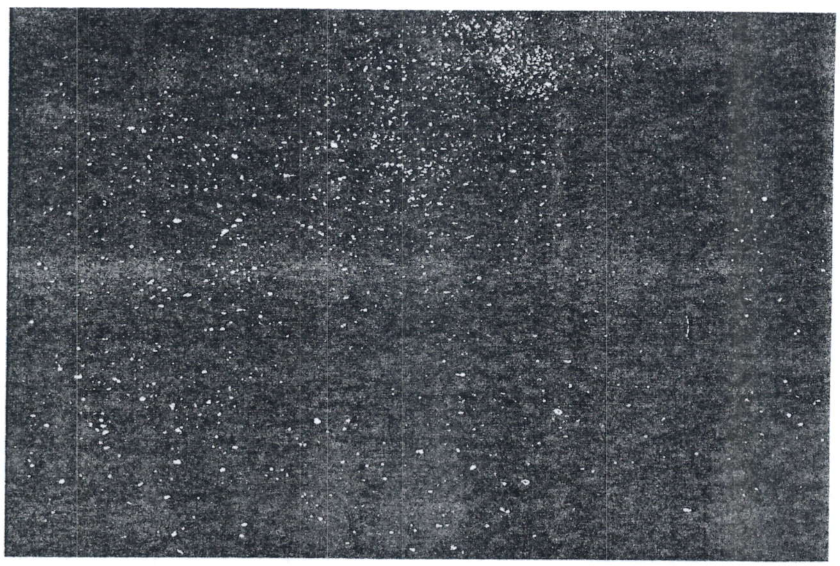

Figure 25. Taxiway at Edwards AFB viewed from treated area toward untreated control section.

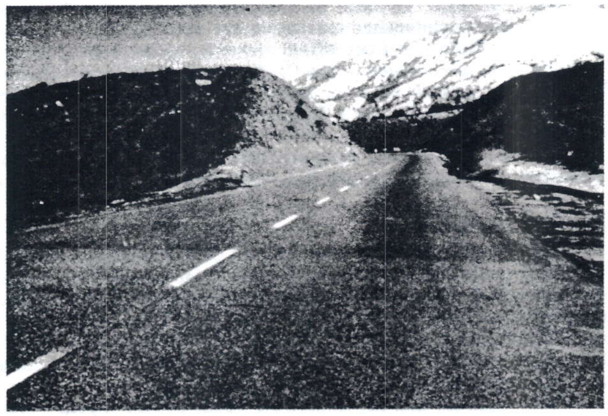

Figure 26. White Wolf Grade section six months after treatment: treated lanes in ba ground; untreated lanes in foreground.

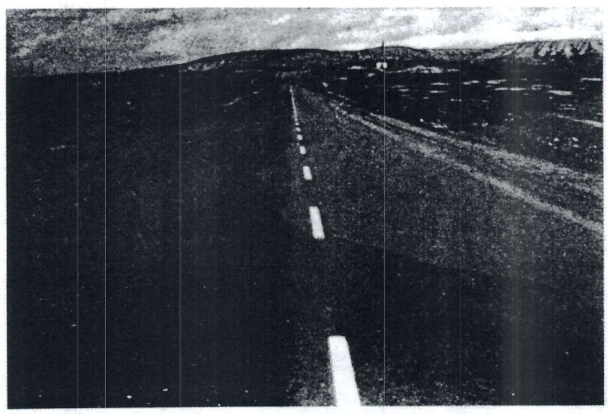

Figure 27. Weathering of road mix more rapid than for asphalt concrete accounting contrast in surface texture nine months after application: treated lane, right; treated lane, left.

TABLE 4

TEST RESULTS ON RECOVERED ASPHALTS FROM CORES, LODI SHOULDERS PROJECT, US 99 (Age: 2 Months)

Depth of Slice (in.)	Viscosity of Recovered Asphalt, Megapoises				
	Untreated	Cationic Maltenes Emulsion[1]			Asphalt Emulsion[1] SS-1h, 0.1 Gsy
		0.06 Gsy	0.14 Gsy	0.25 Gsy[2]	
0 - 3/8	86 (12)	7 (36)	0.35 (143)	0.2 (185)	45 (15)
1/2 - 7/8	21 (21)	19 (22)	11.4 (29)	6.3 (38)	16 (24)
1 - 1 3/8	19 (22)	15 (25)	10.5 (31)	8 (34)	15 (25)
1 1/2 - 1 7/8	--	--	--	11 (29)	--

Note: numbers in parentheses are penetration values of asphalts obtained from conversion chart.
[1] Diluted 2:1.
[2] Approximate.

accumulations of grease drippings, no sanding was required. On the other hand, the asphalt emulsion did not penetrate and sanding was required for safety and to prevent pick-up of the asphalt by traffic.

Two months after application, cores were taken from the various sections and cut horizontally at 1/2-in. intervals. Viscosities of the asphalt recovered from each slice were then determined using the sliding plate microviscometer (Table 4). Figure 28 shows the asphalt penetration values as the ordinate instead of viscosity as penetration value is a more familiar term to highway engineers.

A significant change in asphalt viscosity took place in the pavement to a depth of at least 1/2 in., with a possible effect of the added maltenes to a depth of 1 1/4 in. for the heavier treatments (Fig. 28). Inasmuch as these results were obtained relatively soon after application, it is possible that the oil-resin blend had not had sufficient time to reach a state of equilibrium in depth with the asphalt.

It is also apparent (Table 4 and Fig. 28) that the asphalt emulsion treatment has not influenced the aged asphalt within the pavement in any way. Even the viscosity of the asphalt recovered from the top slice of the core, which includes the asphalt seal, was not significantly greater than the viscosity prior to treatment. This indicates that an asphalt emulsion fog seal should not be considered as a pavement rejuvenator but as a surface dressing.

Meadows Field Test Section

In July 1960, a cationic maltenes emulsion test section was placed on the asphalt concrete light-plane parking area at Meadows Field (the Kern County Airport). Two 230-ft long, 8-ft wide parallel strips were treated with a 1:1 dilution at rates of spread of 0.11 and 0.22 gal per sq yd. Because this was one of the first test sections placed on a commercially-used area, the treatment was deliberately kept on the light side as a precautionary measure. However, penetration was rapid and complete; within 10 min all of the diluted emulsion had penetrated and the area was ready for traffic.

The water permeability test, Calif. Test Method 341-A, (8) was run 24 hr later and results averaged 20 ml per min on the untreated area and 10 ml per min on both treated sections. A value of 10 ml per min indicates that the pavement is impervious to water.

The original four-year-old pavement was dry in appearance at the surface and beginning to ravel slightly. Shrinkage cracks were beginning to form in the characteristic progressive, right-angled pattern. In October, it was observed that the shrinkage cracks had closed completely in the two treated strips but still remained in the surrounding untreated areas. Figure 29 shows the test area in October 1960 with the two parallel strips with all shrinkage cracks in the vicinity outlined with white chalk. The shrinkage cracks in the narrow strip between the two test sections did not close. Figure 30 shows one of the characteristic shrinkage cracks between the two test strips.

As an immediate result of this observation, a full-scale treatment of the entire light-plane parking apron with the emulsion was carried out in October 1960, except for a 30- by 50-ft section retained undisturbed for a long-term study. A spread of 0.20 gal per sq yd of a 2:1 dilution was used, a somewhat heavier treatment than the heaviest treatment of the two test strips, inasmuch as the lower dilution with water provides more oils and resins at the same rate of spread. This increase was made because other projects had indicated that the original applications were on the conservative side.

In July 1962, two 6-in. diameter cores were taken from each of the two test strips and from the adjacent untreated area. Table 5 gives the results of various laboratory tests. The maltenes emulsion treatment was most effective in

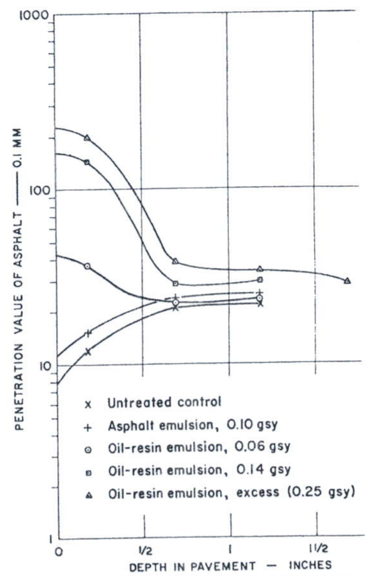

Figure 28. Change in asphalt penetra value with depth in pavement, Lodi Shou Project.

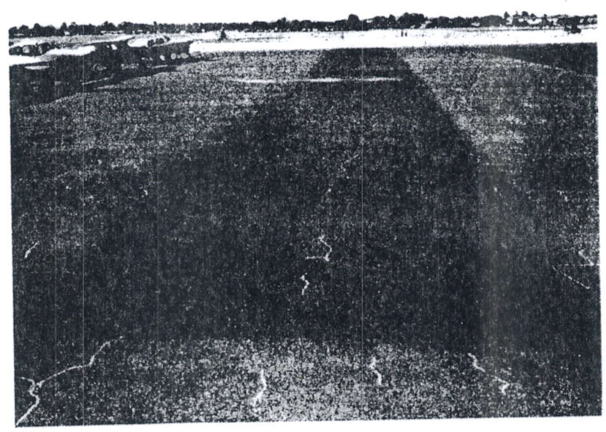

Figure 29. Meadows Field Test Section four months after treatment: absence of shr age cracking in treated areas; chalk outlines cracking still existing in surrounding treated area and in untreated area between passes.

Figure 30. Shrinkage crack between the two test strips (Fig. 29).

TABLE 5

TEST RESULTS ON RECOVERED ASPHALT FROM MEADOWS FIELD CORES (Age: 2 Years)

Determination	MF-Untreated		MF-Oil-Resin Emulsion Treated			
			0.11 Gsy		0.22 Gsy	
	Top	Middle	Top	Middle	Top	Middle
Asphalt content[1] (% agg. wt.)	3.8	4.4	5.2	4.9	5.0	5.0
Viscosity (megapoises)	37.3	14.3	14.0	24.3	2.7	22.0
Penetration value (0.1 mm)	17	26	26	20	56	22
Chemical composition[2] (% by wt.):						
Asphaltenes	25.8	20.6	25.5	21.9	24.9	22.8
Nitrogen bases	31.9	35.3	29.7	34.6	28.1	34.7
First acidaffins	10.2	12.8	10.9	12.7	10.4	11.9
Second acidaffins	18.3	17.2	18.7	16.7	19.9	16.2
Paraffins	13.8	14.1	15.2	14.1	16.7	14.4
Pellet abrasion test (% loss in wt.):						
As recovered	64	27	8	42	1	42
Aged	100	72	39	88	4	90
Maltenes distribution ratio[3]	1.31	1.54	1.20	1.54	1.05	1.52

[1] By Soxhlet extraction.
[2] Rostler method.
[3] $(N + A_1)/(P + A_2)$.

increasing and holding the asphalt content in the top portion of the pavement at a v
of about 5 percent, while the asphalt content in the surface of the untreated pavem
has dropped 3.8 percent indicating that disintegration can be expected to occur ra

After a 2-yr period in the severe weathering conditions of the southern San Joa Valley, the treatment still shows a beneficial effect as evidenced by the lower vis and higher penetration values of the asphalt from the top sections of the treated cc compared to the untreated cores. Even the relatively light treatment of 0.11 gal sq yd of 1:1 dilution has improved the asphalt in the top portion of the treated pave over that in the middle section.

It appears, however, that neither of the test sections had enough material appl to penetrate into and in any way influence the properties of the asphalt in the midd slice. This is substantiated by the essentially constant chemical composition of t three middle sections, particularly the paraffins content, and the maltenes distrib ratio. Definite effect of treatment, however, is shown by the change in chemical position of the top sections of the three cores where a general increase in the per ages of second acidaffins and paraffins is apparent, and the maltenes distribution is successively decreased from 1.31 to 1.20 to 1.05 by the treatments with 0.11 a 0.22 gal per sq yd, respectively.

The significance of the maltenes distribution factor as a measure of asphalt du bility is shown in Figure 31 (3) which is based on abrasion test data on over 100 sa ples of 85- to 100-penetration grade asphalts vs their maltenes distribution factor $(N + A_1)/(P + A_2)$. Rostler and White (3) have shown that a maltenes distribution factor of less than 1.14 characterizes an asphalt of excellent durability as measur by abrasion resistance.

Recovered asphalts from the Meadows Field cores were also subjected to the p abrasion test to ascertain what effect the treatment had on asphalt durability. The values, also given in Table 5, indicate the improvement of the treated asphalt in r sisting further aging.

Panama Lane Test Project

On May 1, 1961, a cationic maltenes emulsion treatment was applied on 600 ft freshly-spread asphalt concrete placed between Stations 118+00 and 124+00 on the westbound lane of Panama Lane in Kern County. The asphalt concrete specified c

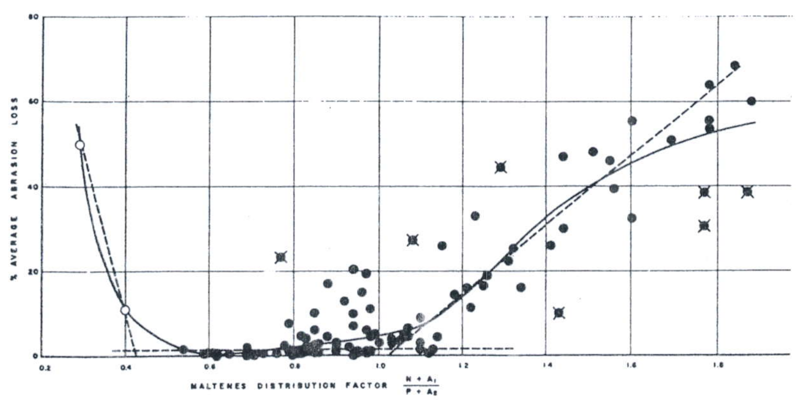

Figure 31. Variation in resistance to abrasion with change in maltenes distribu factor for 101 asphalts (after Rostler and White).

TABLE 6

PHYSICAL AND MECHANICAL PROPERTIES OF ASPHALT MIXTURE, PANAMA LANE PROJECT

Determination	Surface Course							
	Untreated				Oil-Resin Emulsion Treated (0.1 gsy)			
	Sta. 119	Sta. 120	Sta. 122	Avg.	Sta. 119	Sta. 120	Sta. 122	Avg.
Bulk specific gravity[1]	2.29	2.28	2.27	2.28	2.29	2.29	2.29	2.29
Hveem stabilometer[1] value	33	33	34	33	33	30	30	31
Cohesiometer[1] value	155	115	144	138	134	123	126	128
Extracted asphalt content (% wt. agg.)	5.6	5.5	4.7	5.3	5.9	6.0	5.5	5.8
Aggregate gradation (% passing sieve):								
3/4	100	100	100	100	100	100	100	100
3/8	71	70	58	66	73	74	65	71
No. 4	56	57	45	53	58	62	54	58
No. 8	45	47	37	43	48	50	44	47
No. 30	21	21	8	17	21	22	20	21
No. 200	4	3	4	4	4	3	3	3

[1]On laboratory molded specimens.

this project consisted of a 3/4-in. medium grading type A aggregate combined with 5.0 percent 85- to 100-penetration grade asphalt, with all materials and procedures meeting the requirements of Section 39 of California Standard Specifications. Total thickness of asphalt concrete was 3 in., placed in two 1 1/2-in. lifts.

The first 1 1/2-in. lift was spread and compacted in the usual manner, except that three complete coverages with a 25-ton pneumatic-tired roller were used in lieu of the rubber-tired rolling called for in Section 39, as this was also an experimental rolling project. While the mechanical spreader was placing the second 1 1/2-in. lift, a distributor truck applied 0.1 gal per sq yd of a 4:1 dilution of the emulsion to the first lift about 200 to 800 ft ahead of the mechanical spreader. Penetration into the first lift was complete in 2 to 5 min.

The second lift was placed over the treated first lift. While the mix was still hot (255 F), an additional 0.1 gal per sq yd of a 4:1 dilution was then applied by offset spreading after laydown and before the breakdown pass of a 12-ton steel wheel roller. The material soaked into the semi-compacted mix in less than 30 sec. Following breakdown, three passes were made with the 25-ton pneumatic roller with final rolling accomplished with a 10-ton steel-tired tandem roller.

TABLE 7

TEST RESULTS ON RECOVERED ASPHALTS FROM PANAMA LANE TEST PROJECT

Determination	Level Course		Surface Course							
	Untreated Sta. 124 + 50	Oil-Resin Emulsion Treated Sta. 123 + 50	Untreated				Oil-Resin Emulsion Treated			
			Sta. 119	Sta. 120	Sta. 122	Avg.	Sta. 119	Sta. 120	Sta. 122	Avg.
Penetration	56	113	68	70	63	67	91	100	123	105
Softening point	120	110	115	114	117	115	111	110	106	109

Surface Course	Untreated	Treated
Asphaltenes (% by wt.)	15.0	13.2
Nitrogen bases (% by wt.)	37.9	36.9
First acidaffins (% by wt.)	12.8	13.8
Second acidaffins (% by wt.)	22.1	23.3
Paraffins (% by wt.)	12.2	12.8
Maltenes dist. ratio, $(N + A_1)/(P + A_2)$	1.48	1.40

Samples of treated and untreated portions of this newly-constructed asphalt pavement were subjected to laboratory analysis. Table 6 summarizes the physical and mechanical properties of the surface course. The physical and mechanical properties of the asphalt concrete on the Panama Lane project were little affected by the addition of 0.1 gal per sq yd of the emulsion. The most noticeable effect was an increase in average asphalt content from 5.3 to 5.8 percent. The small differences in bulk specific gravity, stabilometer value, and cohesiometer value were well within the limits of reproducibility of the samples and the test procedures. Similar tests were not run on the asphalt concrete samples from the level course, because it was expected that the results would have followed the same pattern. Table 7 gives the results of tests on the asphalts recovered from the samples used to obtain the data in Table 6, together with recovered asphalts from a treated and untreated sample of level course material. The changes in properties of the asphalts were quite significant. Treatment with the emulsion increased the average penetration value of the asphalt by at least 38 points and lowered its average softening point by at least 6 F. Inasmuch as the original asphalt introduced at the pugmill was of grade 85 to 100, it is apparent that the treatment of 0.1 gal per sq yd was more than sufficient to restore the penetration points lost during the hot-mix cycle in the asphalt plant.

To verify results (Table 7) and obtain some indication of effect of treatment with depth, cores were taken one month later from the Panama Lane project in treated and untreated areas and the asphalt recovered. Table 8 gives the viscosity values, using the sliding plate microviscometer, determined on small samples of asphalt taken from the top, middle and bottom of each lift. Corresponding asphalt penetration values obtained from a conversion chart are also given.

The top portions of both the level and surface courses were significantly altered by the treatment with the

TABLE 8

TEST RESULTS ON CORES FROM PANAMA LANE TEST PROJECT

(Age: 1 Month)

Core No.	Location	Bulk Specific Gravity	Viscosity, Megapoises at 77 F, 5×10^{-2} SR					
			Surface Course			Level Course		
			Top	Middle	Bottom	Top	Middle	Bottom
U-1	125 + 00 OWT	2.22	2.7 (56)	2.8 (55)	2.1 (63)	1.8 (67)	1.3 (79)	1.6 (71)
U-2	125 + 00 BWT	2.18	4.8 (38)	3.8 (47)	2.3 (60)	3.3 (51)	1.4 (76)	1.0 (88)
U-3	128 + 75 OWT	2.21	--	--	--	--	--	--
U-4	128 + 75 BWT	2.20	--	--	--	--	--	--
T-1	119 + 00 OWT	2.20	--	--	--	--	--	--
T-2	119 + 00 BWT	2.14	--	--	--	--	--	--
T-3	123 + 00 OWT	2.22	0.13 (225)	1.8 (68)	1.7 (70)	0.65 (115)	0.97 (89)	0.99 (88)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 9

AIR AND WATER PERMEABILITY RESULTS, PANAMA LANE PROJECT, WESTBOUND LANE

Station	Water Permeability (ml/min)			Air Permeability for 4-In. Area (ml/min at 1/4 in. V)		
	OWT	BWT	IWT	OWT	BWT	IWT
(a) Control Section						
124 + 50	--	135	--	--	879	--
125 + 00	85	--	--	471	--	--
+ 50	--	--	55	--	--	389
126 + 00	--	105	--	--	584	--
+ 50	100	--	--	628	--	--
127 + 00	--	--	77	--	--	565
+ 50	--	180	--	--	1,005	--
128 + 00	120	--	--	754	--	--
+ 50	--	--	40	--	--	502
129 + 00	--	190	--	--	1,633	--
+ 50	65	--	--	628	--	--
130 + 00	--	--	50	--	--	220
Avg.	93	153	61	622	1,027	421
Total Avg.		(102)			(691)	
(b) Cationic Maltenes Emulsion Test Section						
118 + 00	--	--	45	--	--	63
+ 50	--	40	--	--	471	--
119 + 00	50	--	--	251	--	--
+ 50	--	--	25	--	--	126
120 + 00	--	40	--	--	314	--
+ 50	40	--	--	170	--	--
121 + 00	--	--	28	--	--	170
+ 50	--	135	--	--	879	--
122 + 00	30	--	--	44	--	--
+ 50	--	--	47	--	--	60
123 + 00	--	90	--	--	295	--
+ 50	80	--	--	502	--	--
124 + 00	--	--	40	--	--	119
Avg.	50	76	37	242	490	107
Total Avg.		(54)			(280)	

Notes: Rolling consisted of breakdown with 12-ton tandem and 3 coverages with 25-ton pneumatic followed with 8-ton steel tandem. OWT = outer wheel track; BWT = between wheel tracks; IWT = inner wheel track.

oil-resin blend, whereas the middle and bottom portions were much less affected. Nevertheless, making allowances for variations in sampling and testing, the data cate that the effects of the application are evident throughout the depth of the core

Another phase of the Panama Lane test project was to ascertain the effect of th emulsion on the permeability to both air and water of the newly-compacted asphal pavements. Table 9 gives air and water permeability results from tests conducte the pavement immediately after final compaction. All water permeability tests w run on the surface course using Calif. Test Method 341-A; the air permeability te method was that developed by the California Research Corporation (9).

The test section has had its water permeability reduced to about 53 percent of t untreated control section. The air permeability has been reduced to about 40 perc of the untreated control section. This is an important feature of the oil-resin emu sion treatment, particularly when the compaction effort required to reduce the pe bility to a similar degree is considered. Moreover, the decrease in permeability achieved in a finite depth of the pavement, and not by a skin coating which could re be worn away by weather and traffic.

Evaluation of Skid Resistance

One of the problems associated with the application of any liquid material on a roadway is the question of its effect on the pavement's skid-resistant qualities. B cause of the oily nature of the residue after evaporation of water, a hazard to traff will exist under the following conditions:

1. If the emulsion is not fully absorbed by the pavement, due to excessive appli tion, and remains at the surface;
2. If there is complete penetration of the emulsion but the oil-resin component can combine with accumulated grease drippings or remnants of previous asphalt se at the surface; or
3. If exposed aggregate particles are smoothly polished and, therefore, easily lubricated.

In such cases, light sanding (1 to 2 lb per sq yd) with a dry and gritty material cor rects the condition. However, such sanding should be delayed as long as possible, preferably a period of at least 45 min so that the emulsion has enough time to ente the pores of the pavement. If slick spots are localized, sanding should be confinec to the specific areas. Problems are most likely to occur at intersections, sharp t and steep up-grades.

Table 10 gives coefficients of friction for two areas subjected to the emulsion tr ment as compared to the same untreated surfaces. Complete penetration occurred

TABLE 10

SKID RESISTANCE MEASUREMENTS WITH CALIFORNIA SKID TESTER

Location and Date	Section	Treatment	Degree of Penetration	Coefficient of Friction[1]			
				Before		After	
				Dry	Wet[2]	1 Hr	4 Hr
Bear Mountain Blvd., July 13-14, 1960	R-1 Sta. 165 + 50	0.06 gsy O-R emul., 4:1	Residue at surface	0.41	0.32	0.29	0.28
	R-2 Sta. 193 + 50	0.08 gsy O-R emul., 2:1	Residue at surface	--	0.34	0.28	0.27
	R-3 Sta. 221 + 50	0.07 gsy O-R emul., 1:1	Residue at surface	0.41	0.32	0.28	0.28
Meadows Field, July 14, 1960	Control	None	--	0.43	--	--	--
	I	0.11 gsy O-R emul., 1:1	Complete in 3 min	--	--	--	--
	II	0.22 gsy O-R emul., 1:1	Complete in 5 min	--	--	--	--

[1] All values average of 5 or more tests made at 50 mph using smooth tire.
[2] With glycerine.

one instance, but a residue remained in the other because of the relative imperviousness of the asphalt concrete. A loss in frictional resistance results when penetration is not complete. Although sufficient frictional resistance remains for traffic to negotiate the area, the traveling public generally cannot be expected to respond properly to such a condition particularly at high rates of speed. Therefore, sanding is recommended as a precautionary measure.

Where penetration of the emulsion is complete, the coefficient of friction remains high and no sanding is required, although it is recommended at intersections and sharp turns as a precautionary measure.

For areas that can be restricted to traffic for long periods of time, it is beneficial to allow the treatment to soak in without any sanding.

CONCLUSIONS

On the basis of the information and data presented, together with the experience gained over the past three years of application under many and varied conditions, the following conclusions are made:

1. The principle of rejuvenating aged asphalts, in situ, with a selected combination of petroleum oils and resins is a sound and workable one.
2. The best procedure for introducing the oil-resin fraction into the pavement and carrying it to the existing asphalt films without displacing them or destroying their cohesiveness is by use of an emulsion.
3. A cationic charge on the emulsion is necessary to effect preferential wetting of the asphalt over the aggregate by the effective ingredients of the emulsion.
4. The simple "dilute, spray, and penetrate" procedure works well as a construction seal on new pavements and in tack or prime coating operations in preventive maintenance treatment of relatively new pavements (2 to 10 years old).
5. Treatment of dense, old, badly-cracked or tightly-sealed asphalt pavement must be done in combination with other procedures, such as heating, planing, discing, scarifying or mixing with the cationic maltenes emulsion applied during the operation to bring the weathered asphalt and the emulsion into intimate contact.
6. When the emulsion and weathered asphalt are exposed to each other, data from both laboratory experiments and large-scale field tests indicate that the properties of the aged asphalt are significantly improved with respect to consistency, adhesiveness, and durability without any detrimental effects on the cohesiveness or stability of the pavement.
7. Combining the oil-resin blend with the aged asphalt causes an expansion of the asphalt which blocks the pores and results in a significant decrease in permeability to both air and water.

REFERENCES

1. "Resistance of Bituminous Materials to Deterioration Caused by Physical and Chemical Changes." HRB Biblio. 9 (1951).
2. Rostler, F. S., and White, R. M., "Influence of Chemical Composition of Asphalts on Performance, Particularly Durability." ASTM Spec. Tech. Publ. No. 277 (1959).
3. Rostler, F. S., and White, R. M., "Composition and Changes in Composition of Highway Asphalts, 85-100 Penetration Grade." Proc. of the Assoc. of Asphalt Paving Technologists, Vol. 31 (1962).
4. Vallerga, B. A., "On Asphalt Pavement Performance." Proc. of the Assoc. of Asphalt Paving Technologists, Vol. 24 (1955).
5. Hveem, F. N., "Types and Causes of Failure in Highway Pavements." HRB Bull. 187, 1-52 (1958).
6. Vallerga, B. A., "Reclamite — New Product for Asphalt Maintenance." Western Construction (Dec. 1960).
7. Vallerga, B. A., "Reclamite — A Report After One Year." Western Construction (May 1962).

8. Zube, Ernest, "Studies on Water Permeability of Asphalt Concrete Pavements Proc. of Fourth Annual Highway Conference, Univ. of the Pacific (March 1961).
9. Ellis, W. H., and Schmidt, R. J., "A Method for Measuring the Air Permeab ty of Asphalt Concrete Pavements." ASTM Spec. Tech. Publ. No. 294 (19

Appendix A

METHOD FOR PREPARATION OF SAND/ASPHALT BRIQUETS

Apparatus

Hobart Kitchenaid Mixer, with Pyrex bowl.

Heating mantle, Glas-Col, top mantle for 5-liter, 3 neck, flask with one side closed by lace or zipper.

Two adjustable transformers (Powerstat), 7 1/2 amp.

Laboratory balance, capacity at least 1610g, accurate to 0.1 g.

One qt Mason jar with lid.

Stopwatch.

Oven, with mechanical circulation of air, capable of holding a temperature of 325 ± 3°F. (Precision Thelco Oven Model 18A).

Flexible steel spatula with wooden handle.

Aluminum or tin-plated steel baking pan, 9x13x2 in.

Carver Laboratory Press.

Mold for molding briquets 2.5 in. diameter, ca 1.6 in. high with 2.0 in. diameter 0.318 in. deep reservoir at top, and accessories for removing briquets from mold.

Materials

Graded Ottawa Sand, ASTM Designation C-109.

Portland cement.

Asphalt (penetration as specified).

Calibration

Determine the voltage required for the heating mantle to maintain a temperature of 325 ± 3°F. in 1000g of graded Ottawa Sand (preheated to 325°F.) in the bowl of the Hobart Kitchenaid Mixer while stirring at speed setting 1.

Procedure

Weigh 900 ± 0.2g graded Ottawa Sand and 100 ± 0.1g Portland cement into 1 qt Mason jar. Mix thoroughly by tumbling. Weigh 75 ± 0.1g asphalt into mixer bowl. Heat sand-cement mixture in 325°F oven for 60 ± 10 minutes; heat mixer bowl with asphalt in 325°F oven for 10 ± 1 minutes (time heating periods to end simultaneously). Meanwhile, preheat mantle (inverted 5 liter top mantle slightly deformed fits Hobart mixer bowl). Set mixer speed control on 1 and control speed of mixer through variable transformer (to avoid overflow at start). At end of heating period, remove sand-cement mixture and mixer bowl with asphalt from oven, dump sand-cement mixture into mixer bowl, place bowl in position on mixer inside preheated mantle and start mixer, increasing voltage to 115 volts promptly. Mix 8 minutes, including one or two stops if required for scraping sides of bowl with flexible spatula. Dump mixture into metal baking pan. One batch makes five briquets; if several batches are made, hold mixture in an oven at 140°F until last batch is made and blend batches with spatula. Cool mixture to approximately room temperature, weigh out 210g portions and mold briquets using 10,000 lbs load (=2000-psi on briquet) for 1 minute.

Appendix B

TENTATIVE METHOD OF TEST FOR LOAD-PENETRATION RESISTANCE OF SAND/ASPHALT BRIQUETS

Apparatus

Hydraulic Unconfined Compression Tester, pneumatic operated, Soiltest Model U-130 (see note at end of method).

Bronze plug, 1.128 in. diameter approximately two inches long, and clip to fasten plug securely to center of upper platen of Unconfined Compression Tester.

Two Stopwatches.

Source of Compressed air, 125 psi minimum.

Materials

Asphalt briquets, as described in Appendix A, treated and/ or aged as specified.

Paper squares, approximately 4x4 in.

Calibration

Adjust rate-of-strain control valve to give a rate, unloaded, of 0.25 ± 0.02 in. per minute at average available air pressure.

Procedure

Convenient operation requires two people, one to operate tester and call out strain readings while the second reads and records stress readings. Place briquet on a paper square on the lower platen of tester; center carefully. Depress main control valve. Start both stopwatches when strain and/or stress gauges first begin steady climb. Record stress readings at specified strain readings and at maximum stress. Stop first watch at point of maximum stress; stop second watch at end of test (0.25 in. strain, but do not exceed maximum allowable stress on proving ring).

Note: With the pneumatic-operated hydraulic tester, the actual rate of strain varies from about 0.25 in. per minute for relatively weak briquets to 0.1 in. or even less per minute on very strong briquets, due to the slowing effect of the resistance on the travel of the piston, and to greater movement of the proving ring. An improved tester is now being designed, utilizing a constant speed drive and an electrical load measurement device which eliminates motion within the load measuring mechanism.

Appendix C

METHOD OF TEST FOR DETERMINING THE QUANTITY AND RATE OF ABSORPTION OF RECLAMITE INTO AN ASPHALT PAVEMENT

Equipment

(1) Watch with second hand, preferably a stop watch.

(2) Six inch diameter template.

(3) Piece of yellow lumber crayon or chalk.

(4) Grease gun or calking gun or commercially available grease-filled plastic tube capable of slowly extruding medium chassis grease in a continuous ribbon approximately 1/4 inch diameter.

(5) Supply of medium chassis grease (for grease gun or calking gun only).

(6) Spatula or putty knife.

(7) Quart can containing a dilution of 2 parts Reclamite to 1 part water (2:1 dilution).

(8) 25 ml plastic or glass graduate (plastic preferred).

(9) Small brush with stiff bristles.

(10) Empty open-end pint can for waste grease.

(11) Quart can of water.

(12) Several rags.

Procedure

(1) Using 6 in. diameter template and crayon or chalk circumscribe circle on asphalt pavement where test is to be run.

(2) With grease or calking gun or grease-filled plastic tube, place a 1/4 inch (approximately) bead of grease on the circumference of the circle.

(3) Run index finger around outside edge of grease ring making sure to push a small amount of grease tightly against the pavement. This will form a sealed reservoir for the test solution.

(4) Measure 8.3 ml of Reclamite dilution (2:1) in graduate and pour in grease ring, simultaneously starting stop watch or re-

cording time to nearest second.

Note: 4.1 ml equivalent to 0.05 gsy spread rate

8.3 ml	"	" 0.10 gsy	"	"
16.5 ml	"	" 0.20 gsy	"	"
24.8 ml	"	" 0.30 gsy	"	"

(5) Using small brush quickly spread Reclamite dilution uniformly over area of circle.

(6) Clean graduate by rinsing with water.

(7) Record time interval required for Reclamite dilution to penetrate into surface.

Note: Complete penetration is generally indicated by loss of pink color of Reclamite dilution, except when an extended time of penetration allows evaporation of water with subsequent breaking of Reclamite emulsion on surface. Latter possibility readily evident because of tacky film of Reclamite residue on surface.

(8) After test is completed scrape up grease ring with spatula and place in open-end pint can.

(9) If 8.3 ml is absorbed within a 15-minute interval, make new grease ring and repeat test with additional testing fluid in increments of 8.3 ml (16.5 ml, 24.85 ml, etc.) until time of penetration exceeds 15 minutes.

(10) If 8.3 ml is not absorbed within a 15-minute interval, repeat test using 4.1 ml of testing fluid.

Test Report

The following information and data should be recorded:

(1) Description of surface being tested.

(2) Location of test ring.

(3) Time of penetration for each quantity of Reclamite dilution used.

(4) Estimate of quantity of Reclamite dilution absorbed by pavement in 15 minutes.

Note: The test rings should be examined 24 hours later to determine visually the effectiveness of the treatment. Test area can also be probed with a knife blade or screwdriver to qualitatively determine depth of penetration.