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PROMISING MATERIALS AND METHODS FOR EROSION CONTROL

Laboratory studies and field tests initiated by the U.S. Air Force resulted in the selection of a family of products and a method of application for combating surface erosion. The main objectives of the investigation were to devise a system of methodical erosion control on Air Force installations and to formulate acceptance specifications based on standardized testing procedures for materials to be used with the system. Although many attempts have been made to find products to correct wind and water damage to natural soils, the present study was directed toward forestalling damage to all types of ground surfaces existing on Air Force installations. Erosion on and around air fields is created not only by wind and water but also by many other forces such as downdraft from aircraft (which is considerably more severe than natural winds), vehicular traffic, fuel spillage, and other man-made causes. The main emphasis of this study was on prevention of erosion rather than a cosmetic treatment of damage caused. In realization of the fact that no single product or treatment can serve all purposes of erosion control but that, on the other hand, logistics requires a simple procedure and a minimum of different materials, an effort was made to find products that, even if used for different effects, could be applied in the same manner, either by themselves or in combination. Another objective was to treat the existing soils as integral parts of the erosion-resistant surface rather than to cover the soils by a protective coating. In other words, soil modification was the objective rather than a "Band-Aid" approach to damaged soils. The products found to satisfy these requirements are emulsions that have characteristics such as a similarity of emulsification systems and common ingredients that make them mutually compatible. The main difference between the products is that they were developed to be combined with specific forms of soils, i.e., rock, gravel, sand or fine particles in loose form or embedded in artificial surfaces such as pavements. The paper describes properties, applications, field experience, and tentative specifications and testing procedures devised for Air Force use. Data, photographs, and case histories are presented to illustrate that the products selected constitute very promising materials for fortifying earth surfaces against the widest variety of forms of erosion.

Erosion control is a branch of geotechnics, the science dealing with enhancing the utility of the earth's surface. Geotechnics is defined in Webster's Dictionary as the applied science of making the earth more habitable. In its broadest definition, erosion control encompasses all measures employed to combat the effects of wind, water, and mechanical forces of traffic on natural and man-made surfaces. Environmental conditions such as temperature fluctuations and exposure to sunlight affect the severity of attack by wind, water, and traffic. The type of erosion control is dictated by purpose, e.g., military, agricultural, or industrial, and severity of forces causing erosion. The erosion forces to be controlled are more severe on and around airfields than for instance in agricultural areas because, besides wind and rain, there are additional man-made forces such as downdrafts from helicopters and direct air blasts from aircraft, fuel spillage, and vehicular traffic by a diversity of equipment.

In an academic sense, the surfaces to be protected from erosion range from open fields and painted surfaces, e.g., traffic signs, to various engineering structures such as pavements and bridges. The area of this study was limited to soil erosion; however, the study was broadened to deal with all soils including rock, gravel, sand, and fine particles such as silt and clay, in loose form or embedded in artificial surfaces such as pavements.

Natural forces are the main powers of erosion. All surfaces of the earth are attacked and shaped by these forces. Examples of erosion on natural surfaces by natural forces are shifting of sand dunes and erosion of shore lines that should be contained by man for benefit to man. Man is concerned with controlling these natural phenomena to enlarge areas of habitation.

Dust, the result of wind erosion, is an ecological problem and at times and in some areas is the largest pollutant of our air. Dust resulting from faulty agricultural practices and inconsiderate construction practices must be held to a minimum for general ecological reasons. For military purposes dust must be controlled because of interference with visibility and damage to aircraft and airfield installations as well as its adverse effect on health. As pointed out, the work reported here was initiated by the Air Force for Air Force purposes, but the facts developed are of utility for all interested in methodical and standardized methods of erosion control.

TECHNOLOGICAL BACKGROUND OF STUDY

Available information on erosion control is voluminous but scattered through various disciplines. No single textbook is available that contains all the essential information an engineer responsible for erosion control would like to have, but there are some outstanding basic textbooks. Bagnold (1) is the most comprehensive book dealing with the action of wind on soils, particularly sand; Winterkorn (2) presents a concise discussion of soil stabilization as it pertains to civil engineering and improvement of soils as foundation and construction material; Stallings (3) deals primarily with agricultural questions, but his book contains a wealth of general information and references to work by Chepil, Woodruff, Zingg, and many other workers in this field. Sherard et al. (4) deal with engineering problems in design and construction of safe and economical structures built from natural soils and rocks. Lambe (5) presents in laboratory manual form a description of basic soil testing procedures and explains the significance of the tests. Hottenstein (6) in a paper describing current practices in erosion control along highways discusses extensively the use of turf for soil protection. In reference to emulsions, he made the statement that they are too new to permit a complete evaluation at this time. Publications originating from the U.S. Army Engineers Waterways Experiment Station are another source of information on testing methods and use of various products. The periodical Soil Conservation published by the U.S. Department of Agriculture is most informative on current problems and new developments.

The purpose of this study was to explore available concepts and to recommend materials that can be used routinely and methodically for control of all types of erosion on Air Force installations.

A previous study performed for the Corps of Engineers had established that emulsion products are most convenient to use in all types of applications and that a spray-on application is adaptable to use in nearly all cases (7). Large-scale use of an emulsion product in conjunction with planting of vegetation was performed in

1959 at Vandenberg Air Force Base (8, 9). The results achieved are described and shown later in the presentation of case histories. Based on this experience, rational considerations, and logistics, the following guidelines were established from the outset of the study, stipulating that the material to be used should be

1. A liquid that combines with the surfaces to be treated forming erosion-resistant surface layers to the depth likely to be disturbed,
2. Usable in spray-on applications,
3. Noncombustible,
4. Capable of being combined or fortified with other liquids to satisfy the widest possible requirements,
5. Commercially available at reasonable cost, and
6. Defined by characteristics determinable in standardized testing procedure suitable for acceptance and purchasing specifications.

Work performed in the laboratory and in the field has established that the listed requirements can be met.

RESULTS OF PREVIOUS WORK

It would be outside of the scope of this summary report to describe in detail the work done preceding this study and the reasoning behind it. Most of the details are given in previous publications (7, 10, 11). It will suffice to report the latest laboratory tests and to give a few case histories of field applications.

The principal earlier findings can be summarized as follows: One multipurpose product, i.e., one effective with all soil surfaces under all conditions of erosion by wind, water, and traffic, is an unrealistic goal, but a family of products, each with different capabilities for reinforcement of soil surfaces, can be used to control various conditions of erosion and can provide a practical means for methodical erosion control, provided the products can be used in conjunction.

Four commercially available products that can be used to demonstrate the feasibility of the approach are produced by Phillips Petroleum Company in emulsion form and are available under the designations Petroset SB, Petroset AX, Petroset RB and Petroset AT (12). Products can be added to this family of materials to satisfy other requirements of performance not considered in the present study, if they are made to be physically and chemically compatible with the other products.

FUNCTIONAL DESCRIPTION OF PRODUCTS TESTED

All four products had the following characteristics:

1. A nearly equal emulsification system, cationic in nature, and very high stability,
2. A high-strength thermoplastic elastomer in a solvent, which is a good solvent for all ingredients contained in the oil phases of the four emulsions,
3. High mutual compatibility of all ingredients,
4. A distinguishing and identifying color for each of the emulsions,
5. Miscibility of the emulsions with each other and with water in all proportions, and
6. Ease of penetration into surfaces having measurable porosity to liquids.

These common characteristics are believed to be important in that these products can be used for various purposes either by themselves or in combination with each other.

Petroset SB has high wetting and bonding power for soil particles below the size of gravel and deposits an elastic bonding agent on the individual particles. The product can be used with fertilizer in mulching operations or with sterilant without breaking the emulsion. Petroset AX contains, in addition to the high-strength polymer, a certain amount of asphaltenes, the asphalt component that provides increased hardness and bearing strength for this cementing agent. Petroset RB contains a bonding agent for large aggregates ranging from gravel to rock, converting loose rock structures into a shock-absorbent and vibration-damping continuum. Petroset AT is a rubberizing agent for asphalt surfacings that, in a spray-on application, penetrates asphalt pavements, reinforces the bonds, and increases the durability of asphalt cements.

The products not only are mutually compatible but are synergistic when used in proper combinations. They can be applied to surfaces individually, consecutively, in blends, and in dilution with water in all proportions. This mutual compatibility offers engineers great flexibility and freedom of design. Petroset SB can, for instance, be reinforced in bearing strength and hardness by blending with Petroset AX; addition of Petroset AT to SB or AX increases elasticity and extensibility.

DEMONSTRATING THE CAPABILITIES OF THE EMULSIONS

The apparatus and procedures used for evaluating the products in the laboratory have been described in previous publications (7, 10, 13, 14, 15). The materials examined were soils ranging in size from fine-grained silt and clay to large rocks and asphalts representative of all ranges of durability. The asphalts and method of rating have been described earlier (15).

The soils were tested in loose form and in form of briquettes of prespecified densities; the asphalts were tested in mixtures with aggregates, in form of briquettes, and in other preformed specimens.

LABORATORY TESTS

Most of the laboratory tests performed consisted of the following steps:

1. Determining physical and chemical properties of the products including storage stability, performance during handling (e.g., frictional stability during pumping), and stability on dilution with water of various hardnesses;
2. Measuring penetration of the emulsions into loose and slightly compacted soils and into briquettes made from standardized test soils; and
3. Comparing erosion resistance of specimens treated with various amounts of the emulsions and blends of the emulsions on exposure to air blasts (defined by wind velocities), simulated rainfall, running water, abrasion, aging, applied loads, and repeated loading.

Some typical tests performed and results obtained are presented later. Descriptions of the test procedures and apparatus used are available from Materials Research and Development, Inc.

Physical and Chemical Properties of Materials Tested

Table 1 gives the compositions of the four products examined. The performance of the individual products and blends made from them is governed by the amounts and proportions of the effective ingredients.

Effect of Blending Products AX and SB on Bearing Strength

Figure 1 shows that, by blending SB with increasing amounts of AX, load bearing capacity is increased proportionately. Figure 2 shows photographs of soil test briquettes that were split after application of the treating agents. Material 104 is AX, material 105 is SB, and 104/105 is a 50-50 blend of SB and AX. Also shown are two split briquettes treated consecutively with 104 and 105. Materials 101, 102, and 103 are solutions of three asphalts in a petroleum solvent. Material 103 contains the same asphalt as emulsion 104. It is significant that the emulsions penetrated uniformly without separation, whereas in the case of the asphalt solutions the asphalt was filtered out on the surface of the specimen.

The composition of the synthetic test soil by weight was graded Ottawa sand (ASTM C 109), 85 percent; ground sand (No. 1 D.M. silica), 10 percent; and Dixie clay, 5 percent.

Figure 1. Load bearing capacity of soil treated with Petroset SB and Petroset AX.

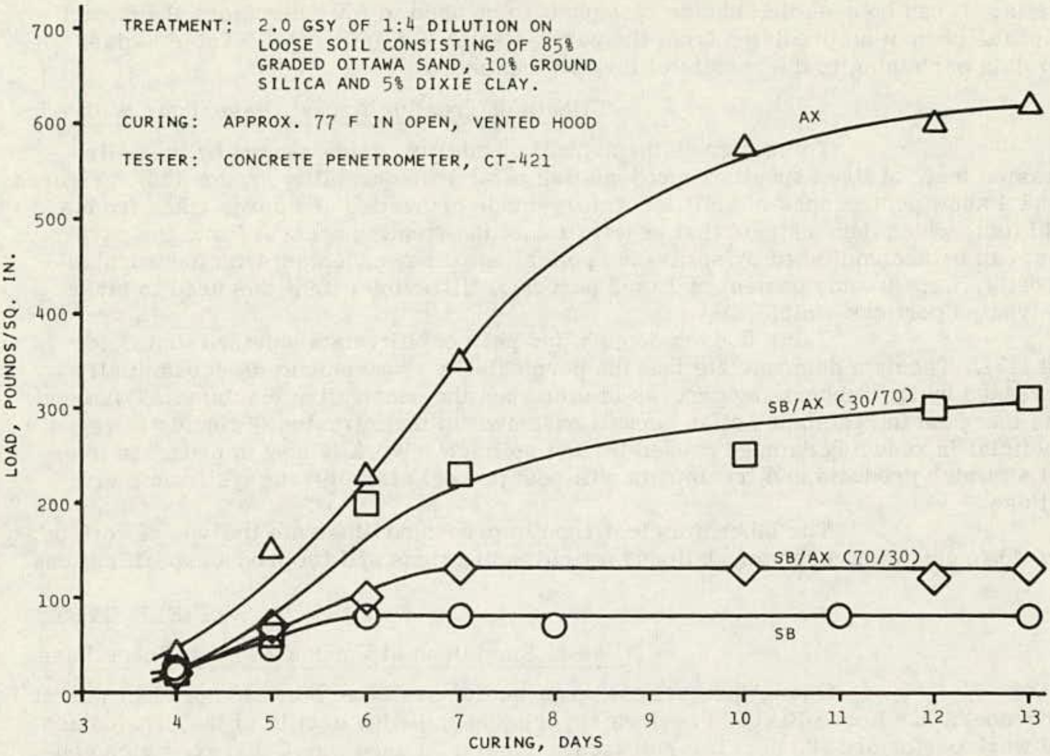


Table 1. Composition of emulsions.

Ingredient	Emulsion RB	SB	AX	AT
Elastomer	22	9	4	18
Resins	11	9	—	—
Asphalt	—	—	46	—
Oils (nonvolatile solvents)	—	27	—	42
Volatile solvents	42	25	14	—
Water and surfactants	25	30	36	40

Figure 2. Split soil briquettes.

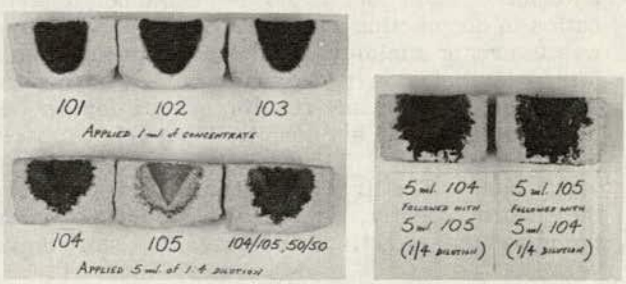


Table 2. Physical properties of materials tested.

Material	Viscosity at 77 F (millipoise) 0.05 sec^{-1}	0.001 sec^{-1}	Shear Susceptibility	Penetration[a] Measured	Calculated[b]	Elastic Recovery (percentage of strain) 1 min	1 hour	Durability Parameter[c]	Abrasion Loss of Aged Ottawa Sand[d] (mg/rev)
101	41.5	61	0.20	17	16	1.5	2.2	1.11	147.8
102	2.09	2.09	0.00	65	62	1.0	4.6	0.905	4.8
103	3.48	4.20	0.05	58	55	3.0	6.3	0.885	1.3
104	3.48	4.20	0.05	58	55	3.0	6.3	0.885	1.3

[a]ASTM D 5-65.
[b]From Saal, Baas, and Heukelom (22).
[c]From Halstead, Rostler, and White (15); $\frac{N + A_1}{P + A_2}$.
[d]Pellet abrasion test (15).

Data given in Table 2 identify the solids in four of the treating materials. It can be seen that choice of asphalt to be used in AX determines the durability of the cement as predicted from the parameter $(N + A_1)/(P + A_2)$. Table 3 gives test data pertaining to the results of the two treatments.

Effects of Treating Asphalt Pavements With AT

Table 4 gives the asphalt durability, as measured by the pellet abrasion test, of five asphalts representative of various durability groups (16). Figures 3 and 4 show photographs of split laboratory-made briquettes and cores taken from a field test, which demonstrate that penetration of the treating agent AT into the pavement can be accomplished by spray-on application on any pavement with measurable porosity, i.e., a voids content of 1 or 2 percent. Ultraviolet light was used to make the treated portions visible.

Table 5 gives density and permeability data obtained in a field test (17). The data demonstrate that the permeability of pavements is substantially decreased by the rubberizing process in situ when the penetrating emulsion AT is used. This increase in resistance of an asphalt pavement to the intrusion of liquids is very beneficial in reducing damage caused by fuel spillage. Work is now in progress to establish which products and treatments will best protect airfield runways from fuel spillage.

The laboratory test results presented illustrate the type of work performed to establish recommendations for field applications and for product specifications.

FIELD TESTS

Use of Emulsions at Vandenberg Air Force Base

One of the earliest large-scale uses of an emulsion product was at Vandenberg Air Force Base. Previous reports describe the details of the erosion control work performed (8, 9). The soil treating material used was Coherex, which contains resinous petroleum fractions that have a great affinity to soils. It contains different ingredients and has a different emulsification system from the Petroset emulsions but is, like Petroset, an oil-in-water emulsion. Because Coherex has only limited resistance to water and moderate resistance to strong winds, it was used in this application in conjunction with snow fences and planting. The purpose of the snow fences was to create miniature sand dunes that function as traps for blowing sand. It was later established that forming 1- to 2-ft berms treated with a soil-stabilizing agent accomplishes the same results as snow fences. Berms have the advantages of not being unsightly and not constituting a general barrier to emergency traffic.

Figure 5 shows photographs of an area before stabilization and 12 years later. The first photograph was taken shortly after stabilization of the area and the second recently. Stabilization succeeded in stopping in a matter of a few months the movement of active sand dunes that shifted around at Vandenberg for thousands of years.

There is much discussion about defacing the earth's surface by man. The work performed at Vandenberg and other air bases shows that man can reclaim and in many cases has reclaimed areas subjected to natural erosion for human habitation.

Stabilization of U.S. Atomic Energy Reservation

The Bechtel Corporation successfully stabilized an excavation approximately 80 ft deep and 360 ft in diameter by means of Petroset SB. Previous to the stabilization, work stoppages were frequent due to dust storms. Figure 6 shows the excavation and the application, which was by water truck and fire hoses. This work was not done by the U.S. Air Force but is reported here because it is evidence that an emulsion belonging to the family of products described can serve a variety of objectives.

Soil Stabilization Tests at Edwards Air Force Base

The purpose of the field tests at Edwards Air Force Base was to repeat on a large scale tests performed in the laboratory on the effect of blending

Table 3. Results of two treatments on soil briquettes.

Sample	Brookfield Viscosity at 77 F, as Applied (cps)	Penetration Into Soil Briquettes: Amount Applied	Time (sec)	Depth (in.)	Wind and Water Erosion[a]: Amount Applied	Test Results	Load Bearing Capacity After 1 Week (psi)	Solids (percentage by weight)
101	60	0.17 gsy, concentrated	60-120	0.30	0.40 gsy, concentrated	Fails 150-mph wind after passing 1 hour of rain	3	50
102	39	0.17 gsy, concentrated	60-120	0.25	0.40 gsy, concentrated	Passes	4	50
103	70	0.17 gsy, concentrated	60-120	0.25	0.40 gsy, concentrated	Passes	3	50
104	3.6	0.85 gsy, 1:4 dilution	30	0.40	2.0 gsy, 1:4 dilution	Passes	>63	51
105	4.0	0.85 gsy, 1:4 dilution	36	0.35	2.0 gsy, 1:4 dilution	Passes	43	45

[a]Specimens cured 72 hours before testing; test methods 1-4, Contract Report 3-165 (7).

Table 4. Effect of Petroset AT treatment on asphalt quality.

Asphalt Composite	Average Abrasion Loss at 50 F (mg/rev): Control	0.75 Percent Polymer	1.0 Percent Polymer	1.5 Percent Polymer
I	3.532	2.837	1.832	
II	6.892	3.644	2.689	
III	8.132		4.391	2.370
IV	14.04		5.814	4.390
V	15.30		7.047	4.018

Figure 3. Effect of voids content and application rate on penetration of briquettes.

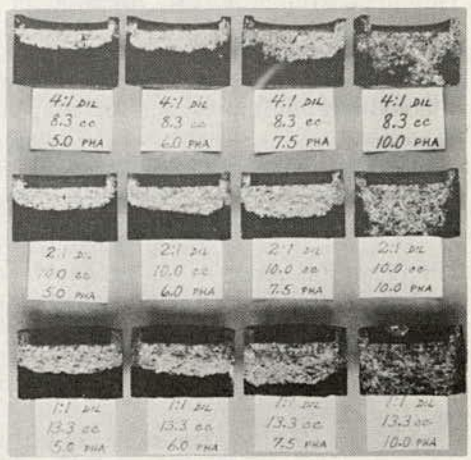


Figure 4. Cores from field test viewed under ultraviolet light.

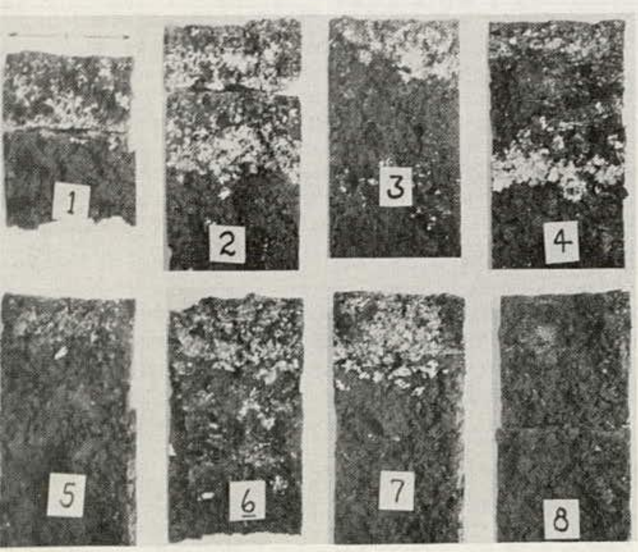


Table 5. Air permeability and density measurements of cores taken 7 months after application of Petroset AT.

Core	Application (gal/yd^2)	Permeability ($ml/min/in.^2$)[a]	Density (lb/ft^3)
Level course[b]	None	2.1	148.0
	0.32	1.4	147.8
Surface course[c]	None	15.7	147.2
	0.32	1.0	148.6

[a]From Kari and Santucci (23).
[b]Asphalt content, 6.2 percent.
[c]Asphalt content, 5.9 percent.

Petroset AX and Petroset SB. As discussed earlier, the two products are compatible and have complementary capabilities. The laboratory tests were performed by treating a synthetic soil. In the Edwards Air Force Base tests, a factorial experiment design provided a number of test sections to explore the behavior of the products in the field individually and in combinations. Figure 7 shows the method of application. Figure 8 shows a closeup of the depth of penetration obtained. The tests were highly successful in that they demonstrated that laboratory results can be duplicated on a large scale, that the treatment with the emulsions resulted in formation of a thick mat of erosion-resistant soil, and that the natural soil responded the same way as the synthetic soil. Recent inspection of the area showed that, during the 3 years since application, wind and rain have not disturbed the treated areas.

Use of Petroset RB to Bind Ballast Rock

Petroset RB was primarily designed to stabilize ballast rock to form a shock-absorbing continuous structure under railroad ties. The effectiveness of the emulsion to stabilize railroad ballast to accommodate high-speed trains was tested by the U.S. Department of Transportation. Because the emulsion is very stable and slow breaking, the ballast rock was pretreated with a dilute ammonia solution. This pretreatment effects breaking of the emulsion and depositing of the cementing agent as shock-absorbing miniature vibration pads at the points of rock contact. The pretreatment of a stratum to accomplish controlled breaking of an emulsion when desired is believed to be superior to using quick breaking, unstable emulsions. This is of considerable importance for purposes of logistics. The treatment with emulsion RB converted the contiguous but loose ballast rock into a continuous structure "welded" together by means of a cementing agent, which constitutes the oil phase of the emulsion. Figure 9 shows the adhesion attained. The rock pile retained its shape in tilting, whereas untreated rock just rolled off.

The process was tested on actual scale by the Association of American Railroads at the research center in Chicago (Fig. 10). The details of the work have been reported elsewhere (18, 19). It will suffice to show the beneficial effects of the treatment on settling. Figure 11 is reproduced here from the AAR report. The abstract of the technical report submitted by the AAR to the U.S. Department of Transportation reads as follows:

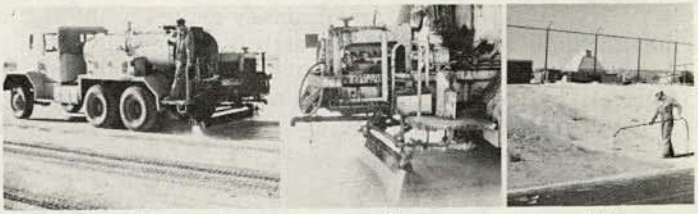
> The purpose of the investigation was to evaluate the ability of a compound developed under the sponsorship of FRA to enhance the load-resistant characteristics of conventional stone ballast. This compound, an emulsion based on a new butadiene-styrene block copolymer, was sprayed on the stone ballast of a short section of railroad track. A second section of track, similar but untreated, provided the sample of conventional construction.
>
> In the conduct of this investigation pulsating, single point, vertical loads varying from 5,000 lb to 50,000 lb (and to 75,000 lb in some cases) were applied to, first, the untreated track and, then, the treated specimen in a uniform manner for 4,000,000 cycles. The treated ballast was finally subjected to 11,000,000 vertical stress cycles. Static lateral stress was also applied to each section. At 2,500 lb the untreated section was in constant motion. At 11,500 lb the treated section had deflected 0.113 in. Upon release of load, approximately 50 percent of this strain was self-recovered.
>
> Comparisons established through this study are, conservatively stated, that the permanent settlement of ties supported on the untreated ballast was 10 times that recorded for the ties of the treated ballast test phase. Resistance to lateral displacement was at least five times greater for the treated specimen than for its companion.

Large-scale tests treating ballast rock have since been performed by the U.S. Department of Transportation and have confirmed the findings. It is self-evident that treatment of large rock has beneficial effects on a variety of structures such as rock placed on embankments and facings of earth dams.

Figure 5. Crest and slip face of active dune area before and after stabilization.

Figure 6. Treatment of excavation with Petroset SB.

Figure 7. Application equipment and procedures: (a) 800-gal capacity distributor truck; (b) 8-ft spreader bar; and (c) hand spraying of slope.



(a) (b) (c)

Figure 8. Depth of penetration in field test.

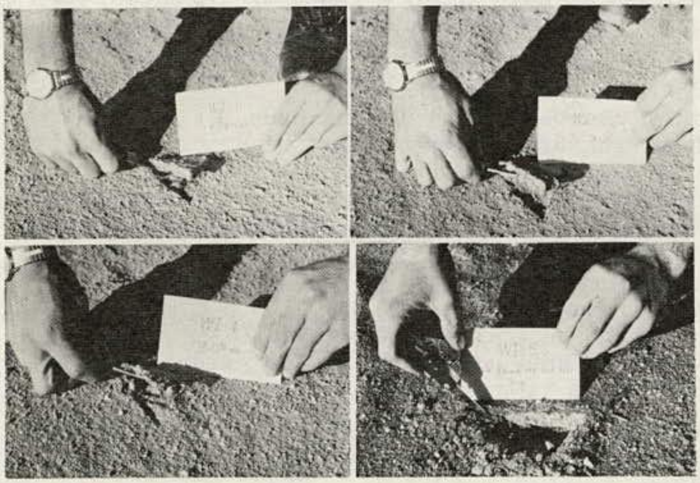
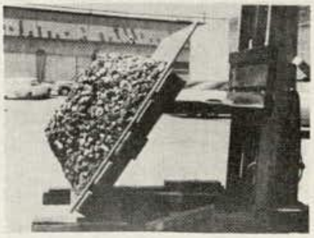


Figure 9. Tilted treated rock pile, demonstrating cohesion of "welded" ballast rock.



Erosion of Asphalt Concrete

Asphalt concrete is basically graded soil of particle sizes ranging from fine grains to rock cemented together by asphalt. It is this graded soil or aggregate that gives the asphalt concrete its strength and traffic-bearing capacity. The asphalt cement serves to keep this soil structure in place and makes it resistant to displacement, oxidation, and the abrasive action of traffic and water intrusion.

Emulsion AT has been used for treatment of highways, county and city roads, parking lots, airport runways, and gasoline stations. Some of the results have been reported extensively (16, 17, 20). One of the most recent uses of AT was an application in North Dakota to test reduction in reflection cracking. The application was made in the fall of 1971. After a severe winter with excessive snowfall and prolonged exposure of the pavement to studded tires, the advantages of the treatment were evident. The photographs shown in Figure 12 document the results obtained. Figure 12A shows that treatment with AT made the pavement highly resistant to cracking. An existing crack in the untreated passing lane had enlarged and continued the spalling process, whereas the crack in the treated traffic lane has healed. Figure 12B shows the difference between the treated and untreated pavements after exposure to the cutting action of studded tires. The photographs are typical of the results obtained over the entire test stretch.

In a preliminary report to the North Dakota State Highway Department, James A. Glick (21) described the results obtained with Petroset AT as follows: "After several days of traffic, the surface of the pavement looked tightly knit and effectively sealed as opposed to untreated sections which were rather porous looking due to the coarseness of the mix."

PROPOSED TENTATIVE SPECIFICATIONS FOR EROSION CONTROL MATERIALS

Based on results obtained to date by the U.S. Air Force, Materials Research and Development, Inc., and other organizations the following tentative specifications have been designed to cover materials to be used in erosion control. In general, the products should be oil-in-water emulsions that can be used individually or in form of blends and in various dilutions with water. More specifically, specification limits encompassing the properties of the whole family of emulsions are shown below as examples of the properties specified (narrower limits are specified for the individual products):

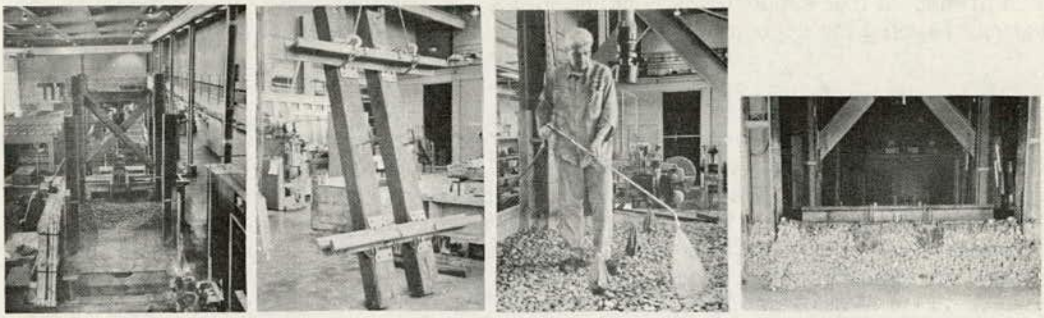
1. Specific gravity, 0.97 to 1.08;
2. Sieve test, retained on No. 100, maximum 0.1 percent;
3. Solids content, 32 to 64 percent;
4. Elastomer content, 4 to 25 percent;
5. Water content, maximum 40 percent;
6. Brookfield viscosity (2:1 dilution, LVT model, No. 1 spindle, 12 RPM, 75 F), 20 to 200 cP;
7. pH, less than 6.5;
8. Particle charge, positive;
9. Heat stability, minimum 24 hours at 140 F;
10. Cold stability, minimum 24 hours at 40 F; and
11. Miscibility with water, unlimited.

The special provision is that performance tests should be made on soils to be treated to ensure adequate penetration into the soil and specified resistance to air blast and exposure to simulated rain.

SUMMARY AND CONCLUSIONS

Cationic oil-in-water emulsions containing a high-strength elastomer or resins or both constitute a family of products most promising for use in

Figure 10. Equipment used in tests performed by Association of American Railroads.



loading frame and test track

tie and rail assembly equipped with deflection roads

spraying operation used for ammonia solution and Petroset RB

cross section through test track after completion of tests

Figure 11. Effect of repeated loads on permanent settlement of cross ties.

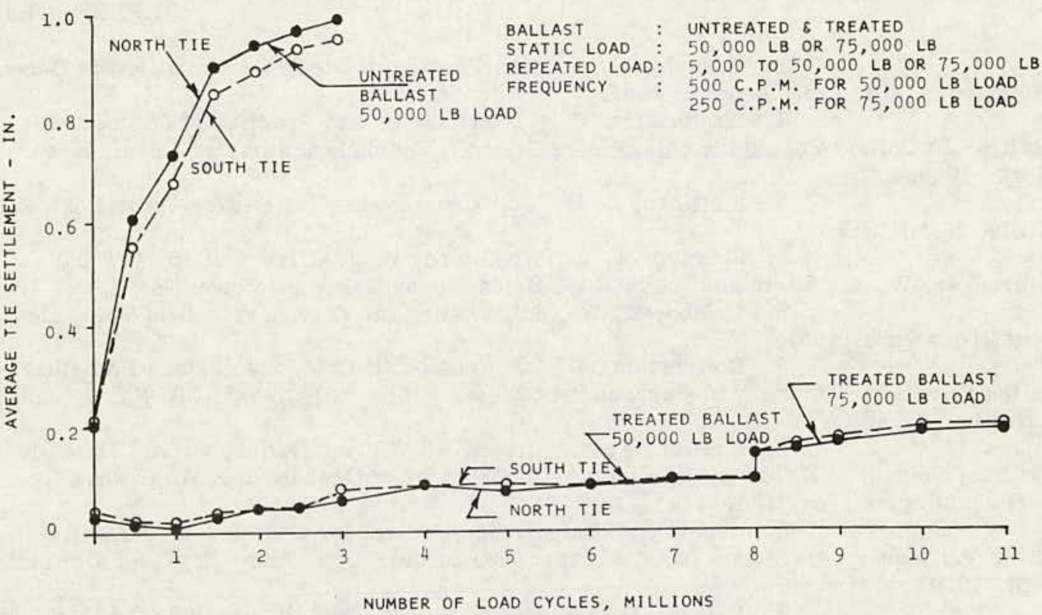
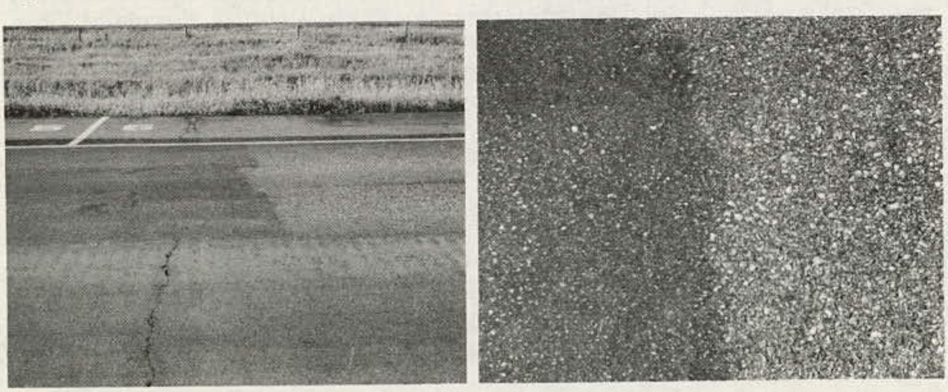


Figure 12. Highway in North Dakota treated with Petroset AT.



methodical erosion control. Tests performed in the laboratory and in the field have been presented that support this conclusion. Tentative specifications for the products that can be used for acceptance and purchasing specifications have been formulated.

ACKNOWLEDGMENT

The work reported in this paper is the result of cooperative efforts of many individuals and organizations. Special mention is gratefully made to the following: Air Force Special Weapons Center, Kirtland Air Force Base; Vandenberg Air Force Base; Edwards Air Force Base; Air Force Systems Command, Andrews Air Force Base; U.S. Army Corps of Engineers; and U.S. Army Corps of Engineers Waterways Experiment Station.

The opinions expressed in this paper are those of the authors and do not necessarily represent the views of the U.S. Air Force. Naming of products does not imply endorsement by any of the agencies concerned. The tentative specifications presented do not constitute specifications in force; they are presented only to demonstrate the type of specifications under consideration.

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