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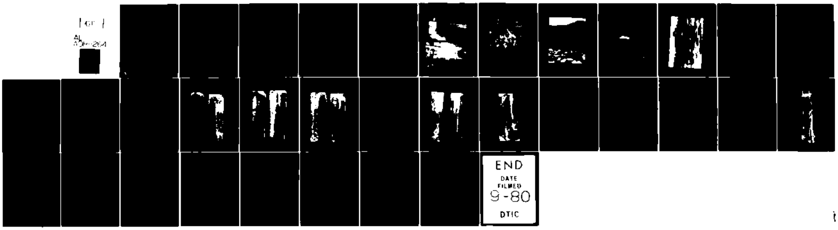

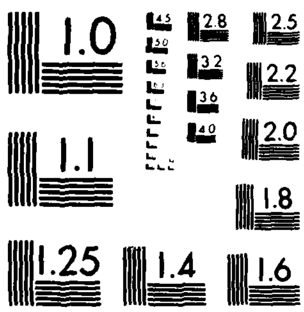

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Describes an investigation that was undertaken to solve the problem of dust raised by military helicopter landings during field operations. Such dust clouds can cause damage to turbine engines as well as create a visual signature for drawing hostile fire. The goal was to develop a convenient, rapid, and inexpensive technique for stabilizing soil for helicopter/VSTOL landing pads and expeditionary airfield runways. Conventional methods, such as concreting or asphalting, are considered much too expensive and time consuming for tactical use in the field. This report presents a detailed evaluation of the stabilization of soil by application of aqueous latex emulsion. The success of a given emulsion application was judged on the basis of one or more of the eight listed criteria.

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34

CONTENTS

INTRODUCTION

An investigation was undertaken in FY 1977 to solve the problem of dust raised by military helicopter landings during field operations. Such dust clouds can cause damage to turbine engines as well as create a visual signature for drawing hostile fire. The goal was to develop a convenient, rapid and inexpensive technique for stabilizing soil for helicopter/VSTOL landing pads and expeditionary airfield runways. Conventional methods, such as concreting or asphalting, are considered much too expensive and time consuming for tactical use in the field.

Experimentation with various ground-coating substances showed that an aqueous latex emulsion* would permeate the ground and stabilize the ground surface. Following application of this emulsion to a hillside to demonstrate erosion control, a more extensive test was conducted at the China Lake Naval Air Facility (NAF). A helicopter landing pad at NAF was treated and observations made for more than a year. Following the NAF demonstration, laboratory tests were conducted using various emulsion concentrations (with and without surfactants added) to determine depth of penetration and homogeneousness and strength of the treated soil. Another local small-scale demonstration was then conducted preparatory to a more extensive test at the Expeditionary Airfield of the Marine Corps Base, Twentynine Palms.

This report presents a detailed evaluation of the stabilization of soil by application of aqueous latex emulsion. The success of a given emulsion application was judged on the basis of one or more of the following criteria:

1. Reduction of dust signature. (Using direct visual and photographic techniques, how well did the emulsion reduce the dust signature?)

2. Structural strength. (To what depths did the emulsion penetrate, and what was the compressive strength of the resulting material?)

3. Curing time. (Did the curing time allow for sufficient emulsion penetration, and was it rapid enough to be practical?)

4. Resistance to erosion. (What was the rate of erosion due to traffic or environmentally induced attrition?)

5. Ease of application. (Could the material be applied conveniently in the field and by what technique?)

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*Airflex 400 (A-400), a vinyl acetate-ethylene copolymer emulsion, was used throughout this project. This emulsion is manufactured by Air Products & Chemicals, Inc., Allentown, Pa; costs $0.38/pound; has a shelf life of 6 months; and must be stored at temperatures greater than 40°F.

6. Cost.

7. Availability.

8. Environmental considerations. (Does the material itself, or its decomposition products, have an adverse effect on the environment?)

Following sections of this report provide a chronology of the various tests conducted and their results relative to the above criteria.

EXPERIMENTATION

NAF DEMONSTRATION

In late August 1977, a test was conducted to compare methods of application and determine the adequacy of the emulsion to stabilize the soil. Using a 10% aqueous latex emulsion, two applications methods were tried--fire hose (Figure 1) and truck spray-bar (Figure 2). Of the two, the fire hose method proved more satisfactory. As can be seen from Figure 3, the spray-bar side (right) of the helicopter pad was considerably roughened as a result of the heavy truck recrossing the area. Also, the light spot near the middle (upper) of the pad is where a surface strip peeled off due to the inadequacy of the spray-bar application method.

The fire hose application method resulted in an average emulsion penetration depth of approximately 1-1/8 inches; where puddling occurred in low spots penetration was as much as 3 inches. On the spray-bar application side, the average depth of penetration was 1-1/4 inches, except where puddling occurred and resulted in penetration of up to 2 inches.

After a 40 to 48 hour drying (cure) period, the ground was stabilized into an adequate helicopter landing pad. Figures 4 and 5 compare helicopter landing conditions before and after application of the emulsion. A helicopter landing operation did cause some damage to the surface soil (Figure 6), but this is easily and quickly repaired. The test pad has since withstood more than a year's weather with little damage.

This test pointed up several factors that warranted further examination. For instance, emulsion penetration was impeded due to the hot arid weather and soil conditions (air temperature at the time of application was 104°F); thus, evaporation and quick drying of the surface was a problem. However, once the area was sufficiently moistened, the lack of moisture in the air was conducive to a relatively short cure time. Once cured, the treated surface was not affected by subsequent rain or humidity.

FIGURE 1. Fire Hose Application Method.

FIGURE 2. Truck Spray-bar Application Method.

FIGURE 3. Aerial View of NAF Site After Application.

FIGURE 4. Helicopter Landing at NAF Site Before Application of Emulsion.

FIGURE 5. Helicopter Landing at NAF Site After Application of Emulsion.

9

FIGURE 6. Damage Resulting From Helicopter Landing.

LABORATORY TESTS

As a result of the NAF experience, it was decided to conduct a limited laboratory test series. The goal was to determine the optimum emulsion concentration and depth of penetration, the homogeneousness and strength of the treated soil, and the possibility of adding surfactants to the emulsion mixture to aid in penetration.

Critical Parameters

The factors considered in the laboratory tests were soil type, emulsion concentration, and surfactant type.

Based on sieve analyses, three general types of desert soils, as well as soil from a specific proposed demonstration site (Twentynine Palms) were tested. The three general soil types were selected to represent

1. Alluvial areas (decomposed granite) - Type 1
2. Wind blown desert sand - Type 3
3. Dry lake beds (clay) - Type 4

The soil from the proposed demonstration site was designated as Type 2. More details on this type soil are provided under a later section (Twentynine Palms Demonstration).

Using the A-400 latex emulsion, mixtures were tested at varying concentrations (5, 10, 20, 30, 40 and 50%) to determine the optimum percentage in terms of adequacy of the solution to stabilize the soil.

Surfactants (eleven total) were tested to determine which would best enhance the wetting capability of the emulsion mixture. Surfactants were employed in a few of the laboratory tests, but the major test was conducted at the hospital helicopter pad site subsequently used for a demonstration.

Test Method

Soil was added to woodframed sample containers measuring 3 inches wide by 3 inches deep by 12 inches long. Each sample was prepared in a dry condition and then tamped down. (This tamping provided a limited degree of compaction but does not represent the "natural" compacted state of a given soil.) The containers were then flooded (350, 400 or 450 milliliters total liquid) with the latex emulsion at varying concentration levels and either with or without a surfactant added. In a few cases, the samples were again tamped down to optimize the distribution of the liquid and the rate of absorption. This second tamping, however, apparently had no effect.

Following emulsion application, each sample was allowed to cure (dry) and subsequently examined to determine polymer penetration depth and if the surface had been sealed. An attempt was made to obtain compressive strength data on same samples, but the results were inconsistent due to the variations in soil composition.

Results

General Soil Types. The sieve analyses indicated that the type 3 soil (Table 1) would probably be most amenable to stabilization via an emulsion application since the largest percentage of particles passed through at the 8 to 100 sieve size range. (That is, there was not an excessive volume of either very fine or very large particles.) As can be seen in Figure 7, the type 3 soil curve (based on the sieve analysis) most closely matches the ASTM standard for a well graded gravel sand soil.

The type 1 soil (see Table 2) would require the addition of finer soil particles before a latex emulsion application would result in a homogeneous bonding. The presence of a significant volume of very large soil particles is not conducive to producing a stable surface using this emulsion system.

Analysis of the type 4 soil (Table 3) indicated the presence of clay and silt of such fineness that good penetration could not be anticipated without the addition of a surfactant to the emulsion. Figure 8 presents the flow curve resulting from liquid/plastic limit computations for the type 4 soil; the 5.8% plasticity (swelling/shrinking) index is indicative of a heavy clay content.

Emulsion Concentration. In terms of penetration, emulsion concentration level had little impact on the type 1 soil samples. In most cases penetration was to the full depth of the sample. However, in every case, loose particles remained on the surface after sample cure. Figures 9 and 10 show type 1 soil samples after application and curing of a 10 and 50%, respectively, concentration emulsion, In each case the time to absorption was less than two minutes and penetration was to full depth; but, loose particles remained on the surface.

The type 3 soil samples treated with either 10, 20 or 30% concentration mixtures (Figures 11, 12 and 13, respectively) all experienced full penetration. In no case did time to absorption exceed five minutes. Samples treated with 40 or 50% concentration emulsion (both with and without a surfactant added) experienced significantly longer times to absorption and considerably reduced depths of penetration. One sample (Figure 14), previously treated with a 5% concentration mixture and cured, received a second coating using a 10% concentration mixture. This provided an even more stable surface.

12

TABLE 1. Sieve Analysis, Type 3 Soil.
(ASTM Standard Test C117-66)

Sieve size	Weight retained, grams	Percent retained	Cumulative	
			Percent retained	Percent passing
1	0	0	0	100
1/2	6.6	0.6	0.6	99.4
3/8	1.8	0.1	0.7	99.3
4	19.2	1.7	2.5	97.5
8	154.4	14.1	16.6	83.4
16	206.6	18.9	39.6	60.4
30	205.0	18.8	54.3	45.7
50	177.9	16.3	70.6	29.4
100	186.3	17.1	87.7	12.3
200	69.3	6.3	94.0	6.0
pan	65.2	6.0	1.0	----

Total weight of sample 1092.3 grams.
Fineness modulus SW-SM (well graded gravel sand-silty and silt mixture.

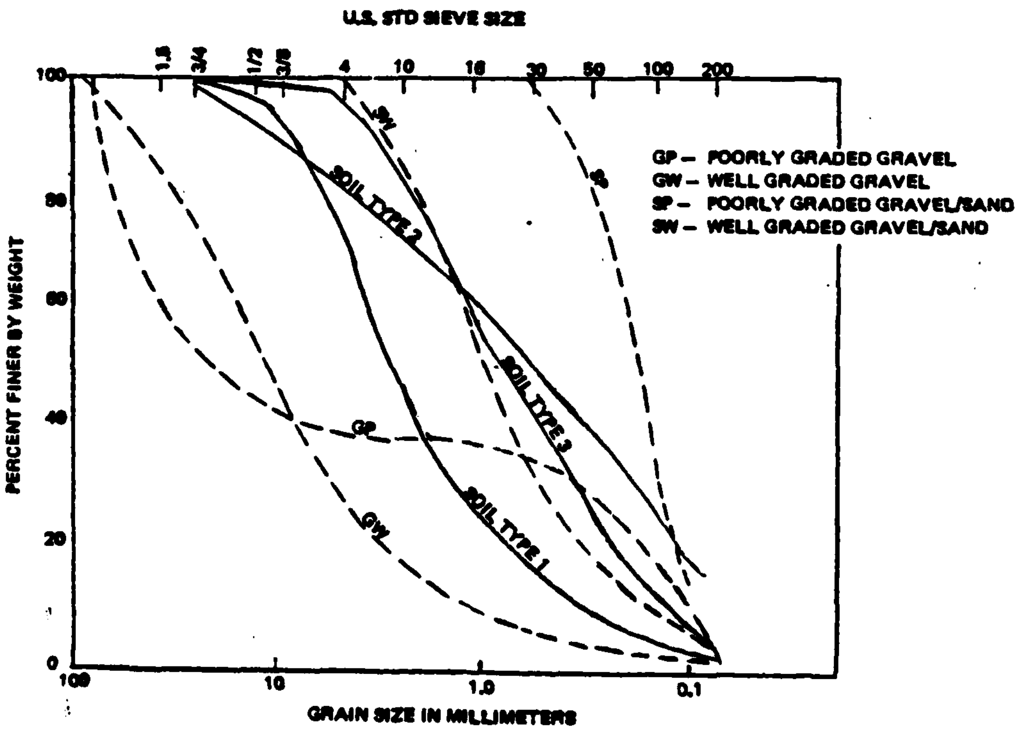

FIGURE 7. Comparison of Typical Well Graded/Poorly Graded Soils with Type 1, 2 and 3 Soil Samples.

TABLE 2. Sieve Analysis, Type 1 Soil.
(ASTM Standard Test C117-66)

Sieve size	Weight retained, grams	Percent retained	Cumulative	
			Percent retained	Percent passing
1	0	0	0	100
1/2	28.0	2.6	2.6	97.4
3/8	49.1	4.6	7.2	92.8
4	232.8	21.6	28.7	71.3
8	259.9	24.1	52.8	47.2
16	187.3	17.4	70.2	29.8
30	131.9	12.2	82.4	17.6
50	73.3	6.7	89.2	10.8
100	50.5	4.6	93.9	6.1
200	26.9	2.5	96.4	3.6
pan	38.6	3.6	1.0	---

Total weight of sample 1078.3 grams.
Fineness modulus SW (well graded gravel sand)

TABLE 3. Sieve Analysis, Type 4 Soil.
(ASTM Standard Test C117-66)

Sieve size	Weight retained, grams	Percent retained	Cumulative	
			Percent retained	Percent passing
4	0	0	0	100
8	0	0	0	100
16	0	0	0	100
30	3.0	0.3	0.3	99.7
50	14.5	1.5	1.8	98.2
100	38.0	3.9	5.7	94.3
200	23.8	2.5	8.2	91.8
pan	883.3	91.8	100	0

Total weight of sample 962.6 grams.
Fineness modulus ML (clayey silt).

RESULTS of ASTM Standard Tests D423-61T/D424-59 (Liquid/Plastic Limit Tests):

Liquid limit 35.1% Plastic limit 29.3%
Plasticity index 5.8% Remarks: 91.8% passing 200 sieve, ML classification

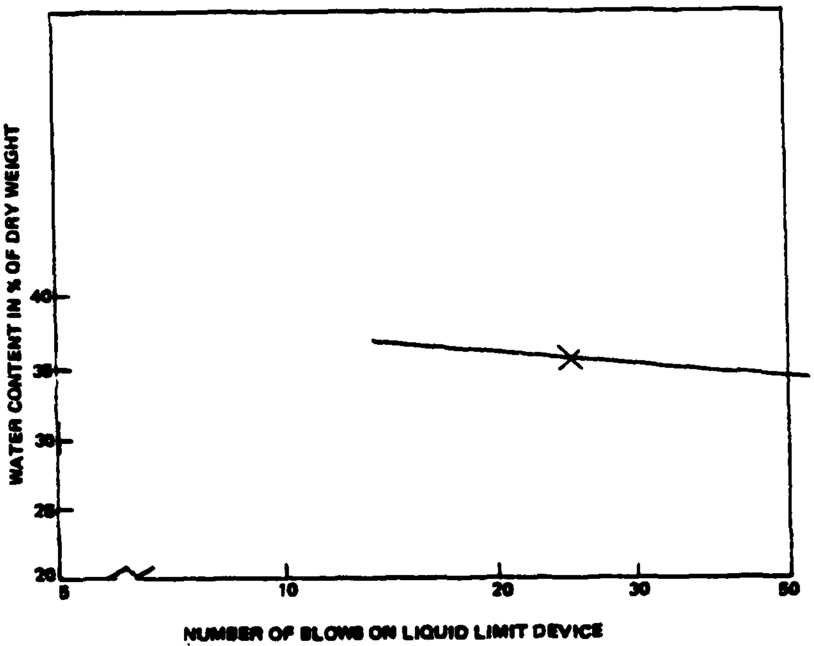

FIGURE 8. Flow Curve, Liquid/Plastic Limit Determinations.

FIGURE 9. Laboratory Sample, Soil Type 1 (10% A-400 emulsion, time to absorption 1 minute, depth of penetration greater than 3 inches).

FIGURE 10. Laboratory Sample, Soil Type 1 (50% A-400 emulsion, time to absorption less than 2 minutes, depth of penetration greater than 3 inches).

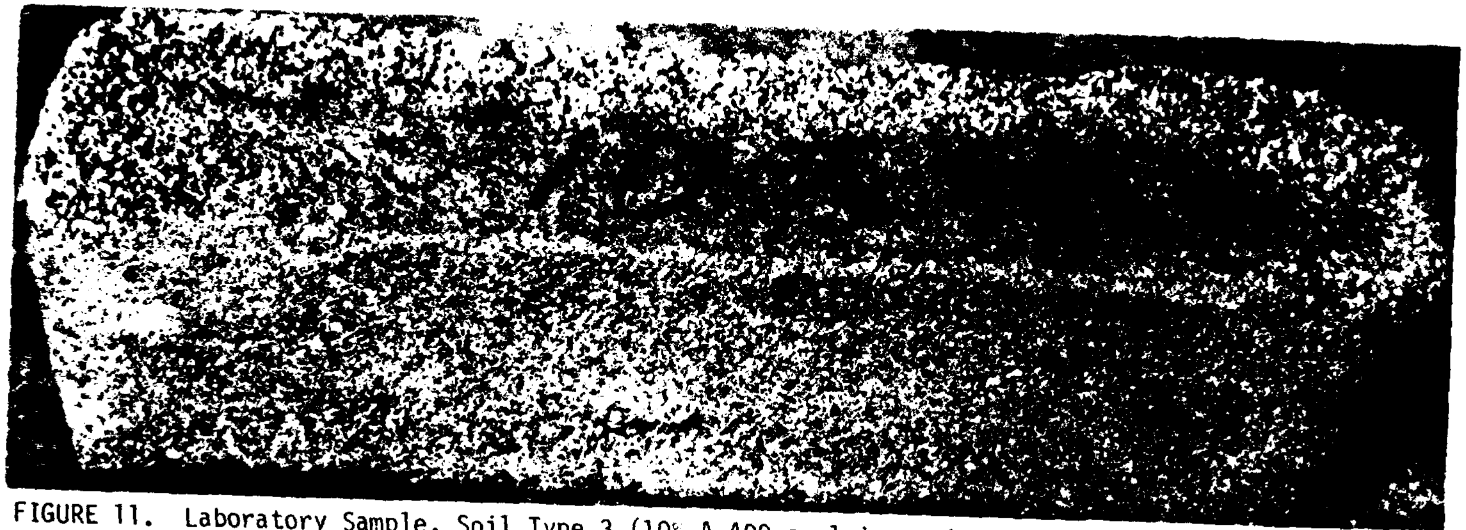

FIGURE 11. Laboratory Sample, Soil Type 3 (10% A-400 emulsion, time to absorption less than 1 minute, depth of penetration greater than 3 inches).

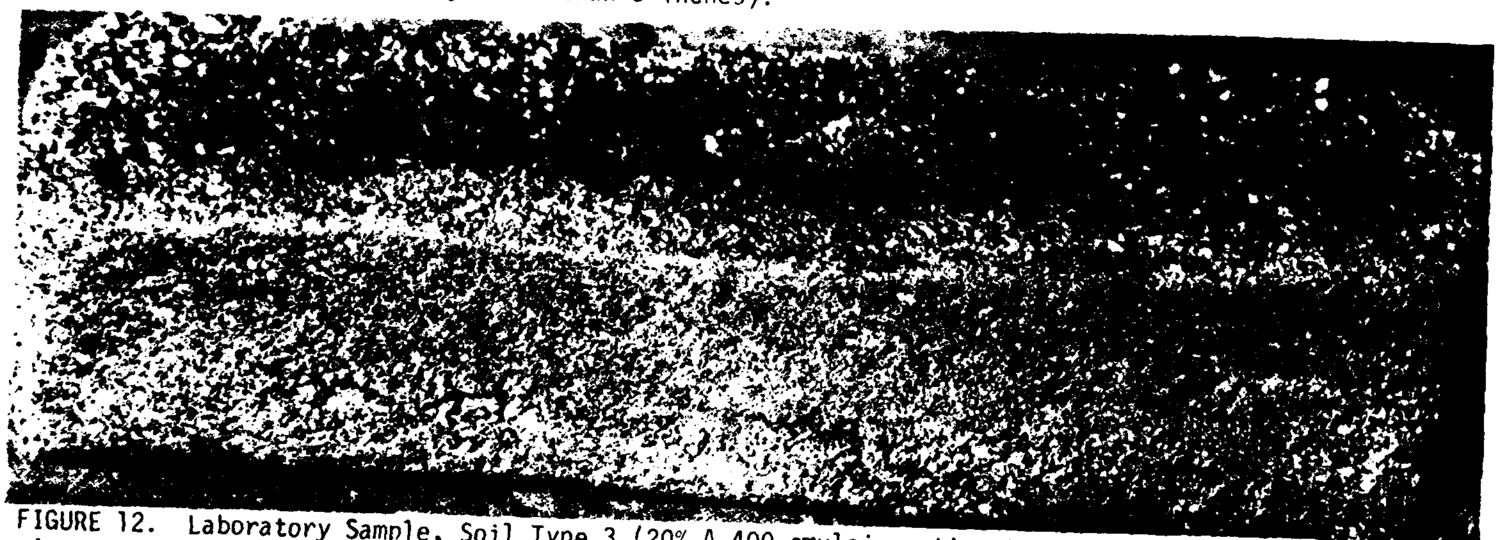

FIGURE 12. Laboratory Sample, Soil Type 3 (20% A-400 emulsion, time to absorption less than 1 minute, depth of penetration greater than 3 inches).

17

FIGURE 13. Laboratory Sample, Soil Type 3 (30% A-400 emulsion, time to absorption approx. 5 minutes, depth of penetration 3 inches).

FIGURE 14. Laboratory Sample, Soil Type 3 (5% followed by 10% A-400 emulsion, time to absorption 1 minute, depth of penetration 3 inches).

As had been predicted by sieve analysis, the type 4 soils treated with emulsion-only mixtures did not show good penetration. No emulsion-only mixture, at any concentration, could significantly penetrate the silt and clay. The maximum penetration experienced was 1/2-inch. The times to absorption ranged from 8 (20% concentration, Figure 15) to 64 hours (50% concentration, Figure 16). The addition of soap (surfactant) to reduce surface tension (Figure 17) did improve penetration and time to absorption.

Data for 22 soil samples are compared in Figure 18 (emulsion concentration versus depth of penetration). It was concluded that the 20-30% concentration emulsions resulted in the most stable soil conditions. However, the 5 and 10% concentration levels did provide adequate strength with a homogeneous bonding. Since mixture cost for a 20% concentration is nearly twice that for a 10% concentration mixture, it was decided to use the 5 and 10% concentration mixtures in subsequent demonstration tests.

Surfactant. To properly evaluate the eleven surfactants under consideration, it was decided to conduct a single test at the hospital site using all the surfactants at the same time. Though a few of the surfactants had been used in the laboratory tests, not all had been tested on a single soil type. Testing of all the surfactants at the hospital helicopter pad site would, therefore, provide realistic and comparative data.

Using twelve one-gallon containers of a 10% emulsion mixture, one container was left "as is" to serve as a control. The remaining eleven containers each received a 1% measure of one of the eleven surfactants. The twelve mixtures were then applied to a designated area at the test site. After being allowed to cure, the area was examined and measurements and observations made as indicated in Table 4. The Renex-31 surfactant was considered to have provided the best wetting.

APPLICATION METHODS

Concurrent with the laboratory experiments, efforts continued to identify a better method of applying the emulsion. Flooding worked well in the laboratory tests because there was a level surface and the mixture could be poured as fast or slowly as necessary to allow it to seep in.

The goal was to find a method which would be convenient and rapid and yet keep the ground surface moist to allow continued penetration of the emulsion; moisture acts as a carrier for the emulsion.

The truck spray-bar application method tried earlier (NAF test) was definitely unsatisfactory. The fire hose technique was adequate but slow and cumbersome. It was therefore decided to try a sprinkler system.

FIGURE 15. Laboratory Sample, Soil Type 4 (20% A-400 emulsion, time to absorption approx. 8 hours, depth of penetration 1/4 inch).

FIGURE 16. Laboratory Sample, Soil Type 4 (50% A-400 emulsion, time to absorption approx. 64 hours, depth of penetration 1/16 inch).

FIGURE 17. Laboratory Sample, Soil Type 4 (30% A-400 emulsion plus 20 ml soap, time to absorption approx. 1.5 hours, depth of penetration 1/2 inch).

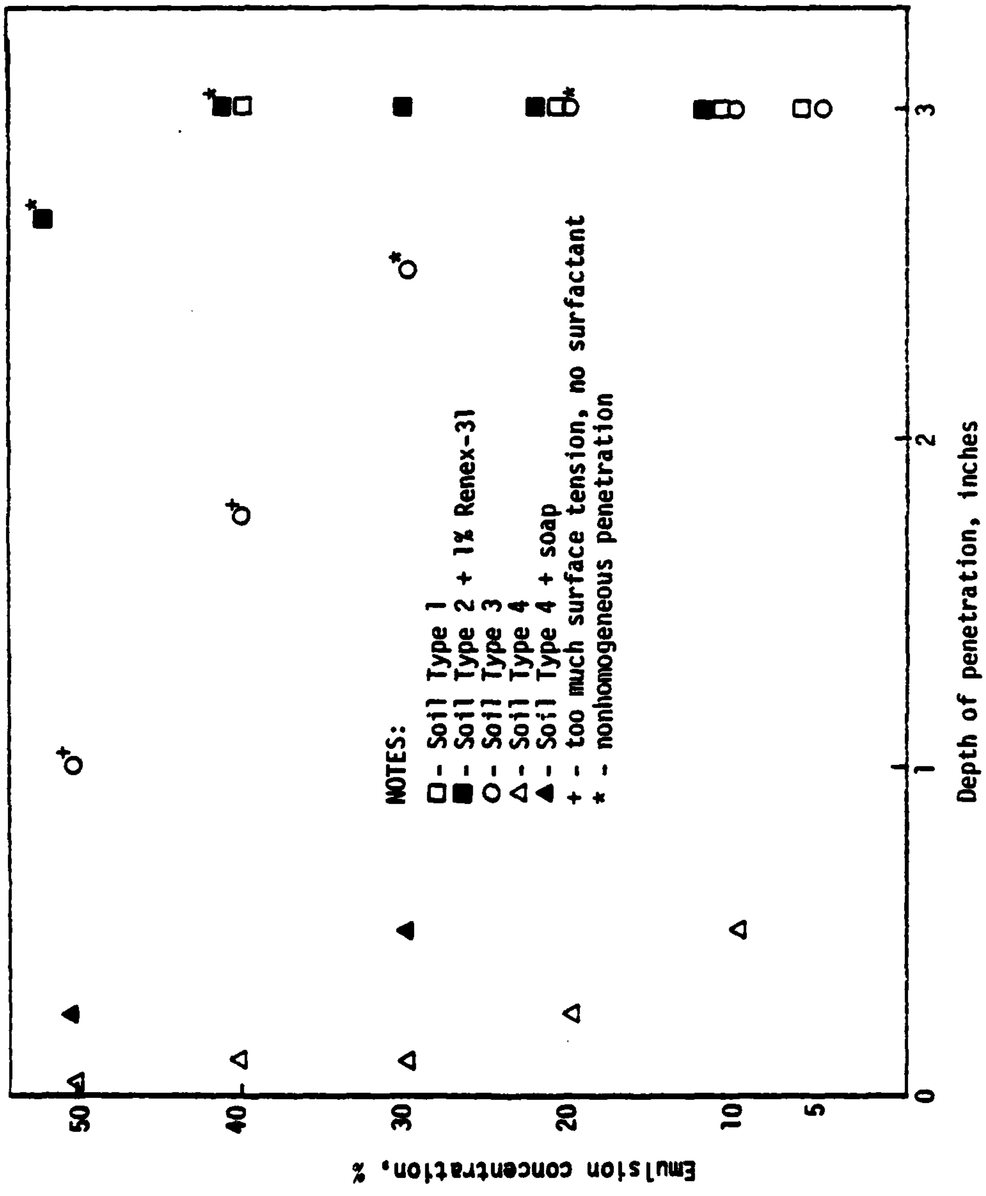

FIGURE 18. Laboratory Test Results.

TABLE 4. Results of Surfactant Test at
Hospital Helicopter Landing Pad Site.

Surfactant[a]	Remarks
1. Witco Neat JP-5 emulsifier	Wets ground well
2. Polagua AD	Not as good as 1
3. Jefferson Neat 120	Coagulated in nozzle
4. Zonyl FSC	Marginal (no significant improvement over control--number 12)
5. Open-All	Did not penetrate well
6. Dow Corning XR-6-3701	Left film before evaporation
7. 410	Soaked in, did not penetrate well
8. Soap (liquid Wisk)	Wets ground well
9. GAFAC RS-610	Marginal (same as 4)
10. L-77	Marginal (same as 4)
11. Renex-31[b]	Best wetting, slight coagulation
12. Control	No surfactant added, did not penetrate well

[a]In each case 1% surfactant was added to a 1-gallon mixture of the 10% Airflex A-400 emulsion.

[b]Atlas Chemicals Division, ICI America, Inc., Wilmington, Delaware.

A "rainbird" type sprinkler system, designed for quick assembly and disassembly, was subsequently designed and used in the demonstration tests.

HOSPITAL HELO PAD DEMONSTRATION

This test was conducted to gain further experience using the techniques and information developed during the laboratory testing. The helicopter landing pad at the Ridgecrest Community Hospital was selected because it provided a local site which closely simulated conditions found at the Twentynine Palms site. The content of the soil closely resembled that at Twentynine Palms, and the ground had already been rolled and treated with a dust abatement chemical so that preliminary preparations for the test would be minimal.

On 19 October 1978, areas surrounding the hospital helicopter pad were treated with either a 5 or 10% concentration emulsion. Figure 19 is a diagram of the area treated and indicates the emulsion concentration (and whether or not a surfactant was added) for given areas. The circled area surrounding the concrete pad was treated with 4800 gallons of a 10% aqueous latex emulsion with 1% Renex-31 surfactant added. The quadrants further out from the circle were treated with either a 5 or 10% concentration emulsion (without surfactant). It was not originally planned to treat these outlying quadrants; however, recent removal of brush to minimize fire hazards necessitated that the surface be stabilized. The application methods employed (Figure 20) were truck-fed "rainbird" sprinklers and water hose.

Weather conditions at the time of application were quite satisfactory. Air and ground temperatures were mild and humidity was low. However, some problems were encountered. The surfactant had solidified in shipment and, therefore, had to be mixed before it could be used. Also, the 10% emulsion caused some coagulation at the water hose nozzle. This required that the nozzles be cleaned between reloading of the tank trucks.

Because it rained shortly after application of the emulsion, it took about 10 days for the area to completely cure. Penetration in the area immediately surrounding the concrete pad ranged from 2.5 to 4 inches. Table 5 provides results of measurements and observations made following cure of the emulsion. The area outside the central 100-foot diameter circle surrounding the concrete pad, again, was treated for dust control only; a minimum application was made as indicated in Figure 19. Penetration in this area ranged from 0.25 to 2.5 inches due to the limited amount of material applied.

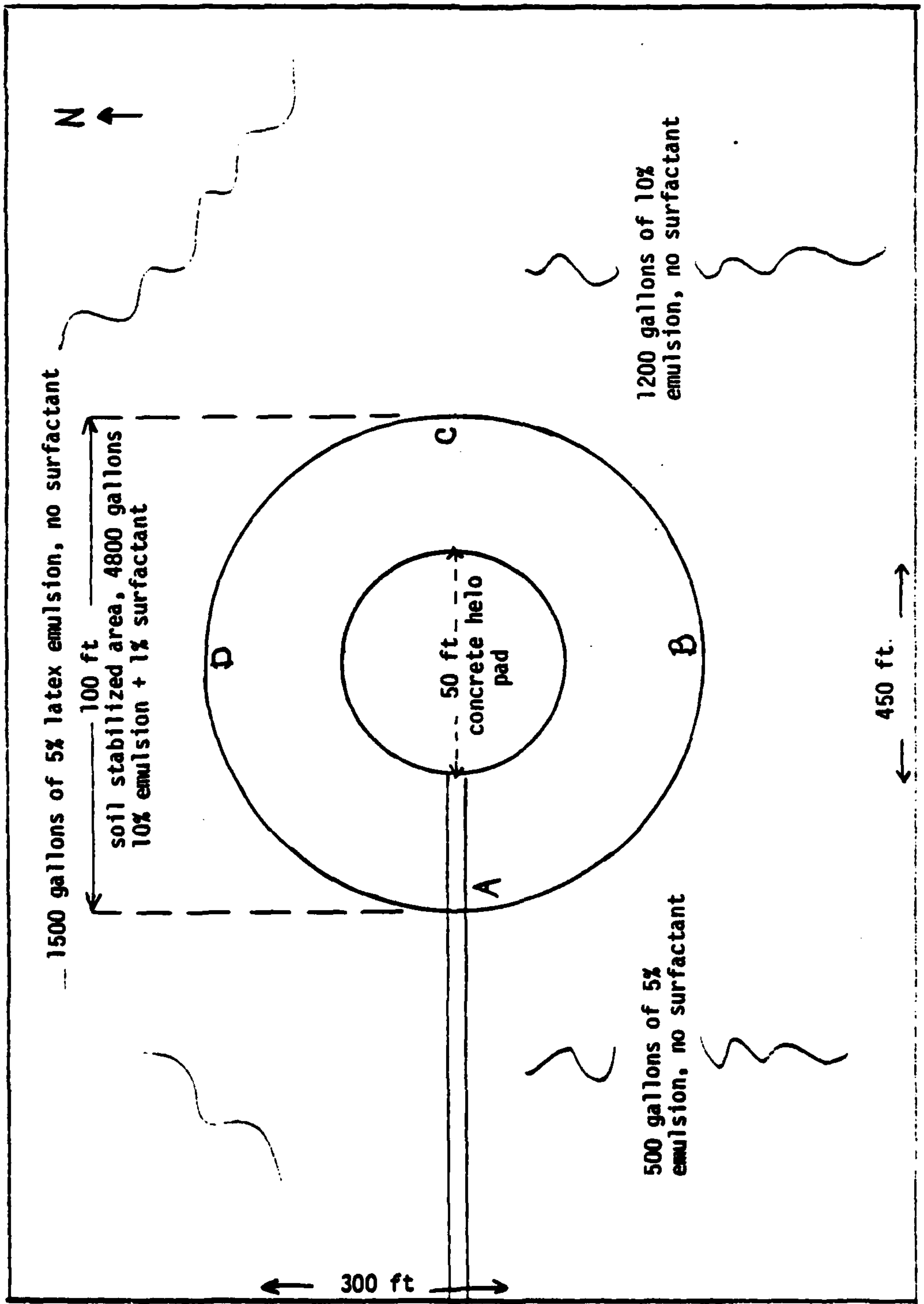

FIGURE 19. Hospital Helicopter Pad Site Layout.

FIGURE 20. "Rainbird" Sprinkler Application Method.

TABLE 5. Soil Samples From Hospital Helicopter Pad Test.

Surfactant[a]	Soil condition[b]	Latex penetration depth, in.	Moisture line depth, in.	Surface condition
1	soft	2.5	not visible	stable
2	very hard	>.38	1	stable
3	hard	>.38	not visible	very stable
4	very hard	.25	0.75	stable
5	hard	>.75	not clearly visible, appears to be at 1.25	stable
6	medium hard	latex on surface appears coagulated	not clearly visible, appears to be at 1.75	stable
7	soft	≥.75	2.5	very stable
8	medium hard	>1	not clearly visible, appears to be at 1.5	stable
9	hard	>.25	not visible	stable
10	hard	.25	not visible	stable
11	soft	1.5	≈3	very stable
12	hard	<.25	not visible	very stable

[a]Numbers correlate with surfactant numbers in Table 4.

[b]Measurements and observations made (see Figure 19) starting counterclockwise at point A and ending at point D.

TWENTYNINE PALMS DEMONSTRATION

Soil Analysis

Prior to the actual demonstration test, soil samples were obtained and analyzed. Sieve analyses (Tables 6 through 8) indicated a range of soil conditions depending on the origin of the sample; i.e., various points along the airfield runway apron, the helicopter landing site. Soil samples from the helicopter landing site showed the presence of considerable clay and silt. Soil compaction analysis (per ASTM standard test D1557-64T) further verified (see Figure 21) the need for adding a surfactant to the emulsion.

Emulsion Application

On 6 December 1978, a 10% aqueous latex emulsion (with 1% Renex-31 surfactant) was applied to the helicopter landing site (designated LSE LZ) at Twentynine Palms. Approximately 6,000 gallons of the 10% concentration emulsion were applied using a 3,000-gallon water trailer, an auxiliary pump and a sprinkler system consisting of PVC pipe and "rainbird" sprinklers. Figure 22 shows a layout of the helicopter landing site as well as the sprinkler system.

Several factors impacted this test. Winds of up to 40 knots tended to limit the effectiveness of the sprinklers. (Rather than covering a 100 by 100 foot area, coverage was more like 80 by 120 feet.) On several occasions sprinkling operations had to be halted due to separations at PVC pipe joints and malfunctions of the sprinkler heads.

Daytime temperatures were in the high 30s (^{o}F). The low temperature caused the surfactant to solidify in the drums, and it had to be removed with shovels rather than by pouring to prepare the stabilizer mixture in the tank trailer.

The site did present a fairly level area with a varying overburden thickness of loose sand. However, soil moisture conditions at the time of application were not optimum. Though the top 3/4-inch of soil was dry, the sand appeared moist below this depth.

Finally, the use of a 3,000-gallon water trailer made it necessary to mix two rather than one "batch" of the emulsion. Since the LSE LZ was a considerable distance from the water source, there was a significant time lapse while the trailer returned to the water source, refilled the tanker and returned to the LSE LZ, where the second batch was mixed and the application operation resumed. This time lapse may have been sufficient to allow the first application to begin to setup. In any case, the second batch did not as readily soak into the sand and tended to pool or puddle on the surface.

TABLE 6. Sieve Analysis, Type 2 Soil.[a]
(ASTM Standard Test C117-66)

Sieve size	Weight retained, grams	Percent retained	Cumulative	
			Percent retained	Percent passing
1	0	0	0	100
1/2	85.1	6.9	6.9	93.1
3/8	57.5	4.7	11.6	88.4
4	99.4	8.1	19.7	80.3
8	100.5	8.2	27.9	72.1
16	97.1	7.9	35.9	64.1
30	116.5	9.5	45.4	54.6
50	152.1	12.4	57.8	42.2
100	208.7	17.0	74.8	25.2
200	123.5	10.1	84.9	15.1
pan	185.4	15.1	100	0

[a]Sample origin - helicopter landing pad site.
Total weight of sample 1225.8 grams.
Fineness modulus SM-SC (silt and silt mixture, clay sand and sand clay mixture.

TABLE 7. Sieve Analysis, Type 2 Soil.[a]
(ASTM Standard Test C117-66)

Sieve size	Weight retained, grams	Percent retained	Cumulative	
			Percent retained	Percent passing
1	0	0	0	100
1/2	5.9	0.5	0.5	99.5
3/8	25.6	2.1	2.6	97.4
4	36.4	3.0	5.6	94.4
8	100.9	8.3	13.9	86.1
14	150.3	12.4	26.3	73.7
35	383.7	31.6	57.9	42.1
50	172.7	14.2	72.1	27.9
100	146.0	12.0	84.1	15.9
200	56.6	4.7	88.8	11.2
pan	135.7	11.2	100	0

[a]Sample origin - 5,000-foot mark of runway.
Total weight of sample 1213.8 grams.
Fineness modulus SM-SW (silty sands and sand silt mixture, well graded sands or gravelly sands with little or no fines).

29

TABLE 8. Sieve Analysis, Type 2 Soil.[a]
(ASTM Standard Test C117-66)

Sieve size	Weight retained, grams	Percent retained	Cumulative	
			Percent retained	Percent passing
1	0	0	0	100
1/2	24.2	1.7	1.7	98.3
3/8	0	0	1.7	98.3
4	50.5	3.6	5.3	94.7
8	111.0	7.8	13.1	86.9
14	182.7	12.9	26.0	74.0
35	438.2	31.0	57.0	43.0
50	177.1	12.5	69.5	30.5
100	140.7	9.9	79.4	20.6
200	55.8	3.9	83.4	16.6
pan	235.0	16.6	100	0

[a]Sample origin - 3,000-foot mark of runway.
Total weight of sample 1415.2 grams.
Fineness modulus SM (silty sands, sand silt mixture).

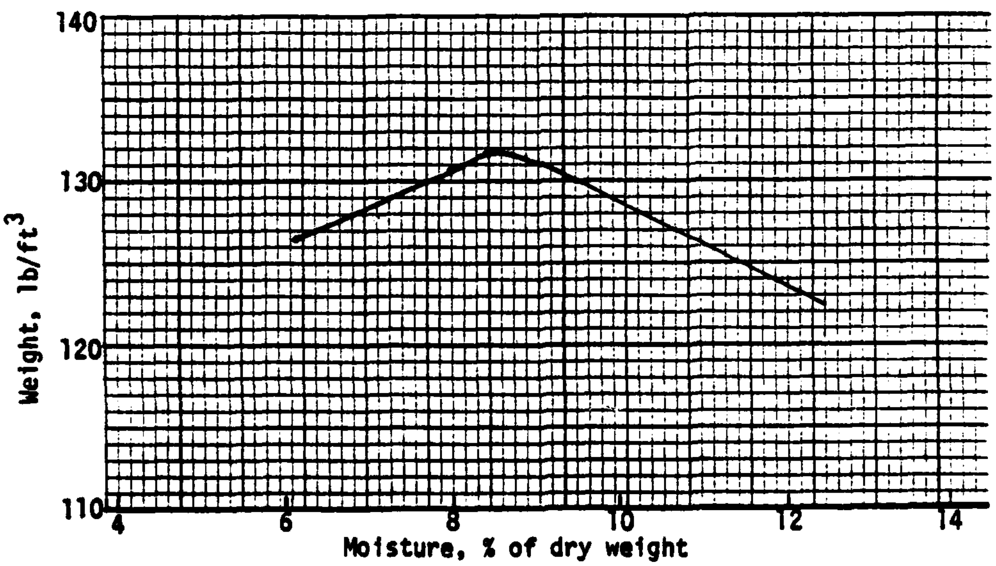

FIGURE 21. Compaction-Plasticity Curve (based on ASTM Standard Test D1557-64T) for Soil Type 2, maximum density 132.5, optimum moisture 9.0%.

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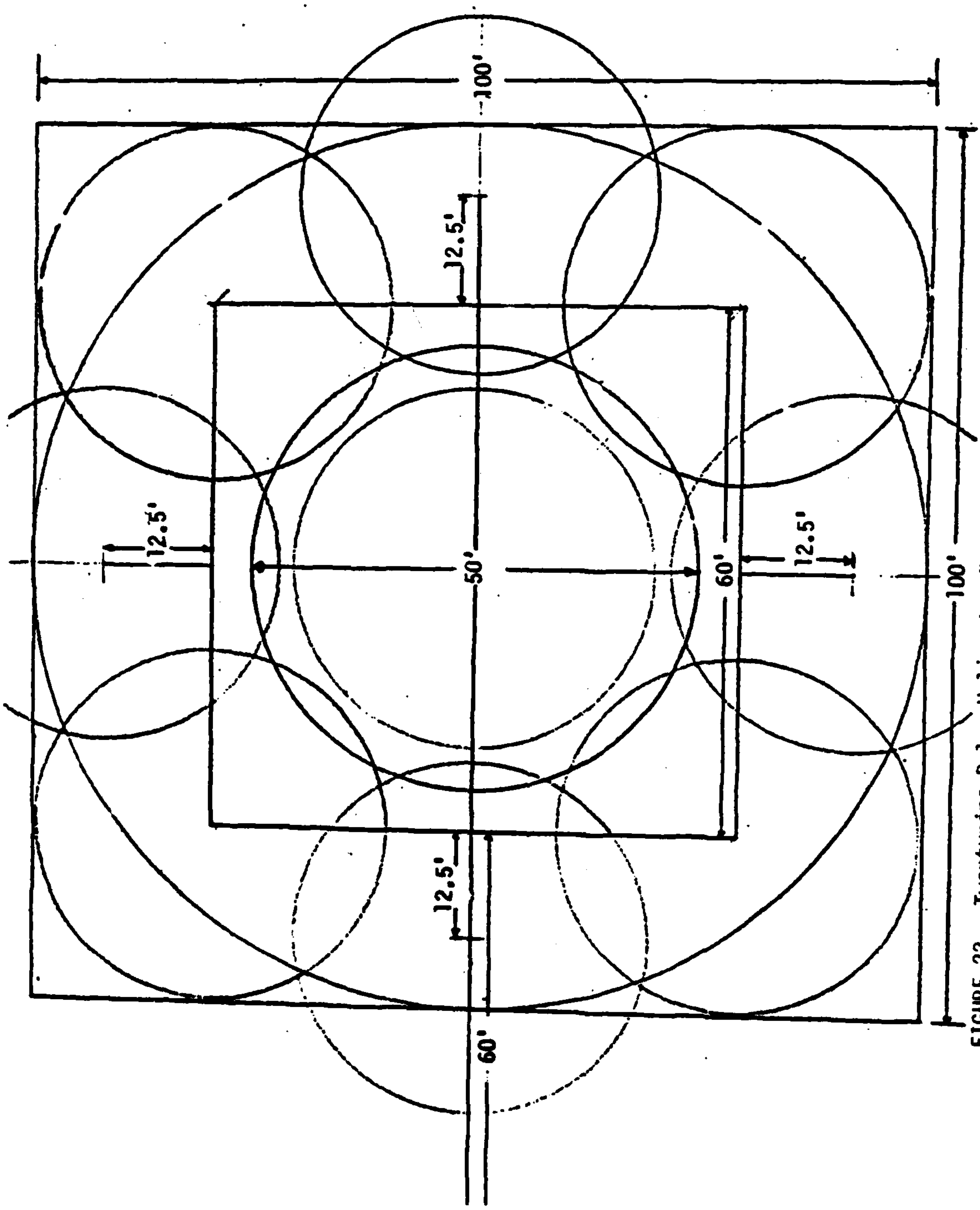

FIGURE 22. Twentynine Palms Helicopter Pad and Sprinkler System Layout.

Inspection of the site on 7 December revealed that much of the moisture still remained in the soil. Also, the emulsion had frozen overnight. Core samples were taken and returned to NWC for further analysis and testing (see "NWC Analysis").

Approximately five weeks after application of the stabilizer at Twentynine Palms, the LSE LZ site was inspected by the Civil Engineering Laboratory (CEL) for the purpose of conducting a limited evaluation.[1] The CEL findings are summarized in a later section (see "CEL Evaluation").

NWC Analysis

Laboratory experiments were conducted at NWC to confirm the effects of freezing temperatures on the strength of latex stabilized samples of dried soil taken from the Twentynine Palms test site. It had already been reported that temperatures below 40°F would "spoil" the pure latex A-400; this effect was confirmed by freezing a sample in the laboratory. After thawing, it was noted that the polymer had agglomerated into one solid mass surrounded by clear liquid. A similar, but less dramatic, effect was observed following thawing of a 90% water/10% A-400 mixture.

Soil samples prepared using a 90% water/10% A-400 emulsion which had been frozen and thawed showed drastically reduced compressive strength. Soil samples treated with unfrozen 90% water/10% A-400 emulsion and subsequently frozen did not show measurably reduced compressive strength.

Finally, tests were conducted on the effect of the surfactant (Renex-31) on the compressive strength of the stabilizer treated soil. Results showed a reduction of compressive strength consistent with the lower concentration of emulsion in the soil which occurs as a consequence of its more effective dispersion due to the addition of the surfactant.

CEL Evaluation

In summary, the CEL evaluation (see footnote 1) found that "the top quarter of an inch or so of soil appeared to be bonded by the stabilizer. However, material forming this crust was weak and could easily be broken up by crushing between the fingers. The underlying layers had the appearance of wet beach sand and could also be easily broken up. When samples of the underlying layers were dried at ambient temperatures over several days, a product similar to the surface crust

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[1] Civil Engineering Laboratory. "Vinyl Acetate-Ethylene Copolymer Emulsion as a Soil Stabilizer - A Limited Evaluation," by M. C. Hironaka. Port Hueneme, Calif., January 1979. (CEL TM M-53-79-1, publication UNCLASSIFIED.)

material was formed. This material was also friable and could be easily broken up in a manner similar to the crust material. Two tentative conclusions can be reached based upon the brief study of these sample materials as follows: (1) the stabilizer has cured to a depth of approximately 1/4 inch in five weeks; and (2) because the cured stabilized soil mass is friable, there is insufficient bonding (cementing agent) between the soil particles."

CEL concluded that the emulsion could be used as a dust controlling agent in nontraffic areas but a much higher percentage of stabilizer would be needed for areas subjected to traffic loadings. Also, a long and indeterminate curing time would be required before the stabilized area could be subjected to traffic. Finally, CEL felt that other soil stabilizing agents are available (portland cement, asphalt emulsions, lime) which are much better suited, more effective and less costly.

SUMMARY AND CONCLUSIONS

In terms of the criteria specified in the "Introduction" of this report, the polymer emulsion soil stabilizer has the following characteristics:

1. Reduction of dust signature. With freshly cured stabilized soil, the dust signature is negligible. Traffic and environmental erosion may require reapplication of emulsion at intervals depending on the severity of conditions.

2. Structural strength. Under favorable conditions (e.g., sandy soil, dry warm weather) sufficient strength can be obtained for applications involving moderate traffic of heavy equipment over a period of many months. Usefulness of the stabilized area may be conveniently extended by periodic reapplication of a small amount of emulsion to re-seal the surface. Under wet, cold conditions or in light clay soil, this technique is unacceptable.

3. Curing time. Under very hot, dry conditions, the curing time is only a few hours. Under cold, wet conditions, the curing time is indefinitely long.

4. Resistance to erosion. The resistance to erosion is very good under favorable conditions. Also, the surface can be easily re-sealed by periodic re-application of small amounts of emulsion.

5. Ease of application. The emulsion is easily applied by a variety of techniques including fire hose and sprinkler.

6. Cost. The cost, using a 10% emulsion concentration, is about $0.20/square foot for a single application.

7. Availability. The Airflex 400 (A-400) is readily available in large (tank car) quantities.

8. Environmental considerations. There is no evidence that the emulsion has a negative environmental impact.

The demonstration tests served to point up the factors that can impact the usefulness of this soil stabilization system. At the NAF and hospital sites, the stabilizer did effectively reduce dust problems. However, in both cases the circumstances at the time of application were favorable. Ground and air temperatures were warm, and there was little moisture present.

At the hospital landing pad, the helicopters land on the central concrete pad and the treated surfaces are subjected to minimal traffic. The NAF site did not have a concrete landing pad and, therefore, some damage to the treated surface was experienced. However, such damage is easily repaired by application of another coat of emulsion.

The experience at Twentynine Palms pointed up that this soil stabilizing process is significantly more time/weather dependent than previously considered. The adverse weather conditions affected the surfactant (solidified), the application system (area covered), and the curing time (moisture remained in the soil). Low temperatures caused the emulsion to freeze and resulted in poor bonding of the soil. The ground surface, therefore, could not be considered "stable," especially if subjected to traffic.

Other factors must also be considered when contemplating the use of this stabilizing system. The A-400 emulsion has a limited (6-month shelf life and must be stored at temperatures above 40°F. The surfactant (Renex-31) also has a limited shelf life (1 year) and recommended storage temperature is room ambient.

On the positive side, the advantages of this soil stabilizer are that it is (1) non-toxic, (2) readily prepared without special precision equipment and extensively trained personnel, and (3) easily cleaned from equipment using water.

Finally, the results of this investigation strongly suggest that, under favorable soil and weather conditions, a dilute aqueous emulsion of vinyl acetate ethylene copolymer can be a convenient and effective agent for soil stabilization. However, the range of useful conditions is too narrow to recommend this technique for general use.

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