Tennessee, is a region well known for its cavernous limestone bed-rock. Luray caverns is but one of a series of natural caverns of large extent. Large size caverns were intercepted and concrete filled under the site for Chicamauga Dam. This great valley is a growing industrial area. Foundation conditions in this and other known soluble limestone areas should be thoroughly investigated and the exact geological conditions determined before building operations are planned and areas overlying badly folded or crushed zones, where the protection of an impervious mantle over the bed-rock does not exist or has been destroyed or seriously disturbed, should be avoided or built upon only after special provisions will assure adequate protection and positive stability.

Where structures are founded on unstable overburden, susceptible to ravelling or erosion into underground cavitations, cap grouting may in many instances be the only economical corrective procedure. The bed-rock cavitations may be of such large volume that grout flowing into them would be entirely wasted, and the risk of cavitations in the limestone bed-rock approaching so close to the surface as to produce relatively thin rock shelves and overhanging ledges, makes an underpinning procedure involving concentrations of load on piles or caissons, unsafe against a shear failure of the supporting bed-rock.

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IX c 6

RESINOUS WATER REPELLENTS FOR SOILS

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SUMMARY

This paper presents the results of a field and laboratory investigation of resinous water repellents for soils to be used in road or airfield construction. The study indicated that certain resin-type repellents are effective in waterproofing soils which have some plasticity. Tentatively, based on the results of field tests, the quantity of Stabinol required for adequate waterproofing is determined by the plasticity index and soil type.

INTRODUCTION

As a part of the investigational program concerned with the design and construction of roads and runways conducted by the Corps of Engineers during World War II, the use of resinous water repellents as an admixture for waterproofing soils was investigated. It is the purpose of this paper to present the pertinent results of a combined field and laboratory study conducted by the Waterways Experiment Station in 1944 and 1945, in which the effects of various repellents on a range of soil types was investigated. Detailed descriptions of the tests are given in the interim report "Resinous Water Repellents for Soils", Waterways Experiment Station Technical Memorandum No. 217-1.

SCOPE OF INVESTIGATION

The laboratory study consisted of tests on fourteen soils treated with two water repellents (321 and Stabinol) to determine types of soils that could be effectively waterproofed according to available criteria. Additional laboratory studies were made on five of the soils to determine the efficacy of other water repellents made available after initiation of the investigation.

The field study included construction of 30 test sections, using five soils from the group studied in the laboratory and using untreated soil and various percentages of treatments. Several treated and untreated sections were covered with prefabricated bituminous surfacing and pierced steel plank. The sections were tested after dry and wet periods under wheel loads ranging from 2000 to 5000 lb.

LABORATORY TESTS

Materials

Only two water repellents were studied extensively at the start of the investigation. These were 321 and Stabinol, both products of the Hercules Powder Company. Another product of this company, Vinsol, was available, but review of data indicated that it would probably not be as effective over as wide a range of soils as the other two; therefore, only limited tests were scheduled with this material. Later on, other repellents became available for research purposes from the National Southern Products Company (NSP-121 and NSP-25-2)and the Hercules Powder Company (NVX).

The fourteen soils tested in the preliminary investigation included alkaline and acid soils ranging from friable sandy soils to heavy clay soils. It was also decided to include gravelly soils with different plasticity indexes. A complete list of the soils studied, together with all pertinent classification and compaction data for each, is shown in table 1.

Laboratory tests and criteria

Capillary rise and full-submersion tests for determining the proper repellent content

TABLE 1

CLASSIFICATION DATA FOR SOILS TESTED IN LABORATORY

Sample No.	Soil Type	Casagrande Classification	Grain Size Analysis - Percent			Specific Gravity	Atterberg Limits in Percent			pH	Standard AASHO Compaction Data	
			0.05 mm Sand	0.05 to 0.005 mm Silt	0.005 mm Clay		LL	PL	PI		w %	γd lb/cu ft
1	Acidic silty clay	CL	22	45	33	2.70	46	20	26	6.6	20.5	102.5
2	Acidic sandy clay	OL	40	25	35	2.63	39	19	20	6.6	16.5	108.5
3	Acidic silty clay	CH	10	55	35	2.70	49	19	30	6.7	21.0	98.0
4	Alkaline sandy silt	ML	20	62	18	2.68	33	22	11	7.3	18.8	103.3
5	Acidic clayey silt	ML	10	66	24	2.70	38	26	12	6.2	20.0	100.0
6	Acidic clayey silt	OL	26	48	26	2.69	41	21	20	6.1	18.5	102.8
7	Acidic sandy silt	ML	22	60	18	2.67	32	24	8	6.4	17.5	104.2
8	Acidic gravelly clay sand	GC	78	6	16	2.67	25	14	11	6.4	9.0	125.0
9	Acidic clay gravel	GW	93	2	5	2.66	19	15	4	6.1	8.0	127.0
10	Alkaline clayey sand	SF	79	2	19	2.68	23	14	9	7.1	12.0	111.5
11	Alkaline clayey silt	OL	10	65	25	2.69	35	20	15	7.2	18.5	108.6
12	Acidic clayey silt	CL	20	57	23	2.70	50	27	23	6.3	19.0	106.4
13	Acidic clayey silt	OL	14	62	24	2.68	29	17	12	6.9	17.5	110.8
14	Alkaline silt (Vicksburg loess)	ML	9	90	5	2.74	26	24	2	6.9	18.0	103.5

were conducted as recommended by the Hercules Powder Company. The capillary rise test is performed on specimens 2 in. in diameter by 2 in. high, compacted to standard AASHO x) optimum moisture and density, with various percentages of a given repellent. The specimens are cured in a moist atmosphere until they have dried back to 55 per cent of the optimum water content. They are then placed in a humid atmosphere in a pan with the bottom 1/4-in. of the specimen submerged in water for 24 hours. The percentage of treatment considered satisfactory is that which will control the capillary rise absorption to a point where not more than 75 per cent of optimum water content is obtained after 24 hours.

The Hercules full-submersion test is performed on specimens prepared and cured as for the capillary rise test. After curing, however, the specimens are fully submerged for 24 hours. That treatment is considered satisfactory which controls the water content pick-up to 90 per cent of optimum water content after 24 hours.

The full-submersion test also required that an unconfined compression test be made on 2- by 2-in. cylindrical specimens, but no criteria had been established. It was decided at the Waterways Experiment Station that a satisfactory treatment would be that which enabled a specimen to have an unconfined compressive strength after 24 hours of full submersion equal to the unsoaked as-molded unconfined compressive strength of a specimen of untreated soil. In this test the height of specimens was increased to 4 in. to enable shear planes to develop in the compression test.

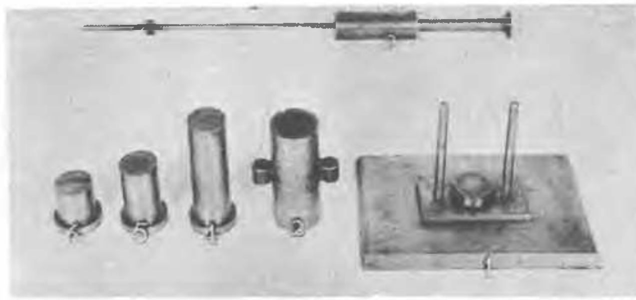
Preparation of specimens

All fine-grained soils were air dried and screened through a No. 10 sieve. Soils containing gravel particles were air dried and screened through a No. 4 sieve. A given per cent of water repellent powder was then added to the soil and the two thoroughly mixed. After the soil and repellent were mixed, water was added in increments to bring the mixture to standard AASHO optimum water content.

The soil was compacted in a cylindrical mold 2 in. in diameter by 4 in. in height. The tamper used had a striking surface of slightly less than 2 in. and a sliding weight of 4 lb, which fell 12 in. to the top of the hammer base. This equiment is shown on fig.1. The samples were compacted in three layers with 14 blows of the tamper on each layer.

Results of preliminary laboratory tests

The results of preliminary laboratory tests are summarized on table 2. It may be noted that only one soil, sample 12, could be satisfactorily treated with 321 according to the capillary rise criterion, even though treatments of as much as 1 per cent were used. Only



1. Base for mold
2. Mold
3. Tamper
4. Piston for removing specimens from mold
5. Special plunger for molding 2" x 2" specimens
6. Plunger for controlling 4" height on 2" x 4" specimens

Compaction apparatus

FIG.1

two of the soils (samples 1 and 6) satisfied the full-submersion criterion, and no soils satisfied the unconfined compressive strength criterion when treated with 321. In contrast to the apparent ineffectiveness of 321, it was found that Stabinol successfully waterproofed, according to all three criteria, the eleven soils tested. Soils 11, 12 and 13 were not treated with Stabinol, as they were included primarily for the purpose of trying to find a soil which could be successfully treated with 321.

Additional laboratory tests

To investigate further the efficiency of 321 as a water repellent, laboratory tests were conducted using soil samples 5 and 7 and 321 mixed with ferrous sulphate and aluminum sulphate. The scope of the tests and summary of results are presented on table 3. These tests indicated that a treatment of 1 per cent 321 with 40 per cent of either ferrous or aluminum sulphate (by weight of 321) would satisfy the laboratory criteria for both soils.

A series of wetting and drying tests was performed on soil samples 5, 6, 7, and 8, treated with 1 per cent of 321. The results of these tests are presented on table 4. The changes in water content with successive cycles of wetting and drying, and the unconfined compressive strengths at the end of the test indicated that material increases in water repellency were effected by the wetting and drying for soil 6, 7, and 8. Soil sample 5 showed a slight increase in water repellency with successive wetting and drying, as evidenced by lower water contents after five cycles. In view of the satisfactory performance of 321 in the field tests (as shown in table 6), it appears that the wetting and drying test gives a better indication of the probable field behavior than the capillary rise, full submersion, and unconfined compressive strength criteria used in the other phases of the laboratory investigation.

However, some of the soils showed an increase in water repellency as indicated by the laboratory tests, but did not satisfy the test criteria. Therefore, it is possible that changes in the limiting values for the capillary rise, full submersion, and unconfined compression tests may be desirable.

x) American Association of State Highway Officials Methods T 99 - 38.

TABLE 2

SUMMARY OF PRELIMINARY LABORATORY TESTS

Sample	Soil Type	pH	PI	Hercules Criterion Minimum Treatment in Percent: 321 Capillary Rise	321 Full Submersion	Stabinol Capillary Rise	Stabinol Full Submersion	Waterways Experiment Station Criterion Unconfined Compressive Strength in Lb per Sq In.: Raw Soil As Molded Unsoaked	Raw Soil Dried Back to 55% Unsoaked	Raw Soil Dried Back to 55% Soaked	321 Dried Back to 55% Soaked	Stabinol Dried Back to 55% Soaked
1	Acidic silty clay	6.6	26	Unsucces*	1	4	4	59	291	7	23 (1/4) 25 (1/2) 54 (1)	23 (1/2) 26 (1) 30 (2) 91 (4)
2	Acidic sandy clay	6.6	20	Unsucces*	Unsucces*	4	2	49	198	7	0 (1/4) 0 (1/2) 5 (1)	0 (1/2) 43 (1) 77 (2) 142 (4)
3	Acidic silty clay	6.7	30	Unsucces*	Unsucces*	2	1	56	235	4	14 (1/4) 23 (1/2) 10 (1)	19 (1/2) 42 (1) 71 (2) 139 (4)
4	Alkaline sandy silt	7.3	11	Unsucces*	Unsucces*	2	1/2	25	No test	No test	12 (1/4) 13 (1/2) 13 (1)	25 (1/2) 31 (1) 63 (2) 131 (4)
5	Acidic clayey silt	6.2	12	Unsucces*	Unsucces*	1	1	36	163	0	15 (1/4) 16 (1/2) 23 (1)	17 (1/2) 42 (1) 72 (2) 146 (4)
6	Acidic clayey silt	6.1	20	Unsucces*	1	2	2	52	237	0	38 (1/4) 34 (1/2) 57 (1)	20 (1/2) 46 (1) 65 (2) 124 (4)
7	Acidic sandy silt	6.4	8	Unsucces*	Unsucces*	1	1	32	125	6	12 (1/4) 12 (1/2) 10 (1)	18 (1/2) 32 (1) 56 (2) 114 (4)
8	Acidic gravelly clay sand	6.4	11	Unsucces*	Unsucces*	4	2	39	246	4	3 (1/4) 4 (1/2) 4 (1)	5 (1/2) 9 (1) 31 (2) 75 (4)
9	Acidic clay gravel	6.1	4	Unsucces*	Unsucces*	1	3	52	No test	No test	4 (1/4) 4 (1/2) 3 (1)	6 (1/2) 8 (1) 32 (2) 102 (4)
10	Alkaline clayey sand	7.1	9	Unsucces*	Unsucces*	1/2	1/2	23	No test	0	4 (1/4) 4 (1/2) 4 (1)	9 (1/2) 16 (1) 31 (2) 58 (4)
11	Alkaline clayey silt	7.2	15	Unsucces*	Unsucces*	No test	No test	35	No test	No test	15 (1)	No test
12	Acidic clayey silt	6.3	23	1	Unsucces*	No test	No test	89	No test	No test	42 (1)	No test
13	Acidic clayey silt	6.9	12	Unsucces*	Unsucces*	No test	No test	25	No test	No test	14 (1)	No test
14	Alkaline silt (Vicksburg loess)	8.9	2	Unsucces*	Unsucces*	2	2	24	No test	1	3 (1/2) 4 (1)	25 (2)

Notes:

Results tabulated are average of two tests except pH and PI test results.
Figures in parentheses are percentages of repellents used.
All specimens molded at Standard AASHO optimum water content and density.
All soaked specimens were wrapped in paper towels or filter paper and packed in fully saturated sawdust for 24 hours.
On samples containing gravel, all material passing No. 4 sieve was used for preparing test specimens.

* Treatments up to as much as 1 percent did not satisfy criterion.

Additional water repellents were submitted to full submersion and unconfined compression tests when used as treatments with several of the soils in the investigation. The repellents tested were Vinsol with 2 per cent of caustic soda (by weight of Vinsol), NSP-121, NSP-25-2, and NVX. The results of tests on these specimens are summarized on table 5. Soil sample 6 treated with 2 per cent Vinsol and 2 per cent caustic soda satisfied the criterion for full submersion and was essentially satisfactory for unconfined compressive strength; however, soil samples 3, 5 and 7 were not successfully waterproofed with this treatment. NSP-121 did not perform successfully in the laboratory on soils 5 and 6, the only two tested. A treatment of 2 per cent of NSP-25-2 met the laboratory criteria for full submersion and unconfined compression with soil sample 7, but was unsuccessful on soils 3, 5, 6, and 8. Tests with NVX on soil samples 3, 5, 6, 7 and 8 showed that only soil sample 7 met the full submersion criterion, and none of the soils satisfied the criterion for unconfined compression.

FIELD TESTS

Layout

All field tests were made at a site near the Waterways Experiment Station where the subgrade consisted of a clayey silt soil.

Construction

All soils were hauled from stock piles or borrow pits with tractor-drawn scraper units. Material was spread on the sections with a bulldozer or a motor patrol until a loose lift of 6 to 7 in. was obtained. Because of wet soil conditions, it was necessary to aerate the soils as much as possible.

The water repellents were added as soon as the equipment used for mixing could perform with a reasonable degree of success, even though the water content was higher than optimum. All repellents were applied by hand spreading. The quantities of ferrous sulphate and caustic soda were added, where required, by hand-spraying water solutions of these chemicals with sprinkling cans after the repellent

TABLE 3

SUMMARY OF LABORATORY TESTS ON 321 WITH CHEMICALS ADDED

Sample	Soil Type	Hercules Criterion Minimum Treatment in %: Capillary Rise	Hercules Criterion Minimum Treatment in %: Full Submersion	W.E.S. Criterion Unconfined Compressive Strength in Lb per Sq Ft: Raw Soil As Molded Unsoaked	W.E.S. Criterion: Treated Soil Dried Back to 55% Soaked	
		321 plus 10% $FeSO_4$ (by weight of 321)				
5	Acidic clayey silt	Unsucces. (1)	Unsucces. (1)	36	16	(1/2)
					18	(1)
7	Acidic sandy silt	Unsucces. (1)	Unsucces. (1)	32	7	(1/4)
					7	(1/2)
					8	(1)
		321 plus 20% $FeSO_4$ (by weight of 321)				
5	Acidic clayey silt	Unsucces. (1)	Unsucces. (1)	36	21	(1/2)
					24	(1)
7	Acidic sandy silt	1	1	32	6	(1/4)
					8	(1/2)
					28	(1)
		321 plus 40% $FeSO_4$ (by weight of 321)				
5	Acidic clayey silt	1	1/2	36	24	(1/2)
					34	(1)
7	Acidic sandy silt	1/2	1/2	32	7	(1/4)
					22	(1/2)
					46	(1)
		321 plus 10% $K_2AL_2\ (SO_4)_4 . 24\ H_2O$ (by weight of 321)				
5	Acidic clayey silt	Unsucces. (1)	Unsucces. (1)	36	15	(1/2)
					15	(1)
7	Acidic sandy silt	Unsucces. (1)	Unsucces. (1)	32	6	(1/4)
					8	(1/2)
					7	(1)
		321 plus 20% $K_2AL_2\ (SO_4)_4 . 24\ H_2O$ (by weight of 321)				
5	Acidic clayey silt	Unsucces. (1)	1	36	15	(1/2)
					28	(1)
7	Acidic sandy silt	1	Unsucces. (1)	32	6	(1/4)
					11	(1/2)
					9	(1)
		321 plus 40% $K_2Al_2\ (SO_4)_4 . 24\ H_2O$ (by weight of 321)				
5	Acidic clayey silt	1	1	36	19	(1/2)
					28	(1)
7	Acidic sandy silt	1/2	1	32	7	(1/4)
					23	(1/2)
					36	(1)

Notes:

All specimens molded at Standard AASHO optimum water content and density.

Figures in parentheses are percentages of repellents used.

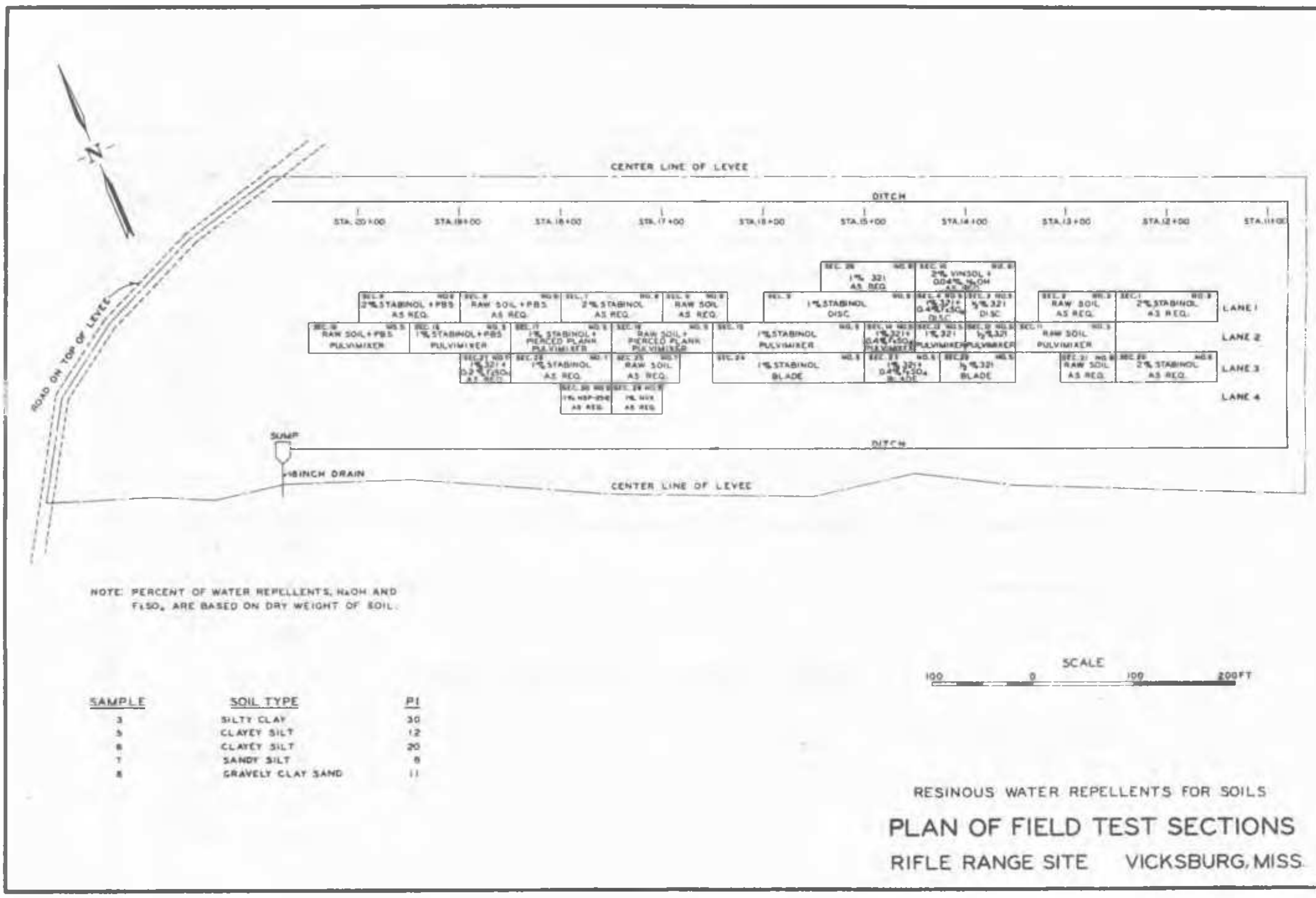


FIG. 2

Section 11 - Untreated

FIG. 3

Section 15 - Treated with 1% stabinol

FIG. 4

had been added and mixed into the soil by one or two coverages of the mixing equipment.

The major mixing of repellents was generally accomplished by use of a Seaman pulvimixer. For comparison, sections 3, 4, and 5 were restricted to mixing by disks only, and sections 22, 23 and 24 were restricted to mixing by motor patrol blade only. Untreated soils were given the same processing.

All sections, after being properly mixed, were compacted by 20 passes of a sheepsfoot roller. The water content was generally at AASHO optimum. After compaction, all sections were surface-compacted with empty 3-cu-yd trucks and then bladed with a motor patrol. The surface of the soil was finished by one coverage of an 8-ton tandem smooth roller.

As shown on fig. 2 , several sections were covered with PBS (prefabricated bituminous surfacing) and PSP (pierced steel plank). These materials were placed in the usual manner, with the exception that the PSP was not anchored at the edges.

TABLE 4

WET - DRY LABORATORY TESTS ON SAMPLES TREATED WITH 1% OF 321

Cycle No.	Duration of Cycle - Days		Water Content - Percent of Dry Weight							
			Soil Sample 5		Soil Sample 6		Soil Sample 7		Soil Sample 8	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	-	2	20.0	5.5	19.5	6.0	18.0	4.0	19.5	3.5
2	1	2	23.5	10.0	21.5	9.5	18.0	6.5	12.5	3.5
3	1	2	22.5	8.0	18.5	7.5	16.5	5.5	9.5	3.0
4	1	2	21.5	7.5	14.0	5.5	14.5	4.5	7.0	2.5
5	2	2	21.0	10.5	14.0	7.0	14.0	6.0	7.0	3.0
6	1	2	20.5	6.5	11.5	5.0	11.0	3.5	5.5	2.5
7	1	2	20.0	5.5	9.5	4.0	8.5	2.5	5.5	2.5
8	1	4	20.0	3.5	9.5	4.0	8.5	2.5	5.5	2.0
9	1	-	18.5	—	10.0	—	8.5	—	5.5	—

Notes:

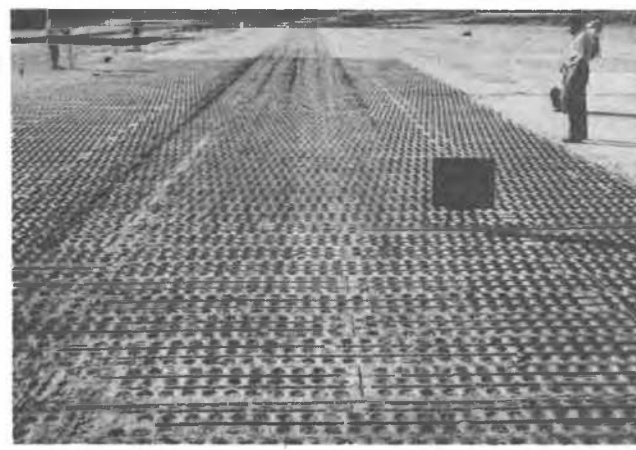
Drying took place at temperatures of 70-90° F. and humidity of 50-80%. After drying, specimens were submerged in saturated sawdust for period shown.

Unconfined compressive strengths were as follows:

Soil Sample	Raw Soil Unsoaked	Treated Soil After Last Cycle
5	35	19
6	52	90
7	32	58
8	35	46

Section 16 - Untreated + PSP

FIG. 5



Section 17 - Treated with 1% stabinol + PSP

FIG. 6

Traffic tests

Tracking with 2000-, 3000-, and 4000-lb wheel loads was performed on a 9.5-ft lane, located in the middle of each section, immediately following a sustained drying period and a sustained rainy period. Tracking was also accomplished with a 5000-lb wheel load after a sustained rainy period and with a 3000-lb wheel load during a rain. Tracking usually ranged from 6 to 18 coverages of a given wheel load for a given condition, depending on the performance of the sections.

Performance of test sections

It is not intended to give a detailed description of the behavior of each section; however, the over-all performance of each, immediately following and during a rain, is given in table 6. Typical pictures of the condition of treated and untreated sections are shown on figs. 3 through 6. Generally speaking, all uncovered treated soils showed marked improvement in performance over uncovered untreated soils.

The performance of each section during a dry period is not shown on table 6 because it was not considered to be a major item in these tests other than the development of dust. All sections covered with PBS were, of course, dustproof, whereas all other sections developed dusting in various amounts. In general, it can be stated that none of the repellents prevented the formation of dust.

Untreated and treated sections covered with PBS performed with about the same effectiveness and were much superior to untreated, uncovered section, This type of surfacing is a good waterproofing material when used on subgrades or base courses which have been properly compacted.

Both untreated and treated sections covered with PSP performed very poorly under traffic. However, the sections performed better than untreated uncovered sections of the same soil, but were inferior in performance as compared to the uncovered treated sections. Typical views of sections covered with PSP are shown on figs. 5 and 6 and contrast sharply with the well-drained, dried-out appearance of the uncovered untreated soil as shown on fig. 4 after the same amount of traffic.

CONCLUSIONS

The following generalized conclusions and recommendations are believed warranted as a result of tests performed in this investigation:

1) The laboratory capillary rise, full submersion, and unconfined compression tests did not conclusively determine whether a given water repellent will work, or the amount of water repellent required to satisfactorily waterproof a given soil. However, the study indicated that such tests might be acceptable if the criteria were changed. Sufficient information was not obtained to establish the desired changes in criteria.

2) The wetting and drying test has definite possibilities as a laboratory method of determining the effectiveness of water repellents. It is not a rapid method, however, since it requires at least four days, and possibly longer for some soils, to conduct the test.

3) The repellents are not recommended for cohesionless sands and sand gravels.

4) None of the resin-type repellents in the quantities used for successful field treatment (1/2 to 2 per cent by dry weight of soil) prevented "dusting".

5) Resin-type repellents appear to have good possibilities in the stabilization of sand-clays, sand-clay gravels, and similar base course soils of relatively high plasticity indexes.

6) Based on the results of field tests, Stabi-

TABLE 5

SUMMARY OF ADDITIONAL LABORATORY TESTS

Sample	Soil Type	Hercules Criterion Minimum Treatment in Percent: Capillary Rise	Hercules Criterion Minimum Treatment in Percent: Full Submersion	W.E.S. Criterion Unconfined Compressive Strength in Lb per Sq In.: Raw Soil As Molded Unsoaked	W.E.S. Criterion: Treated Soil Dried Back to 55% Soaked	
		VINSOL plus 2% NaOH (by weight of Vinsol)				
3	Acidic silty clay	Unsucces. (2)	Unsucces. (2)	56	13 15 28	(1/2) (1) (2)
5	Acidic clayey silt	Unsucces. (2)	No test	36	No test	
6	Acidic clayey silt	No test	2	52	43	(2)
7	Acidic sandy silt	No test	Unsucces. (2)	32	5 15 17	(1/2 (1) (2)
			NSP-121			
5	Acidic clayey silt	No test	Unsucces. (1	36	5 10 10	(1/4) (1/2) (1)
6	Acidic clayey silt	No test	Unsucces. (1)	52	10	(1)
			NSP-25-2			
3	Acidic silty clay	No test	Unsucces. (2)	56	9 20 23	(1/2) (1) (2)
5	Acidic clayey silt	No test	Unsucces. (2)	36	21 19 15	(1/2) (1) (2)
6	Acidic clayey silt	No test	Unsucces. (2)	52	15 23 34	(1/2) (1) (2)
7	Acidic sandy silt	No test	1	32	20 31 33	(1/2) (1) (2)
8	Acidic gravelly sand	No test	Unsucces. (2)	39	5 8 14	(1/2) (1) (2)
			NVX			
3	Acidic silty clay	No test	Unsucces. (2)	56	20 27 27	(1/2) (1) (2)
5	Acidic clayey silt	No test	Unsucces. (2)	36	27 30 30	(1/2) (1) (2)
6	Acidic clayey silt	No test	Unsucces. (2)	52	28 26 28	(1/2) (1) (2)
7	Acidic sandy silt	No test	1	32	22 28 22	(1/2) (1) (2)
8	Acidic gravelly sand	No test	Unsucces. (2)	39	3 3 3	(1/2) (1) (2)

Notes:

All specimens molded at Standard AASHO optimum water content and density.

Figures in parentheses are percentages of repellent used.

TABLE 6

PERFORMANCE OF SECTIONS UNDER TRAFFIC

Group	Section	Soil	Treatment in Percent	Performance	
				After Rain[1]	During Rain
Untreated, uncovered	2	3	0	Bad	Very bad
	11	5	0	Bad	Very bad
	21	6	0	Bad	Good**
	25	7	0	Bad	Good***
	6	8	0	Fair	Very good*
Untreated, covered with PBS	19	5	0	Good[2]	Good[2]
	8	8	0	Good[2]	Good[2]
Untreated, covered with PSP	16	5	0	Fair	Poor
Treated with Stabinol, uncovered	1	3	2	Excellent	Good*
	5	5	1	Excellent	Very good*
	15	5	1	Excellent	Very good*
	24	5	1	Excellent	Very good*
	20	6	2	Excellent	Very good*
	26	7	1	Very good	Very good**
	7	8	2	Excellent	Excellent
Treated with 321, uncovered	3	5	1/2	Very good	Very good*
	12	5	1/2	Very good	Very good*
	13	5	1	Excellent	Very good
	22	5	1/2	Very good	Very good*
	28	6	1	Excellent	Very good
Treated with 321 and $FeSO_4$, uncovered	4	5	1 + 0.4	Excellent	Very good*
	14	5	1 + 0.4	Excellent	Very good
	23	5	1 + 0.4	Excellent	Very good*
	27	7	1 + 0.2	Very good	Very good**
Treated with NVX	29	5	1	Good to very good	Good
Treated with NSP-25-2	30	5	1	Good to very good	Good
Treated with Vinsol and caustic soda, uncovered	10	6	2	Excellent	Very good*
Treated with Stabinol, covered with PBS	18	5	1	Good[2]	Good[2]
	9	8	2	Very good	Very good
Treated with Stabinol covered with PSP	17	5	1	Fair	Poor

Notes:

[1] This is intended to cover only the performance of the section during application of the first 2 to 6 coverages. In all instances this was the critical tracking period. A larger number of coverages would tend to compact the material as it began to dry and sections would not "heal."

[2] Not believed to be a true indication of performance, because of construction conditions. These sections would all normally rate very good or excellent.

* 1/2 to 1 in. washed away but tracked without difficulty.

** 1 to 2 in. washed away but tracked without difficulty.

*** 2 to 3 in. washed away but tracked without difficulty.

nol appeared to be the best water repellent. Next in order were 321 with ferrous sulphate, 321 only, and Vinsol with caustic soda, all of which performed with about equal effectiveness. NVX and NSP-25-2 were satisfactory and were equal in performance but were not as efficient as the other repellents.

7) The permanency of the waterproofing effects of the water repellents is not known.

8) In lieu of laboratory tests to determine satisfactory water repellent treatments for a given soil type, it is suggested that the plasticity index and the soil type be used as a guide in determining the quantity required. Based on the results of field tests, the following treatments of Stabinol for various soil types are tentatively recommended:

Material	Plasticity Index Range	Per cent of Stabinol by Dry Weight of Soil
Silty sands, sandy silts and silts	2 to 6, approx.	2
Sandy silts, clayey silts and silty clays	6 to 20, approx.	1
Silty clays, medium to fat clays	20 and above	2
Sand clays, clayey sands, gravelly clay sands, sandy clay gravel, eta.	4 to 12	2

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