STATUS OF SOIL STABILIZATION IN THE UNITED STATES—DECEMBER, 1939

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SYNOPSIS

This report is a summary of answers to a questionnaire sent to all State highway departments and covers work done since 1924. Of the 47 States answering, all but 6 have performed some stabilization work, which has been defined as the alteration of soil by the addition of other materials. The types of stabilization are divided into 10 groups as follows: soil-aggregate, RC type cutback, MC type cutback, SC type cutback, calcium chloride, sodium chloride, lignin binder, emulsified asphalt, tar, and portland cement. One table and 4 graphs are used to present statistical data showing the miles of each type constructed by States and by years and the totals to date. It is noted that the mileage of the soil-aggregate type greatly exceeds the total of all other types. In general, the various types are distributed throughout the country depending upon the soil conditions and the cost of the admixture. No data were received from municipalities, counties, or private concerns.

In compiling a summary of stabilized roads, the question of what roads should be included is paramount because of the very vague understanding of the term "stabilized roads" and also because of the application of this term to such varied types of construction work. It was decided to confine this summary to those roads in which the soil had been changed by the addition of an admixture. Accordingly, the questionnaire sent out requested a report of the mileage of all types of stabilized roads which would conform to the following definition: "A stabilized road may consist of subgrade, base, or surfacing mixtures in which unsatisfactory local soil, either as found on the project or hauled in from nearby pits, is altered by the addition of some other material such as soil, aggregate, bituminous materials, chemicals or portland cement so that it will support the loads applied to it by traffic."

This definition is intended to include only roads in which local soils have been treated by the addition of other materials. As compared with natural mixtures of sand-clay, clay-gravel and similar materials the distinction is purely arbitrary as these materials when used correctly certainly provide a stabilized road. The definition is intended to eliminate naturally mixed materials such as the limerock in Georgia and Florida, caliche in Texas, sand-clay-gravels in the New England States and the Middle West and the sand-clays or top-soils found in the Southeastern States unless these materials are combined with some admixture.

Information has been obtained through questionnaires answered by 47 of the highway departments, the National Park Roads Division of the Public Roads Administration and the U. S. Forest Service. An attempt was also made to secure information from the offices of the Chief of Engineers, U. S. Army, the Works Projects Administration, and the Public Works Administration; but these agencies reported that they did not have the information readily available.

No attempt has been made to include stabilized roads or airports constructed by private individuals, municipalities or other political subdivisions because of the impossibility of obtaining the necessary information in the short time available. It is well known that a large amount of stabilization work has been performed by such agencies and the projects should be included in order to obtain a complete picture of the stabilization work which has been performed. Several

producers have furnished valuable information which shows that the projects constructed by the state highway departments constitute only a part of the total stabilization work performed to date. With some materials, less than half the totals reported by the producers has been under state supervision.

In the questionnaire the types of stabilization were separated into subdivisions depending on the type of admixture and information was requested on the total mileage of each of these types constructed during the period 1925-1929 and each year thereafter. This grouping was selected in order to obtain data on the trends in this type of work, especially during the last few years. Information on the types of soils stabilized and on the intended use of the stabilized mixture was also requested.

According to the reports received, very little stabilization work was performed prior to 1929, but since that time there has been a steady increase. Five states have not yet constructed any stabilized roads on account of an abundant supply of suitable local material, but all the other states reporting have constructed at least some of the sections included in this definition. Many of them consider that the work performed to date is experimental and does not warrant definite conclusions at this time. This is especially true where admixtures other than local aggregates have been used. In other states, however, the feeling appears to be that sufficient background has been obtained to justify the construction of certain types as a part of the regular program.

Most of the stabilization work has been the treating of soils in place to form a base to which a relatively thin bituminous wearing course is applied but there are several instances where the subgrades for high type pavements have been treated and there are also some types of stabilized roads such as the soil aggregate mixes and most of those treated with calcium or sodium chloride to which no wearing surface is added. In certain parts of the country it is common practice to wet the subgrade to approximately the field moisture equivalent immediately prior to the laying of concrete pavement but this type of soil treatment is not included in this summary.

Soils of every classification have been treated, from pure sands to the most plastic clays. Stabilization of sand soils consists of adding a binder material but with clay soils the admixture must change the clay either by waterproofing it, binding it together or improving the grading. The type of soil and the cost of the various admixtures have the greatest influence on the type of stabilization selected.

The total mileages of individual types of stabilization are given in Table 1. Curves summarizing this information for each year are shown in Figures 1 through 4. Points on the curves were obtained by adding the mileage each year to the previous total.

Curve 1 of Figure 1 shows the total mileage of soil and aggregate type stabilization constructed during the different years to date and curve 2 on this same figure shows the total of all other types of stabilized roads. The reason for showing these curves separately is because the soil-aggregate type is often not considered stabilization as it is distinctly different from stabilization by the addition of a bituminous material, portland cement or chemical. The tremendous mileage of naturally mixed soil-aggregate combinations used as blanket courses or bases for all types of surfaces is, of course, not shown as they are excluded by this definition. However, the mileage of soil-aggregate roads exceeds by far the total mileage of the other types. This is quite natural and consistent with one of the first principles of good engineering

TABLE 1

SUMMARY OF STABILIZATION PROJECTS CONSTRUCTED 1925 THRU 1939

State	Soil or aggregate	Type of stabilization (Length in miles)											
		Asphaltic materials				Chemical							
		MC	RC	SC	Other	Calcium chloride	Sodium chloride	Lignin	Other	Portland cement	Tar	Emulsion
Alabama	....	...	23.0	...	...	10.0	...	...	...	...	...	20.0
Arizona	Naturally occurring stable materials used.											
Arkansas	....	...	....	0.5	...	....	...	...	...	4.6	...	17.4
California	Cut-Back Asphalt used each year, mileage not reported									8 0	...	23.3
Colorado	1154.0	...	....	...	...	....	...	...	...	...	...	...
Connecticut	No Stabilization (Natural mix Sand & Gravel plentiful)											
Delaware	No Stabilization (Natural mix Soils used)											
Florida	807.0	...	443.0	...	...	....	...	...	..	..	69.5	...
Georgia	441 0	9 0	....	....	...	12.0	...	...	..	15.0	51.0	25.0
Idaho	....	.	....	...	...	....	...	130.0	..	...	...	1.0
Illinois	No report received.											
Indiana	372.4	...	....	...	...	140.5	52.6	...	2.2[c]	...	...	...
Iowa	220 3	3.9	....	4 3	...	1.8	...	...	..	4.2	2.5	10.5
Kansas	76.7	...	....	...	...	8.0	8.8	...	..	2.0	...	3.4
Kentucky	....	1.0	....	35.1	...	11.2	...	...	..	6.5	1.0	20.0
Louisiana	1598.7	...	....	...	...	....	...	...	..	...	...	...
Maine	....	...	....	...	...	38.0	...	...	..	...	...	1.0
Maryland	62.0	29.8	....	...	...	27.5	3.8	12.0	..	3.8	15.7	...
Massachusetts	....	.	1.0	...	...	....	...	...	..	0.9	...	0.5
Michigan	....	...	....	...	. .	91.0	100.0	...	31.0[e]	1.3	...	...
Minnesota	277.0	...	.. .	...	. .	498.0	...	..	..	...	...	...
Mississippi	487.5	...	34 0	...	...	5.0	2.0	...	..	24.0	...	8.0
Missouri	256.0	28.4	....	122.6	. .	17.0	...	...	..	12.9	16.4	20.4
Montana	7 0	2.0	....	3.3	...	....	...	...	..	...	...	8.0
Nebraska	784.0	11.0	...	..	327.0[b]	36.0	....	...	.	10 0	4.0	4.0
Nevada	Gravel used in Stabilization each year, mileage unreported											2.5
New Hampshire	....	...	....	...	...	94.8	...	...	..	...	...	...
New Jersey	....	..	....	...	...	....	...	...	..	3.2	...	...
New Mexico	No Stabilization (Various Asphalts used for surface only)											
New York	....	...	....	...	...	213.0	4.4	...	..	10.3	272.7	...
North Carolina	482.4	...	79 0	...	...	....	...	...	..	7.2	46.9	1.2
North Dakota	....	1.0	(Gravel used in Stabilization each year)							...	...	1.0
Ohio	....	.	....	...	...	71.3	2.4	...	..	5.0	...	6.6
Oklahoma	84 0	1.3	....	18.8	...	2.4	2.4	...	..	6.1	...	31.4
Oregon	...	...	....	...	...	....	...	...	..	...	...	2.5
Pennsylvania	38 6	...	....	...	. .	70.2	23.6	...	..	1.9	...	...
Rhode Island	No Stabilization, Local gravel plentiful											
South Carolina	21 6	1.4	718.5	27.2	1.4[f]	....	...	...	..	71.3	64.2	1.8
South Dakota	No Stabilization											
Tennessee	54.8	0.7	0 7	...	...	4.1	..	...	.	1.5	1.4	1.5
Texas	[g]	58.4	196.5	457.6	...	0.6	7.8	...	..	27.5	...	56.3
Utah		...	....	..	...	....	...	0.9	..	...	...	...
Vermont	....	...	....	...	...	1 5	0.3	...	.	...	0.5	0.5
Virginia	....	4.0	0.5	...	...	40.5	14.0	...	.	4.8	...	3.8
Washington	....	..	....	..	...	....	...	0.8	..	1.0	...	...
West Virginia	....	5.8	8.0	...	...	8.8	...	...		...	14.0	8.1
Wisconsin	13.6	...	....	...	...	....	...	...	..	3.3	...	...
Wyoming	....	..	....	50.0	...	....	...	...	..	...	...	...
Nat. Park Rds.[a]	....	10.9	....	..	...	43.3	...	...	.	11.6	12.7	35.9
Forestry Service	1312.0	1 2	11 4	29 5	...	34.8	11.3	25.8[d]	..	0.8	...	...
Totals	8550.6	169.8	1515.6	748.9	328.4	1481.3	233.4	169.5	33.2	248.7	572.5	315.9

Remarks: [a]Of Public Rds. Adm. [b]Unclassified Cut-Back Asphalt. [c]Natural brine. [d]By-product of paper mills—similar to lignin. [e]$MgCl_2$. [f]Colprovia process. [g]Soil-aggregate stabilization each year, approximately 500 mi. built to date.

for a good engineer uses the materials available in the most economic and efficient way. The curves show a steady increase in the use of both methods of

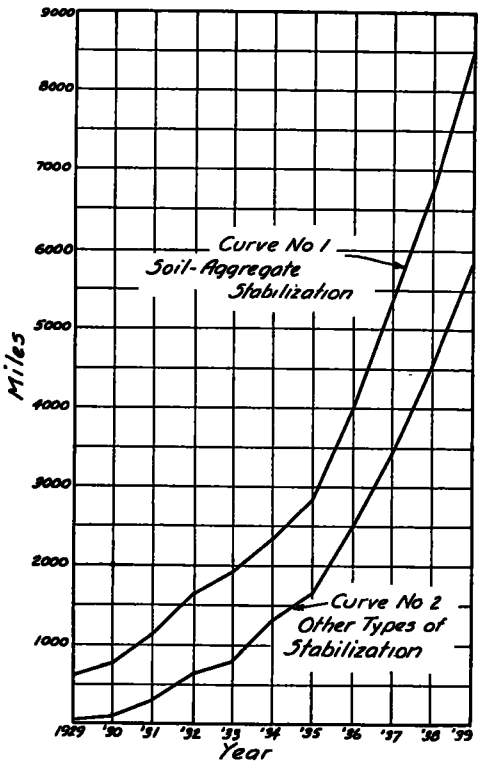

Figure 1. Soil-aggregate stabilization compared with all other types. Cumulative graphs

used. One of the striking facts in comparing cut-back asphalt is that, in various sections of the country, the engineers appear to prefer a certain type of cut-back to the comparative exclusion of others. For instance, rapid curing cut-back asphalts are used almost exclusively

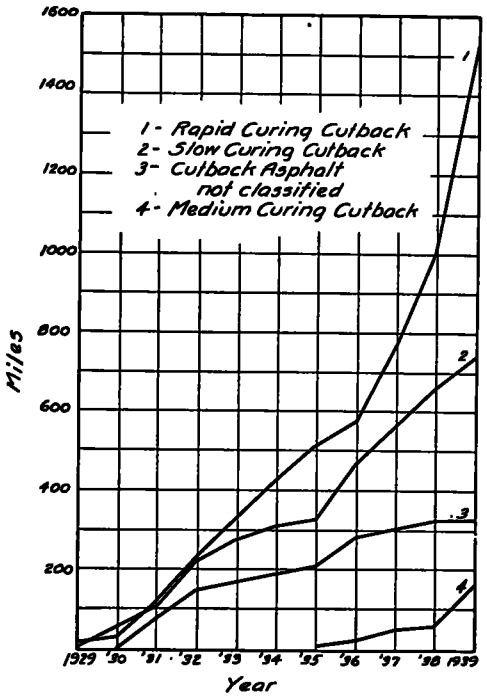

Figure 2. Miles stabilized with different cutback asphalts. Cumulative graphs

stabilization with much greater increases during the last four years. The aggregates which are used consist principally of sand and gravel although crushed stone, stone screenings, mine tailings and similar waste materials have been used successfully. The controlling factor is the availability of the material. The grading of the mixture is adjusted by the addition of these aggregates so that the mix will be stable with a clay content sufficient to bind the particles together but which will not soften in wet weather.

Figure 2 shows the mileages in which cut-back asphalt materials have been in the southeastern States whereas the slow curing type is used West of the Mississippi River. The great increase shown for RC type cut-back asphalts in the last three years is the result of work in the southeastern States in combining this material with sandy soils. California reports that "any soils which can be satisfactorily mixed with cut-back asphalt are not considered stabilization." This state has used great quantities of SC and MC oils but none of this mileage was reported.

Figure 3 shows the mileages of roads to which chemicals of different types

have been added. This type of stabilization is largely confined to areas having an abundant supply of coarse aggregates, particularly gravel, and the greatest mileages of this type are to be found in the New England States and States adjacent to or near the Great Lakes. All of this work has been performed since 1934 and the use of calcium chloride has increased very rapidly.

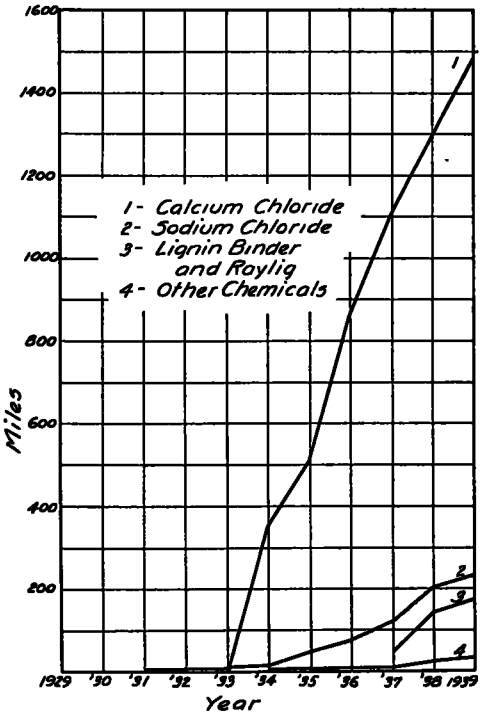

Figure 3. Miles stabilized with chemicals. Cumulative graphs

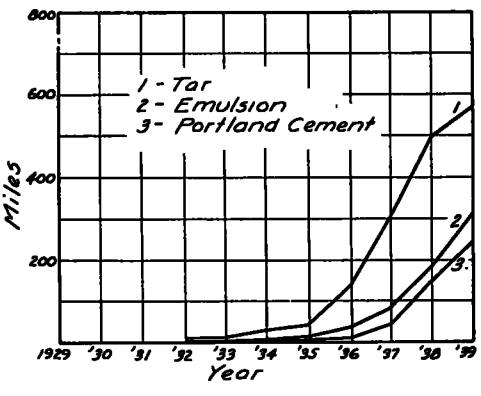

Figure 4. Miles stabilized with Tar, Emulsion and Portland Cement. Cumulative graphs

Figure 4 shows the mileages stabilized with emulsified asphalt, tar and portland cement. Of course, there is no special reason for grouping these materials together except that they do not fit into either of the classifications just discussed. Work with these materials has developed since 1932 and the increases since 1936 have been fairly rapid.

Table 1 gives the totals of each type of stabilization constructed by each state from 1925 through 1939. This tabulation shows the distribution of the different types.

1. The soil-aggregate type is reported by 19 States, many of which have constructed several hundred miles.

2. Medium curing cut-back asphalt has been used in 14 States—generally in short sections as only two report more than 25 miles.

3. Work with rapid curing cut-back asphalt is confined almost exclusively to the southeastern States and 76 per cent of the mileage reported is in two of the ten States in which it has been used.

4. Slow curing oils or cut-backs have been used in 9 States—mostly west of the Mississippi River. Only two States report more than 100 miles of this type but it is our understanding that great quantities of slow curing oils are used in California and other western States in work closely allied to stabilization.

5. Stabilization with calcium chloride is widely distributed, 23 States reporting its use. Three States report more than 100 miles, with one practically up to 500 miles.

6. Sodium chloride has been used by 12 States and only two report more than 50 miles.

7. The use of lignin binder in soil sta-

bilization is practically confined to one State as this State reports 77 per cent of the total.

8. Portland cement in soil work is well distributed. Mileage in which this material was used is reported by 24 States. The sections are, however, generally short and only two States report more than 25 miles.

9. Tar has been used in 13 States; approximately 50 per cent of the mileage is in one state but several report more than 40 miles.

10. Stabilization with asphalt emulsion is also well distributed, being reported by 26 States, but the sections are generally short and only two States report more than 25 miles.

11. Data submitted from the U. S. Forest Service shows that they have used practically all of the methods of stabilization mentioned above. Their work is scattered in different parts of the country and most of the sections are short. The National Park Roads Division of the Public Roads Administration has constructed sections using several of the methods contained in this report. Their work is widely distributed and is confined usually to short sections.

SUMMARY

It must be emphasized that the information may be somewhat indefinite due to variations in the interpretation of the definition of a "stabilized road." For instance, several of the States report hundreds of miles of bases stabilized with naturally mixed gravel, sand-clays and similar materials which are not included in this summary as the work is not considered to be within this definition. This is particularly true of base and blanket courses but any naturally mixed materials which have been used are not included. The sum of these mileages would be several thousand. Mention of such construction was made by Tennessee, North Dakota, South Dakota, Nevada, Utah, Connecticut, Delaware and Rhode Island and no doubt most of the States use construction of this type quite extensively.

In addition, there has been some confusion concerning the inclusion of the oil type road developed in the west, particularly in California. It is understood that thousands of miles of this type have been constructed in California and that there is considerable mileage in Colorado, Idaho, Montana, Nevada, Oregon, Utah, Wyoming and New Mexico. This type of construction is not included in the summary because it would be almost impossible to obtain accurately the entire mileage involved and also because there is some question as to whether this type of road fits in with the definition of stabilization which is used herein.

The information presented does show, however, a definite trend in stabilization work. There have been great increases in the rate of construction of these particular types in the last few years. The total mileage is believed, however, to be only a fraction of the total mileage of highway construction performed during this period. During 1937, for instance, information from the American Association of State Highway Officials shows that 30,632 miles were constructed by the 48 highway departments. This summary shows that 2410.9 miles or 7.9 per cent was stabilization work. Similarly in 1938 the mileage of stabilized roads was 8.2 per cent of the total constructed. These figures, while not particularly impressive, do indicate that soil stabilization is taking a place as a distinct method of road building to supplement other types.

DISCUSSION OF STATUS OF SOIL STABILIZATION

MR. C. N. CONNER, *Public Roads Administration:* I would like to ask Mr. Mills if his survey of binders used in soil stabilization showed that best results with calcium chloride or other salts are limited to areas of relatively high humidity.

MR. W. H. MILLS, *South Carolina State Highway Department:* The information shows that the States near or adjacent to the Great Lakes or the New England States were the principal users of calcium chloride.

MR. C. L. MCKESSON, *American Bitumals Company:* Mr. Mills' report deals principally with work of this type constructed by State highway departments, and I believe that the picture will be made more complete by the inclusion of some data regarding stabilization work by other organizations.

My knowledge pertains principally to soil stabilization in which emulsified asphalt has been used as a stabilizing medium. The first project of this type was an experimental section constructed at Clover Field, Santa Monica, California, in 1929.

The first sizable project of soil stabilization with emulsified asphalt was at the Glenn Martin Airport, in Baltimore, Maryland, in 1930. In 1939, the Glenn Martin Company undertook a large program of airport runway construction and again selected emulsified asphalt stabilization. This is a significant indication of the satisfactory performance of the first large stabilization project.

My record of projects includes a large number of State highway jobs, but I have no way of determining how many of these have been included in Mr. Mills' data, and I have, therefore, omitted my figures on State highway projects. I have, however, a lengthy, although incomplete, list of jobs not on State highway systems which will doubtless be of interest to those following this type of construction.

Projects constructed by Governmental Departments, including the Army, Navy, Public Roads Administration and National Park Service, aggregate 1,825,266 sq. yd.

Jobs constructed by municipalities and counties aggregate 5,664,184 sq. yd.

Projects constructed privately and without public funds aggregate 769,276 sq. yd.

My tabulation includes only projects with which I have had personal contact and is, therefore, far from complete. The projects here reported, if converted to a 20-ft. road surface, would total over 720 miles, exclusive of all State highway projects.

DR. C. D. LOOKER, *International Salt Company:* Mr. Mills' report indicates limited use of salt by State highway departments, which does not make a true picture of situation. The bulk of salt stabilization this year has been in counties, townships and municipalities with at least 250 miles in New York, 250 miles in Michigan, 30 miles in Kansas and the Municipal Airport in Hutchinson, Kansas and some additional mileage in Rhode Island and elsewhere.