SOIL STABILIZATION WITH EMULSIFIED ASPHALT IN THE MID-CONTINENT AREA

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SYNOPSIS

Stabilization with emulsified asphalt in Texas. Oklahoma, Iowa. and Nebraska is described. Costs on this work have ranged from $0.22 to $0.28 per sq. yd. for a 4 in. compacted base. These costs obtained on 200 mi. of an equivalent 18 ft. roadway. The author expresses the opinion that while high density in the finished construction is commendable, the obtaining of this is often an expensive luxury. The chief reason for the use of bituminous material in stabilization is to make the resultant mixture more resistant to the effects of moisture. No failures have been noted in the projects that were compacted while below the optimum moisture content. It is deemed advisable to dry the stabilized base to below 5 per cent, and 3 per cent is advisable, as the presence of water aids the entrance of more moisture into the mix. It is recommended that the stabilized mix be compacted in relatively thin layers.

This review lists emulsified asphalt soil stabilization projects in Texas, Oklahoma, Iowa and Nebraska, with a total area equivalent to 225 to 250 miles of 18-ft. roadway. (See Tables 1, 2 and 3.)

The term "Soil Stabilization" has been used to define practically all types of construction, wherein a soil or an aggregate not ordinarily satisfactory for construction purposes, is either mechanically or both chemically and mechanically changed in character from a waste material to a desirable building material. All soil stabilization has as its main objective, the reduction in cost of construction over the usual or conventional methods of construction. Table 1 lists base construction projects in Texas and Oklahoma. It is notable that treatment of a 4-in. depth of base has been accomplished for as low as 22 cents per sq. yd. (This is total cost, in place.)

This discussion is limited to the projects that are of special significance, from either a cost or a technical viewpoint and as related to the following conclusions:

1. Maximum dehydration is a more important factor effecting durability of soil stabilized by the use of emulsified asphalt than maximum density at time of compaction.
2. The quantity of emulsified asphalt necessary should be determined by test mixtures of the emulsion to be used and representative samples of the soil to be treated, following the efficiency requirements designated by McKesson (10,000 lb. minimum stability in lower ½-in. after 7 day absorption), or other requirements known to provide adequate control.
3. Four-inch compacted depth should be the minimum thickness. If the base is placed on a subsoil of high plastic index such as A-6 or A-7 type, the stabilized base should have a minimum thickness of 6 in.
4. Control tests should be made on the finished work to guarantee that all material placed will meet minimum requirements of efficiency test. (From a practical standpoint, this may require 1 per cent more emulsion than is indicated by laboratory test, since it is rarely possible to have field control as accurate as laboratory control).

The term "Soil Stabilization" is used to refer to treatment of any type material

TABLE 1

COSTS ON TYPICAL EMULSION STABILIZED BASE JOBS

Actual or bid cost[1] per sq. yd.	Equivalent cost per mile 18 ft. wide	Thickness compacted	Emulsion quantity	Aggregate	Type of mixing	Date constructed	Description
$	$	in.					
0.28	2956.80	4	4%	Soil from pit average haul 2.5 mi.	Stationary plant	1938	Texas SHD, Lee Cty., U. S. 77, Giddings to Lincoln, 4.5 miles.
0.276 (0.235)[2]	2914.56 (2481.60)	4	Min.[2]Contractorrequired to meet McKesson standard absorption and stability.	Gravel and soil from pits.	Stationary or travel plant, alt.	July, 1939	Texas SHD, Lee Cty., U. S. 77, Giddings-Fayette County Line, 7 miles.
0.248	2618 88	4	4.5%	Soil in place blended with blow sand from pits.	Stationary plant.	1938 and 1939	City wide, street paving. Midland, Texas.
0.262	2766.72	4	4%	"Blue shale" in place.	Blade.	1937	5 miles, between Rhome and Decatur, Texas. Highway U. S. No. 81.
0.640	6758.40	5	4% plus .5 gal. S. Y. bottom seal[3] and 1 gal. S. Y. topseal.	Mudshell-85% and soil-15% blend, hauled in.	Traveling plant.	1939	P. W. A. county job, 38 miles of various Nueces County Roads, Texas.
0 229	2418 24	4	3.5%	Soil in place.	Traveling plant.	1938-39	P. W. A. county job. 46.6 miles various county roads, Major Cty., Oklahoma.
0.222	2344.32	4	4.5%	Soil from various locations airport property.	Traveling plant.	1939	164,336 S. Y. Airport runways, Midland, Texas, Municipal Airport.

[1] Includes all costs of base complete, in place.

[2] Bid of .235 per S. Y. was received on stabilized base itself, but this contractor was high on preliminary work and topping, which was included in the same contract.

[3] Bottom seal consists of .25-.5 gal. per S. Y. sprayed on subgrade or mixed into bottom 1" of stabilized base. Usually costs .03 to .05 per S. Y. Used where there is high water table or bad subgrade.

which has more than 50 per cent passing a No. 40 sieve.

There is no denying the fact that compaction at optimum moisture content will give higher density, however, subsequent statements may seem to conflict with the established theories concerning compaction of aggregate and soil mixtures. They are offered with the hope that they will emphasize the relationship between actual application and the various moisture density theories.

TABLE 2

Moisture and Density Tests Made in 1937, 1938 and 1939, Cass-Pottawattamie Counties

(Courtesy of the Iowa State Highway Department)

		Asphalt emulsion 9% water		Asphalt emulsion 9% water		Asphalt emulsion 6.6% water	
		Wt. lb.	%	Wt. lb.	%	Wt. lb.	%
October and November	1937	118.7	12.3	101.8	19.3	92.5	23.2
March	1938	115 4	11.8	106.0	15.5	103.2	18.3
June	1938	117 3	10.1	110.5	14.7	108.5	17.3
November	1938	114 5	11.2	105.6	16.2	101.9	18.6
May	1939	117.6	11.2	116.1	14.4	107.2	17.1
September	1939	.....	9.9	.....	14.6	.....	18.2

TABLE 3

List of Major Construction Projects in Iowa, Texas, Oklahoma and Nebraska, Where Emulsified Asphalt Stabilization Has Been Used

Sponsor	Location	Depth of base	Width	Size	Year built
		in.	ft.		
Iowa					
Iowa Highway Commission	P–39 Harrison Cty.	5	24	9.5 miles	1937
Iowa Highway Commission	P–144 Greene Cty.	5	24	5.2 miles	1937–8
Iowa Highway Commission	P–83 Cass-Pottawattamie	5	24	.9 Miles	1937
Town of Little Rock	Streets	4	..	7000 sq. yd.	1938
Town of Sutherland	Streets	4	..	56,000 sq. yd.	1938
Town of Soldier	Streets	4	..	18,000 sq. yd.	1938
Texas					
S. H. D.	Kaufman Cty.	4	24	6 miles	1939
S. H. D.	Kennedy Cty.	4	24	1½ miles	1937
S. H. D.	Lynn Cty.	4	34	3 miles	1939
S. H. D.	Eastland Cty.	5	3	12 miles	1939
S. H. D.	Hunt & Collins Cty.	4	24	5 miles	1939
S. H. D.	Hemphill Cty.	6	6 (shoulder)	7 miles	1939
S. H. D.	Gorman, Highway 67	4	22	1 mile	1937
U. S. Army Q. M. Airports.	San Antonio	4	..	300,000sq.yd.	1936–7
Oklahoma					
S. H. D.	Binger, Highway 41	4	20	5 miles	1937
S. H. D.	Norman-Moore U. S. 77.	6	2 (shoulder)	9 miles	1937
S. H. D.	Oklahoma City, U. S. 270	6	2 (shoulder)	25 miles	1937
S. H. D.	State Highway 17, Grady Cty.	5	20	3000 ft.	1936
Nebraska					
S. H. D.	Crete	5	..	4.3 miles	1939
W.P.A. and City	Grand Island Airport	3	Runways	..	1936

In current procedures for soil stabilization, the terms optimum moisture content and maximum density are often emphasized to a point where one studying the literature on any type of bituminous stabilization, may get the impression that the item of most importance is to obtain density in the finished construction and that if high density is not obtained, the construction is a failure. There is no doubt that high density is commendable, but we believe that it is often an expensive luxury. The only excuse for the use of bituminous material for soil stabilization is to make it resistant to the effects of moisture. We add bituminous material, not to get density or maximum compaction, but to render the soil particles as nearly water-proof as possible. Of the 250 miles of stabilization reported here, there are no failures that can be attributed to the base being compacted while below the optimum moisture content. On the other hand, there are unsatisfactory projects which were compacted under the so-called optimum conditions.

Table 2 gives density and moisture content tests of a series of soil stabilization projects in Pottawattamie County, Iowa. These sections were compacted in 6-in. layers by the use of a sheepsfoot roller, which was used until the feet of the roller "walked" out of the mix, so that there was no chance for further compaction by that method. This rolling was accomplished as near as possible to the optimum moisture content. The moisture content of these bases is essentially the same now as when constructed two years ago, even though the compacted base was allowed to dry for several months before a prime coat was added. A thin prime coat was used to prevent abrasion of the surface but still did not prevent drying. There is no indication from the above tests that these base projects will ever dry. For soil stabilization with emulsified asphalt to be effective, it must be dried. We often say that the stabilized base must dry to below 5 per cent. It would be preferable to have them contain less than 3 per cent moisture when completed, as the presence of water aids the entrance of more water.

Some will say that if the base has been compacted to maximum density there is no space for water to enter, therefore, such a base is stable regardless of moisture. It is of course true, that a material that is compacted at high moisture content will not have high density if water content in excess of voids is present. It does not follow that density is the answer to stability for if such a conclusion were justified, there would never be any reason for the use of bituminous material for stabilization. When we recognize waterproofing as the paramount purpose in bituminous stabilization, we can arrange our construction procedure so that it will result in maximum water-proofing and stability.

In the 46 miles of stabilization mentioned in Table 1, as job No. 6, located in Major County, Oklahoma, the moisture content at the time of rolling was 5 per cent or less. The procedure outlined as follows would seem to be expensive since it requires several operations, but the total cost of 22 cents per sq. yd. does not bear this out, since this cost compares very favorably with those of other jobs in this vicinity. I think the reason for this will be shown in the following discussion.

CONSTRUCTION PROCEDURE, MAJOR COUNTY SOIL STABILIZATION

The soil on this job was a sandy soil with 90 per cent passing the No. 40 sieve with 15 per cent passing a 200 mesh sieve. The soil was mixed with 3 to 4 per cent bituminous emulsion and sufficient water for complete dispersion by the use of a traveling machine known as the Woods Roadmixer. The completed base was 18 ft. wide, 4 to 4½ in. in depth.

Prior to the application of the emulsified asphalt, the roadway was scarified and bladed into two even parallel windrows. These were placed as closely together as possible and in the center of the road. The machine was such that it would straddle the windrows and by mechanical means, pick the material from the road, mix it with water and emulsified asphalt and re-deposit it in approximately the same position. To prevent the excess moisture in the mixed windrows from affecting the subbase immediately beneath the windrow, it was immediately bladed towards the edge of the road, leaving a layer 1 in. to 1½ in. thick, spread from the center to the side of the road. The operation of moving this windrow naturally assisted the dehydration so that when the moved portion reached the side of the road, it had very little excess moisture with less detrimental effect than if it had remained in the center of the road. The 1-in. to 1½-in. layer which was left on the subgrade was then allowed to dry from 24 to 48 hours, or until the moisture content was less than 5 per cent, during which time it was thoroughly rolled by a pneumatic roller. Care was taken to roll the 1-in. layer as soon as it was dry enough to bear the weight of the roller so it was compacted but not tracked.

While the 1-in. layer was drying and being rolled, the remaining soil remained in a windrow on each side of the road. To the casual observer, the outsides of the windrows were apparently drying very fast. Many of the engineers assisting with this work, were alarmed by the fact that the windrow seemed to be drying and would soon be too dry for compaction, but when the windrow was moved again, it was found that it had not dried appreciably, below 2 or 3 in. from the surface, so that as a whole, it was not only wet enough for compaction, but in some cases, was even too wet to allow immediate compaction after spreading.

As the windrows were moved from the side to the center of the road, approximately one inch of material was allowed to spread and was rolled while what was left of the two windrows was consolidated in the center of the road as one windrow of approximately the size of each of the original windrows. As soon as this second layer had dried the third layer was spread and rolled immediately. This last layer was handled with greater ease as this thickness is from 1½ to 2 in. Sometimes in the final stages of levelling this layer, we get an accumulation of approximately ⅛ to ¼ in. of dusty material on the surface. In order to prevent the loss of these dusty materials and to attach them to the materials below, it was sometimes necessary to sprinkle with a dilute emulsion (1 part emulsion—10 parts water) then blade or sweep into place with thorough rolling as the final operation. The total time consumed by all of the above operations would naturally be affected by weather conditions but during the 46 miles constructed by this procedure, four days was usually sufficient for completion of any section of the base. Rarely was over seven days necessary. At the end of this time, the entire 4 in. of base was compacted and contained less than 3 per cent moisture. The weight per cubic foot of the compacted material was 110 to 120 lb.

The contractor on this job was naturally interested in finishing with a minimum cost, so that at first he preferred to spread the mixed material in one 4-in. lift, instead of in three separate spreads. Spreading in one 4-in. lift might be economical if it were possible to get uniform and complete dehydration throughout the depth. Usually the fact that the top drys faster than the bottom results in formation of cracks and fragments in the dried top layer, from movement of the top layer on the wet and unstable bottom layer.

Two weeks after laying the first mile of this road in one 4-in. lift, the contractor was still trying to spread it and roll it to a satisfactory grade. The top 3 in. of the 4 in. was then bladed into one windrow and relaid in layers each of which was rolled. Subsequent use of layer compaction and spreading resulted in the saving to the contractor of at least 50 per cent of the time which would have been required in the original 4-in. trial. The layer construction is preferable because it permits a contractor to mix, spread, dry and compact a base in from 3 to 10 days, whereas from 3 weeks to 10 weeks might be insufficient time for drying if the entire depth is laid at once. This is proven by the moisture test on the sections shown in Table 2, where tests after two years still show excessive moisture.

This method of drying and compacting has advantages other than speed of construction. For instance, the first 1-in. to 1½-in. layer acts as a bottom seal. This allows the bottom of the base to dry thoroughly, thus getting the maximum stabilizing effect of the emulsified asphalt which will prevent moisture from the subbase affecting the upper portions of the treated material. Multi-layered spreading and compaction will also tend to give a more even base.

There are those who object to this layer construction because there will be a plane of cleavage between layers that would cause *lamination* or *stratification*. These two terms are used in much of the literature on soil stabilization and this effect is said to be definitely something to avoid. I believe that those who have written of lamination and stratification have done so principally because usually the only time that this effect is noticed, is after there has been a failure in some particular base. This failure is usually due to the fact that when mixtures are placed in 4 to 6-in. layers, the bottom 2 or 3 in. seldom dry to a point where maximum stability is developed. When loads are applied to the road, the top which has dried, will transmit the load directly to the undried, unstable bottom layer. If the load is sufficient to cause movement, the movement will result in lamination. Naturally, if this continues, the upper layer will ravel, causing holes in the base. These holes and raveling are then attributed to lamination, where as, the lamination is the effect and not the cause, the cause being lack of uniform dehydration.

SUMMARY

For successful stabilization by the use of emulsified asphalt, design the base with a 4-in. minimum thickness and with sufficient emulsion to give a finished base meeting some known efficiency requirement. To provide for maximum dehydration before compaction depend upon subsequent traffic to increase density rather than upon weather conditions favorable to complete drying of 4 to 6-in. depth.