SOIL STABILIZATION USING ASPHALT CUT-BACKS AS BINDERS

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The term "Soil Stabilization" has been used rather loosely and with considerable confusion to describe the construction of many types of road structures, especially bases, wherein soil is used as one of the material constituents. In general, no distinction is made between constructions in which the existing soils on the roadway are used and those in which selected soils or cheap, available aggregates are incorporated with the existing roadway soils. To add to the confusion, total replacement of existing roadway soils with pit or bank materials or other available aggregates is also called soil stabilization. When suitable binders are used with the combinations mentioned above it may be seen that the term "Soil Stabilization" really has various meanings at the present time.

For our own purpose, the term "Soil Stabilization" is subdivided into the following three groups:

1. *Structural Stabilization*, which includes only the incorporation of the proper amount of a suitable binder with the natural soils as they exist in the roadway, whether they be predominantly sands, silts or clays, irrespective of their grading, the object being to produce a soil-asphalt mixture which will have satisfactory load bearing qualities under all anticipated roadway conditions.
2. *Mechanical Stabilization*, whereby necessary quantities of aggregates and perhaps soils of suitable grading are mixed with the roadway soils so that a specified final grading is obtained.
3. *A Combination of Structural and Mechanical Stabilization* in which a specified grading is first obtained with the soils and aggregates, after which the proper amount of a suitable binder is incorporated with the soil-aggregate mixture.

No attempt will be made here to discuss the economics of soil stabilization other than to point out that the factors which have been considered in the past for the higher type asphalt pavement constructions are still applicable. The factors which must be considered in order to determine whether a stabilized base construction or an orthodox construction of a standard base is warranted are:

1. Relative performance.
2. Comparative costs.
3. Availability of materials.
4. Type, number and thickness of the pavement courses necessary for use in the respective constructions.
5. Maintenance costs over a period of years in conjunction with original construction costs.

The evaluation of these factors is mainly determined by observation and experience although relative expected performance may be indicated by the proper laboratory tests, especially when the laboratory tests are correlated with known performance in the field of the various types of construction.

This paper gives briefly a method of design and a recommended procedure for road construction using soils and asphalt cut-backs or soils, aggregates and asphalt cut-backs to produce suitable bases for pavement structures.

A survey of the available laboratory testing equipment resulted in the selection of the Hubbard-Field Stability Testing Apparatus although it was realized that in certain theoretical aspects the strengths determined with this equipment may not be directly interpretative of the actual loading conditions to which a road structure may be exposed in the field. Consequently, although we have found that satisfactory soil stabilization studies can be made with this equipment, we are continuing to observe and attempting to develop equipment which may be more suitable for purposes of design.

Enough adequate information was available on the field performance of pavement structures designed with the Hubbard-Field apparatus and procedure to justify its adoption for immediate use in connection with soil-asphalt mixtures.

Information was also available from the investigation reported by Miller and Klinger before the Association of Asphalt Paving Technologists in New Orleans, Louisiana, January, 1937, and published in the proceedings of the Association.[1] The authors used the Hubbard-Field apparatus in their investigation. They pointed out that although their study was a preliminary one it was believed that certain principles had been established for design and construction of soil-asphalt mixtures and that further investigation was justified.

It is agreed, as other investigators have pointed out, that the "Stability Load", as determined by this apparatus, is a measurement of combined compression and shear. However, a reading in pounds is obtained which is a direct measurement of the resistance to particle displacement in the specimen. The greater the resistance, the higher the load reading. Over a long period of time, the Hubbard-Field apparatus and procedure, when used for design of bituminous mixtures, has proved entirely satisfactory when field results are studied and correlated with laboratory data.

[1] "Preliminary Report of Studies in the Use of Bitumens in Soil Stabilization and Flexible Pavement Types," *Proceedings* Association of Asphalt Paving Technologist, Jan. 1937, p. 132.

Other investigators have reported that it is difficult to obtain check results on the Hubbard-Field equipment, but an incomplete study with stabilized soils seems to indicate that check results may be obtained, if the rate of application of load is maintained constant throughout the test. The results of this study will be available later.

When the Hubbard procedure is followed, the test specimen is produced by placing the mixture in the two-inch mold in one layer. Specimens made by placing and compacting the mixture in more than one layer almost invariably contain compaction planes and, quite frequently, failure occurs along these planes rather than in the compacted mixture.

In the laboratory study to determine the most suitable treatment for a given soil, we feel that satisfactory design will result if the ultimate treatment is selected from tests made on specimens which have been subjected to conditions at least no better and preferably worse than those which might be expected in field construction. Although this procedure may in most cases provide a very high safety factor, design is actually based on the worst conditions to be expected, rather than on average conditions. Consequently, the possibility of local failures in the finished job is reduced to a minimum.

A procedure has been developed which tests for four possible conditions; three of which are probably worse than those which might occur in the field, while one illustrates ideal conditions. The proportions of soil, asphalt and water which are to be recommended are:

(1) those which show good mixing qualities;
(2) those determined by the maxima occurring on curves in which the Hubbard stability load in pounds is plotted against the percentage of asphalt cut-back in the mixture, consistent with minimum

loss in strength when the specimens are immersed in water;

(3) those having low water absorption; and

(4) those having low volumetric swell.

In general, the major design is based on results obtained with uncured soil-water-cutback mixtures which have been exposed to the direct effects of water.

For a given soil, the laboratory is able to decide whether the treatment selected will produce a suitable base, whether aggregate must be added for economy or to provide a base of higher strength, or whether another type of base, with the soil under study excluded, would prove more satisfactory.

The final test of any laboratory design is the field application and performance. Observations have indicated that, in the majority of cases, failures have resulted from disregarding fundamental construction knowledge and poor design resulting from the lack of adequate or proper laboratory investigations and not from any failure on the part of the binding material used.

Miller and Klinger, in their report,[1] established that the "dry"-mix method of construction is most suitable for soil stabilization. This was really nothing new but was merely the expression of a belief, later corroborated by field observations, that if soil was to be used with a binder for road construction, the soil should be considered and treated in a manner similar to that used for any other aggregate and that the *fundamental rules of road construction* need not be changed for soil stabilization. Relatively low moisture content in the soil is still believed to be desirable since field manipulation is decreased, immediate compaction is possible, failures resulting from unexpected rainfalls are reduced and the hazard of visually estimating the time when a "wet"-mix can be compacted is eliminated. The trend away from the use of wet, sloppy mixes to those containing much less water is indeed notable. The laboratory results indicated that some moisture is required by a soil to aid in dispersing the binder. This is probably due to the reduction of absorption of the binder by the finer fractions of the soil.

By the "dry"-mix method, the soil is sufficiently waterproofed when approximately one-third of the specified asphalt cut-back has been applied and mixed with the soil so that unexpected rainfall does comparatively little damage and time lost in construction due to rainfall is, therefore, greatly reduced.

Compaction in the field should be obtained through the use of the proper amounts of asphalt cut-back and of water and not by the use of an excess amount of water alone. It has been found that when the proper combination of asphalt cut-back and water is incorporated with the soil so as to obtain maximum stability after the water absorption test, the necessary compaction is also obtained. This need not be the same as maximum compaction. We have found no relation between strength and density, density meaning pounds per cubic foot of compacted material. We do know that the strength is considerably less at maximum density than at maximum stability. Miller and Klinger based their design on maximum stability for this reason. Other investigators have also found that the strength at maximum stability is considerably more than the strength at maximum density.

LABORATORY PROCEDURE FOR PROPORTIONING SOILS AND ASPHALT CUT-BACKS

The minimum number of soil samples necessary to obtain adequate information as to the soil types present in any project are taken from the road site and prepared for testing in accordance with the following requirements:

The soil is dried thoroughly at 220°F., pulverized, sieved on the No. 4 sieve and the portion retained, discarded. Portions of the pulverized soil are mixed in a Model G. Kitchen-Aid Mixer using a definite amount of water and of asphalt cut-back while observations are made to determine the ease of mixing. This procedure is repeated with other proportions of water and asphalt cut-back. When the amount of water necessary to use with the particular soil to obtain satisfactory distribution of the asphalt cut-back has been determined by observation of ease of mixing, at least three sets of mixtures are prepared, using percentages of water both below and above the observed moisture content for ease of mixing. For example, if it is found that 5 per cent of water allows thorough mixing of asphalt cut-back with soil, sets are prepared using 3, 5, and 7 per cent water with asphalt cut-back percentages on each set ranging from zero to the value determined by the exudation point. The exuding of water or asphalt cut-back from the specimen while under the compacting load in the mold is called the "exudation point". The mixing observation calls for a certain amount of experience but different operators agree on the approximate quantity of water necessary to use with a particular soil. All percentages are by weight, and for ease in calculations, on the basis of oven-dried soil passing the No. 4 sieve equals 100 per cent.

Immediately after mixing, 100 g. of the mixture is placed in the Hubbard-Field 2-in. dia. molds, tamped 50 times with the No. 1 tamper and then 15 times with the No. 2 tamper. The tamped mixture in the mold is then subjected to 10,000 lb. total pressure, with the compacting load held constant for two minutes after equilibrium has been reached.

Four specimens from each mixture are so prepared and the resulting four series are designated Series A, B, C, and D. Series A and B are then placed in an oven maintained at 140°F. and dried to constant weight. Series C and D are tested without curing.

The apparatus for the absorption test consists of a tight cabinet and flat bottom trays. Specimens from series B and D are placed in the trays which contain water and the water height is adjusted until the specimens are immersed to a depth of ½ in. (approximately one-half their thickness). The weight of each cylinder is determined at each 24-hour interval for a total of 168 hours and the grams of absorbed moisture per 100 sq. cm. of exposed surface is recorded.

When the specimens are ready for the stability test, they have been treated as follows:

Series A: Cured at 140°F. to constant weight.

Series B: Cured at 140°F. to constant weight and after water absorption for 168 hours.

Series C: Uncured.

Series D: Uncured and after water absorption for 168 hours.

The Hubbard stability load in pounds is then determined on each specimen according to the approved Hubbard procedure with the exception that the test is run at room temperature, and the water bath is not used. The resulting data are plotted as Hubbard stability in pounds vs. percentage of asphalt cut-back, keeping the water content of the soil constant in each set. The percentages of water and of asphalt cut-back are plotted on the basis of oven-dried soil being equal to 100 per cent.

Typical curves are shown in Figures 1 to 6. Figures 1, 2 and 3 show the data obtained in the laboratory investigation of an A-2 soil, while Figures 4, 5 and 6 were obtained on an A-5-7 soil.

It will be noted that although there may or may not be a maximum on the curves showing strengths before water absorption, a maximum is obtained on the curves showing strengths after water absorption on both the cured and uncured

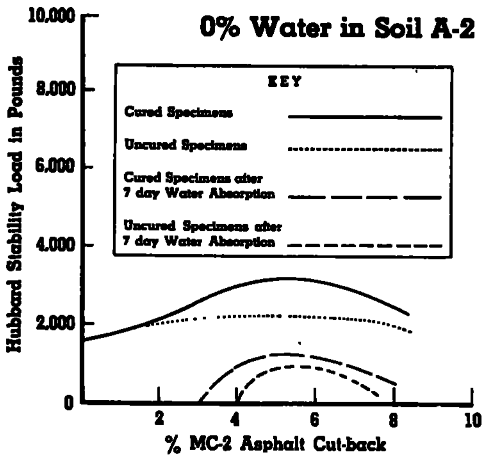

Figure 1

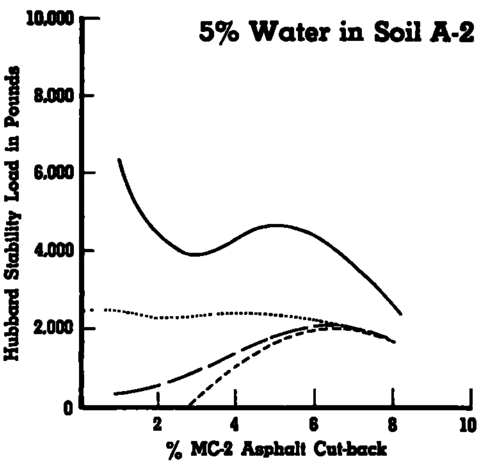

Figure 2

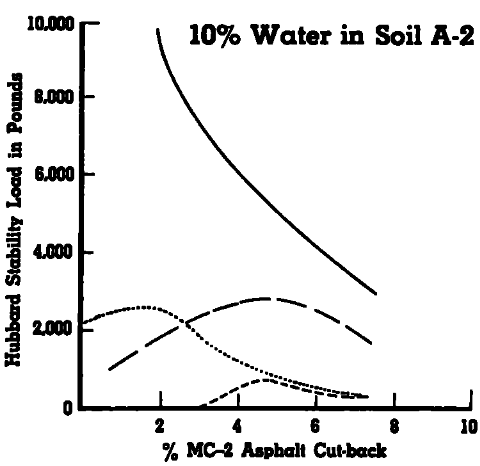

Figure 3

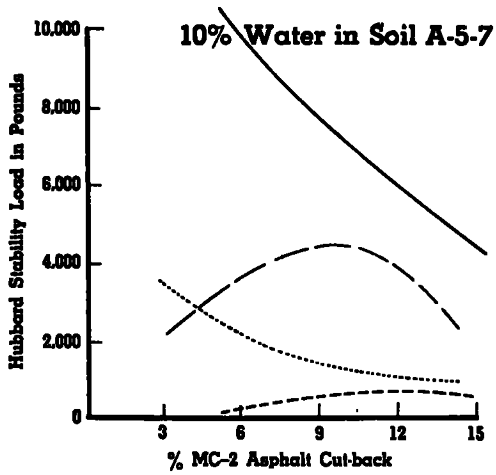

Figure 4

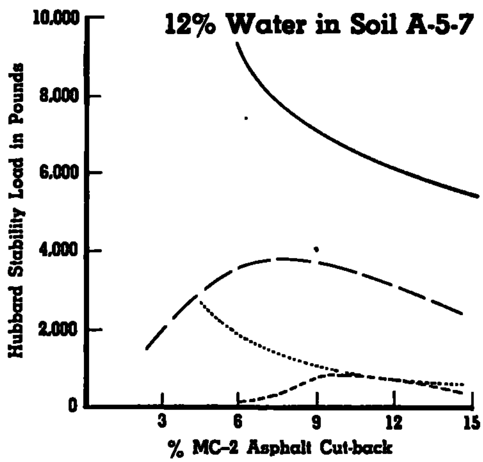

Figure 5

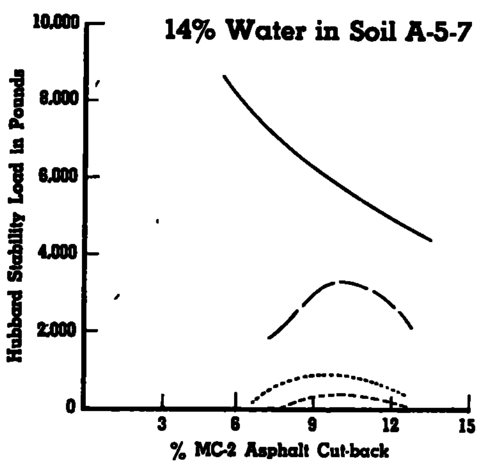

Figure 6

specimens. The proper proportions for soil, water and asphalt were taken from Figures 2 and 5 for the respective soils at the maximum point of strength obtained after water absorption on the uncured specimens. This represents the worst possible condition which might be expected in the field. We believe it is safer to recommend these proportions, knowing that any degree of curing in the field, which does of course occur, will give higher strengths and that we can reasonably expect to construct a base having greater strength than that shown on the curve representing Hubbard stability after water absorption on the uncured specimens.

The danger in designing for high strength without considering the effects of water on the mixture may be realized when it is noted that low percentages of asphalt cut-back may give higher strengths on cured and uncured specimens but these strengths may be nil after water absorption. This is exemplified by the fact that the strength of soil-water mixtures may be higher than soil-water-asphalt mixtures but obviously the former are not stable. This is shown graphically since the strengths of the soil-water mixtures as well as the mixtures having low percentages of asphalt cut-back are zero, after being subjected to water absorption.

In the work herein described, the densities of the compacted specimens in pounds per cubic foot are obtained by calculation from their measured dimensions and their weights. The densities are used only to permit the calculations of the quantity of asphalt cut-back required per square yard per inch of compacted final material.

The amount of asphalt cut-back to be used on each section of the project is proportioned according to the ratio of soil passing the No. 4 mesh sieve to the material retained, using sufficient asphalt cut-back to "wet" the coarser particles but not to provide for binding or waterproofing, and the percentage of asphalt cut-back as chosen from the curves plotted as Hubbard stability load in pounds vs. asphalt cut-back in percent.

RECOMMENDED CONSTRUCTION PROCEDURE

When the thickness of the compacted base is to be 4 in. or less, the base is constructed in one layer. Bases of more than 4 in. compacted depth are constructed in two equal layers up to 8 in. The length of the section should be determined by the amount of asphaltic material that can be applied to one layer in three days or less. Traffic may be allowed to use the road at all times. The equipment suggested for use in the following sequence of operations is generally available to the contractor. However, other suitable equipment may be substituted.

Scarifying: The compacted roadway should be loosened by means of a scarifier, to the depth required for the construction of each layer. The scarifier should be of such design that the depth of scarifying can be accurately controlled. Clumps of bonded material should be broken up by use of tractor, roller, blade, traffic or other suitable equipment. It will be found that working with soils containing low percentages of water will prevent further balling of the soil.

Distributing and Blotting: Asphalt cut-back should be applied in an amount not to exceed 0.5 gal. per sq. yd. at each application. Enough distributors should be furnished by the contractor so that continuous application may take place. The application should be on one-half the road from one end of the section to the other, then on the other half of the road in the opposite direction so that the distributors are moving in a complete round-trip and therefore overlaps will not be encountered.

After each application, the asphalt cut-back should be blotted with the soil by using the 22-in. disc harrow immediately behind the distributor. It will be found advantageous to use the scarifier or the large-size orchard cultivator so that the bottom material is brought over the top material.

This distributing and blotting operation should be repeated on the first layer until the whole section has received the total amount of asphalt as determined by the laboratory and as specified on the plans. By this method, full advantage may be taken of the penetration properties of the solvents present in the asphalt cut-back and the delays due to rainfall are reduced to a minimum since all of the loosened soil is waterproofed to some extent with each application of asphalt cut-back.

Mixing and Windrowing: Mixing should then proceed, using the blade grader and a suitable, adjustable multiple-blade drag or maintainer. The blade grader is used first and the loosened soil and asphalt cut-back is moved from the edges to the center, then moved to a windrow at the edge of the roadway, keeping the blade full of material at all times and exerting all the pressure possible. One-third of this windrow is then moved to the other side of the exposed roadway and the adjustable multiple blade-drag is used for the final mixing. One pass of the drag is generally sufficient to disperse the asphalt cut-back evenly throughout the soil. The second one-third of the windrow is then brought over the finished mixture and the mixing operation is repeated with the multiple-blade drag. The rest of the windrow is then mixed in the same manner.

If the construction of more than one layer is called for on the plans, the finished mixture is windrowed onto the shoulder of the road and the foregoing operations are repeated for each successive layer.

Spreading, Leveling, and Initial Compaction: The mixed material in the windrows should be brought to the center of the roadway, one complete layer at a time, and spread from the center to the edges of the sub-grade.

Sheepsfoot rollers should be used until they are supported 1½ in. below the loose surface on each layer except the top one. Compaction on the top layer with the sheepsfoot rollers is continued until they are supported 1 in. below the loose surface.

Final Finishing and Final Compaction: The multiple-blade drag should be used to remove the sheepsfoot marks on the top layer by cutting with the front blades, to a depth of 1½ in. and spreading the loosened material uniformly from the strike-off blade. A motor grader or a blade drawn by a smooth-tread tractor should be used to keep the road shaped up and to follow behind the rubber-tired roller or loaded trucks which are used for compacting the top surface. Compaction with a smooth-wheel roller is not essential unless there is sufficient loose material on the surface to justify its use.

Application of the Blotter Treatment: The blotter treatment should be applied within one month after the road base is completed. This blotter treatment is a sand-seal coat and should consist of 0.25 gal. per sq. yd. of RC-1 or RC-2 asphalt cut-back covered with an excess, or about 25 lb. of concrete sand, or chips of a grading required for concrete sand. The sand should be broom-dragged lightly.

Application of the Surface Course: The surface course should be applied over the blotter treatment after traffic has removed the excess sand. The surface course may be an approved type of surface treatment or a higher pavement type depending on what is necessary for anticipated traffic requirements.