SOIL STABILIZATION WITH TAR

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A relative improvement in the supporting power of natural soils under load is obtained by the use of tar products as admixtures with the soil. The soil is also made water-resistant. As a general rule, the tar acts as a waterproofing agent, and the natural binder in the soil serves as the cementing medium. In the stabilization of very sandy soils, the tar acts as a binder. In addition to the tar, sand or similar aggregate is often mixed with the soil to increase its bearing value. A tar-stabilized base, however, does not depend upon gradation for its stability.

A typical tar-soil stabilization project will be described and discussed.

The first step is to inspect the project and obtain samples of the natural soil to be stabilized. About 150 lb. of soil will be needed for the tests. If the quality of the soil varies in different parts of the project, several samples may be needed. Usually it will be sufficient to obtain one large sample of the worst soil and smaller samples (25 lb.) of the others. All available information concerning the behavior of the existing soil under adverse weather conditions should be obtained. Any sections of the existing road which break badly in the spring should be noted and soil samples obtained from those points.

On many projects it will be advisable to add sand or similar aggregate, and samples of available aggregate should be obtained. About 25 lb. of these materials will be sufficient.

PRELIMINARY DETERMINATIONS

Before the construction is started, several questions must be answered. Some will be decided as a result of the laboratory investigation, and others on the basis of information obtained at the site of the project.

Use of Aggregate Admixture. Whether to use aggregate or not is both an engineering and an economic problem. Soils containing some sand are easier to mix and are more readily stabilized by the use of tar. Less tar can be used with a sandy soil, and the saving in tar cost will often pay for the aggregate. Generally soils containing more than 50 per cent of material passing the No. 200 sieve will be materially improved by the addition of sand or similar aggregate.

Grade of Tar. The grade of tar to be used on any particular project will depend upon the kind of soil to be stabilized, the climatic conditions under which the work is to be done, and the equipment available for construction. Generally speaking, the heaviest grade of tar which can be satisfactorily handled should be used. Tars meeting the A.A.S.H.O. consistency requirements for grades RT-1 to RT-7 have been used. The major portion of the work done has been with Grades RT-3 to RT-6. The selection of the particular grade to be used will be made on the basis of information obtained in the laboratory, modified by a consideration of the conditions under which construction must be done on the particular project.

Amount of Tar. The amount of tar to be used is determined in the laboratory on the basis of material passing the No. 10 sieve and including any sand or other aggregate which is to be added to the project. This is the tar needed to make a satisfactory soil mortar. The amount will generally fall between one-third and one-half gallon per sq. yd. per in. of consolidated depth.

Material above the ten-mesh size may

be considered as coarse aggregate which will be bound together by the soil mortar. Since the larger particles will be surrounded by the soil mortar, no additional tar need be provided for coating these larger particles.

In calculating the amount of tar required for the project, the following formula may be used:

$$A = .0000077\ BDE$$

wherein:

A = gallons of tar per square yard per inch of consolidated depth.
B = weight of consolidated soil mortar in pounds per cu. ft.
D = percentage of tar in soil mortar.
E = percentage of soil passing No. 10 sieve.

The weight of the tar binder is assumed as 9.7 lb. per gal.

Optimum Moisture. The correct moisture content for efficient consolidation to maximum density may be obtained by the Proctor method. Half the tar added to the soil may be considered as moisture in obtaining the optimum moisture content during construction.

Depth. The depth to be stabilized must be determined by considering the type of sub-grade, the climatic conditions, and the load to be supported by the stabilized base. A 4-in. consolidated depth is the least that should be considered, and a greater depth will often be necessary. Excessive depths must be built in two or more layers. Some difficulty may be experienced in handling the large amount of material involved in the construction of deep bases on roads of the ordinary width. It may be necessary to resort to plant mixing to accomplish the results.

LABORATORY PROCEDURE

The methods described are those used by The Barrett Company in determining the grade and amount of tar to be used for stabilizing a particular soil. They have been developed by B. A. Anderton and M. K. Smith and are presented as a record of what is being done rather than as final recommendations for the operation of the tests. Undoubtedly changes will be made in the procedure from time to time, and these tests may be entirely replaced by new methods. However, they are used as the basis for recommendations at the present time.

Requirements. The natural soil—including aggregate admixture, if used—shall be so treated with tar that the stabilized soil shall have a capillary water absorption for 14 days of not more than 25 per cent of the capillary water absorption of the untreated soil.

The stability of the tar-stabilized soil after exposure to capillary moisture for 14 days shall not be less than 7500 lbs.

Sampling. A sample from the project representative of the material to be stabilized (or samples from major sections of the project) shall be obtained for laboratory examination. These samples shall be based on a field survey of the project (Tentative Methods of Surveying and Sampling Soils for Use in Place as Subgrades for Highways; A.S.T.M. Designation: D 420-35T).

When it is anticipated that the mixing of aggregates or other soils with the existing soil may be desirable, samples of such materials should also be furnished to the laboratory, accompanied by a statement of availability and economy in use of these materials.

Preparation of Samples. Soil samples shall be dried thoroughly in the air, with all lumps broken to small size. The percentages of the sample passing and retained on a No. 10 sieve are determined. Dried lumps are broken before screening by means of a mortar and rubber covered pestle so that the material retained on the No. 10 sieve is substantially free from finer material.

Mechanical Analysis. Mechanical analysis of the portion of the sample retained on the No. 10 sieve shall be made in accordance with A.S.T.M. method D7-27.

Mechanical analysis of that portion of the sample passing the No. 10 sieve shall be made in accordance with A.S.TM. Tentative Method of Mechanical Analysis of Soils D 422-35T. Note: Additional sieves may be used when desired.

The mechanical analysis of the portion passing a No. 10 sieve and computed mechanical analysis of the entire sample shall be reported.

Soil Constants. Determination of the

Liquid Limit, Plastic Limit, Plasticity Index, Centrifuge Moisture Equivalent, Field Moisture Equivalent, and Shrinkage Factors shall be made in accordance with A.S.T.M. methods. While this information is not used directly in determining the grade and amount of tar needed for stabilization, the tests are useful in classifying the soil and serve to indicate the probable behavior of the soil in the field.

Preparation of Specimens. Approximately 300 g. of that portion of the air-dried soil passing a No. 10 sieve shall be weighed into a dish to an accuracy of 0.2 g. (A 6-in. porcelain evaporating dish is convenient). The desired amount of water shall be mixed with the soil and the dish and contents weighed. For mixtures containing tar, the desired amount of tar, based on the air-dried soil, shall then be weighed into the dish and uniformly distributed throughout the moistened soil. This quantity of mixture is sufficient to make three specimens.

Specimens shall be made from mixtures by tamping approximately 95 g. of the moist mixture into a cylindrical mold having an internal diameter of 2-in. and a height of about 5 in. resting on a flat metal plate, and fitted at the bottom with a well-fitting plug ½ in. high. The cylindrical mold and tampers are standard equipment for the Hubbard-Field stability test.

After the mixture has been manipulated in the mold with a spoon, it shall be tamped with the No. 1 tamper (blade type), dropping the tamper 25 times from a height of 2 in. and distributing the blows uniformly over the specimen. Any loose material is distributed over the top surface of the specimen, which shall be finally compacted by five light blows of the No. 2 cylindrical tamper weighing approximately 1400 g. Two or three light tamps with the 1.998-in. plunger will smooth the top surface of the specimen. The plunger is then used to expel the specimen from the cylinder. Each specimen shall be immediately weighed to an accuracy of 0.1 g.

Drying of Specimens. Specimens containing no tar shall be dried for 16 hours in an oven maintained at 105°C. ± 2°C. Specimens containing tar shall be dried for 41 hours at 60°C. ± 1°C. in an oven maintained uniformly at this temperature and so constructed as to permit the entrance and ventilation of a small volume of air by convection.

After removal from the oven, each specimen shall be weighed to an accuracy of 0.1 g. immediately after cooling.

Determination of Moisture in Specimens. From the weights of moist specimens and dried specimens, the percentage of moisture in each specimen as compacted shall be computed. For convenience, this percentage shall be based on weight of oven-dried mixture as 100 per cent.

Determination of Apparent Density and Weight per Cubic Foot of Specimens. The volume of each dried and weighed specimen shall be determined by displacement of mercury, following the general procedure described in A.S.T.M. Tentative Method D 427-35T, Section 4 (d), but using a glass cup the top rim of which is ground smooth and level and is of dimensions suitable to accomodate the specimens. The apparent density of each specimen shall be calculated and expressed in pounds per cubic foot of dried mixture.

Note: It is convenient to weigh the displaced mercury as a means of determining its volume.

Determination of Optimum Moisture Content.

A. Soil and Water. A series of mixtures with successively increased percentages of water shall be made and specimens prepared as described.

B. Soil, Water, and Tar. Selecting a proportion of tar which may be estimated to produce approximately the most effective stabilization (usually in the range of 4 to 6 per cent), a series of mixtures shall be made with successively increased percentages of water and the selected percentage of tar. From these mixtures, specimens shall be prepared as described.

Determinations of moisture and weight per cu. ft. shall be made for the series of specimens, averaging the results for each group of three specimens. From a study of the relation between percentage of moisture and weight per cu. ft. the percentage of moisture to obtain maximum weight per cu. ft. may be determined for the conditions of compaction used in making the specimens.

Note: The procedure for compaction has been selected to approximate compaction by the Proctor Test.

Determination of Water Absorbed by Capillarity. A series of mixtures shall be made as described, using in each a different percentage of tar within a range sufficient to include the most desirable percentage. In addition, a mixture with no tar shall be made. Approximately the percentage of water to obtain maximum apparent density shall be used in each mixture, adjusting the water for variations in percentage of tar. Dried specimens shall be made from these mixtures, and determinations of moisture and apparent density shall be made.

The specimens shall be weighed to an accuracy of 0.1 g. immediately prior to subjecting them to the capillary absorption test. Equipment for this test comprises a tightly-closed cabinet in which there is a plane horizontal surface covered with heavy white blotting paper and equipped with a device which will continuously maintain water at a constant level within the thickness of the sheet of blotting paper. A convenient plane horizontal surface is a suitably adjusted and level brass plate with numerous small perforations.

Note: With many specimens it is convenient to interpose a small disc of thin, soft filter paper between the wet blotting paper and the specimen.

The weighed specimens shall be placed in the cabinet with the bottom face (originally molded against the plug in the molding cylinder) down and in contact with the moist blotting paper. Subsequently they shall be removed periodically for weighing. Before weighing, any free water adhering to the bottom surface of specimens shall be removed by momentarily resting the specimen on a sheet of blotting paper. At the end of 14 days' exposure, the weights of specimens shall be determined and the percentage of absorbed water, based on the weight of dried specimen, computed.

Determination of Water Absorbed on Immersion. A series of specimens similar to those used in the capillarity test shall be made for determinations of moisture and apparent density.

The specimens shall be weighed to an accuracy of 0.1 g. immediately prior to subjecting them to the moisture test. They shall then be immersed in water at room temperature so that the top surface of the specimens is from one to two inches below the surface of the water. When immersed, the specimens shall rest on a sheet of white blotting paper, which facilitates observations of behavior. Any slaking, cracking, swelling, or other disintegration of specimens shall be noted, together with the period of immersion. (It is convenient to immerse specimens which will slake rapidly in vessels other than those used for non-slaking specimens.)

Specimens shall be removed periodically for weighing. Free water shall be removed by light pressure of absorbent paper or a towel before weighing them. At the end of 14 days' exposure, the weights of specimens shall be determined and the percentage of absorbed water, based on the weight of dried specimen, computed.

Stability Test. The equipment comprises a suitable standard testing machine, or a Hubbard-Field Stability Testing Machine; a heavy steel cylindrical testing cylinder about 5-in. high and $2\frac{1}{16}$-in. in internal diameter equipped at the bottom with a tool steel disc, in the center of which is a circular aperture with an area of 1 sq. in. The edge of this aperture is tapered outward to provide a cutting edge on the face toward the inside of the testing cylinder. The cylinder is also equipped with a cylindrical plunger two inches in diameter.

Specimens for this test shall be prepared as described, and, as required, may be tested as prepared, dried, or after being subjected to a moisture absorption test. The specimens shall be protected from any change prior to testing, particularly from changes in moisture content.

The specimen to be tested shall be inserted in the testing cylinder with the bottom face (originally molded against the plug in the molding cylinder) down and in contact with the orifice disc. The plunger is then inserted in the cylinder and the assembly placed over a rigid support on the weighing platform of the testing machine directly under the traveling head of the machine. The machine is then operated so as to depress the plunger at the rate of one inch per minute, recording the total load against depression of the plunger.

Stability shall be reported as total load (1) at 0.5 in. depression of the plunger, (2) maximum load—if attained at less than 0.5-in. depression of the plunger, or (3) capacity of testing machine at less than 0.5 in. depression of the plunger.

CONSTRUCTION METHODS

After the preliminary and laboratory investigations have been concluded, the construction of the tar-stabilized base can be started, using the information obtained. A definite series of steps is necessary, and each step in a typical project will be described and discussed.

1. *Aggregate Admixture.* If sand or similar material is to be added to the soil, it may be spread over the surface before any other work is done. It may be more convenient, sometimes, to add part of the aggregate during the loosening and pulverizing operations. All of the aggregate must be added to and mixed with the soil prior to the application of tar.

2. *Loosening.* The soil should be loosened to the depth necessary to

provide the required thickness of foundation. This may be done with a scarifier, blade grader, plow, or similar machine. All roots or other foreign material should be removed from the loosened soil. It is the best practice to loosen not more than one day's work ahead of the stabilization operations in order to conserve the moisture in the soil. (Figure 1.)

Figure 1. Breaking

3. *Pulverizing.* The soil should be pulverized so that no particles larger than one-half inch remain. This applies to soil particles only and not to aggregate particles which may be present. The pulverizing may be accomplished by means of a disc harrow, spring tooth harrow, blade grader, or similar machine. If the soil is very dry, it may be necessary to add some water to assist in the pulverizing operations. (Figures 2 and 3.)

4. *Application of Water.* When the soil layer is ready for consolidation, it should contain the optimum amount of moisture. At the time of mixing, the soil should be damp and may contain more than the optimum moisture without causing any mixing difficulty. However, such excess moisture must be removed before the consolidation operations are started.

The necessary water can be added at any convenient time during the operations, keeping the foregoing requirements in mind.

Water may be applied with any convenient sprinkling apparatus.

Figure 2. Pulverizing with Blade Grader

Figure 3. Pulverizing with Disc

5. *Application of Tar.* The tar to be mixed with the soil should be applied to the surface by means of a pressure distributor. One good method is to build up alternate layers of soil and tar. To accomplish this, the pulverized soil

is piled in a windrow, leaving from one to two inches of loose soil on the subgrade. Tar is spread over this at the rate of one-third to one-half gallon per square yard, and an additional layer of loose soil is spread from the windrow over the tar. The operation is continued in the same manner until all of the soil has been spread from the windrow and the required amount of tar has been applied. (Figure 4.)

An alternate method is to apply all of the tar to the top of the pulverized soil. To accomplish this, the pulverized soil is distributed evenly over the area

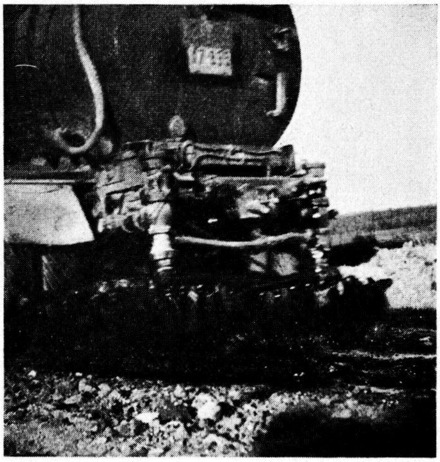

Figure 4. Applying Tar

to be stabilized. The tar is then applied to surface of the pulverized soil at the rate of approximately one-half gallon per square yard. Immediately following each application, the tar is cut into the soil by means of a disc harrow. The operations are repeated until the required amount of tar has been applied.

6. *Mixing.* The tar and the soil must be mixed together as thoroughly as possible. This is accomplished by the use of disc harrows, spring tooth harrows, blade graders, multiple blade drags, or other road mixing machines. (Figures 5 and 6.)

It will usually be necessary to move the tar-soil mixture into a windrow with the blade grader and crowd the end of the blade into the windrow, thus producing a scouring action before the soil particles are thoroughly coated with tar.

Various machines have been devised for mixing soil and tar. When they are used, the soil is usually piled in a windrow and fed from there into the mixing ma-

Figure 5. Mixing with Disc

Figure 6. Mixing with Retread Mixer

chine. While ordinary concrete mixers have been used, the pug-mill type seems to produce somewhat better results. A comparatively dry mix can be used in the mixing machine and the proper amount of water added to the tar-soil mixture after it has left the machine. If the water is added during the mixing operation, it will usually be necessary to add sufficient water to produce a wet or sloppy mix. A mixture of this sort can

not be consolidated at once, but must be allowed to dry until approximately the optimum moisture content is present.

7. *Consolidation.* The tar-soil mixture should be consolidated by an apparatus which will start the consolidation at the bottom of the layer. The sheepsfoot roller (Figure 7) is the most commonly used tool for this purpose. Disc rollers and truck wheel rollers have also been used. The sheepsfoot roller will not produce a smooth, consolidated surface and must be supplemented by either a flat wheel or a truck wheel roller (Figure 8). It has been general practice to operate the sheepsfoot roller until it would compact as much of the depth as possible, thus leaving a thin layer of loose material on the surface. It is very difficult to consolidate this thin top and tie it into the lower layer. Better results are obtained by stopping the sheepsfoot roller when not less than two inches of loose material remain on the surface and finishing the job with the truck wheel roller.

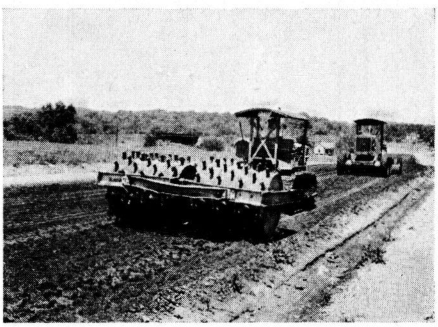

Figure 7. Consolidation with Sheepsfoot Roller

The moisture content in the tar-soil mixture should be as near the optimum as possible at the time of consolidation.

In order to insure uniform consolidation, the surface of the tar-soil mixture should be worked with a blade grader or drag during the operation of the sheepsfoot roller.

8. *Tack Coat.* Immediately after the rolling, the consolidated surface should be sprayed with one-quarter gallon of tar per square yard. In most cases no cover will be needed, and only the smallest necessary amount should be used.

The object of the tack coat is to produce a rich tar layer at the top of the stabilized soil to prevent surface water from entering the tar stabilized foundation.

The project may now be opened to traffic, although at this time it should not be expected to carry traffic for any great length of time.

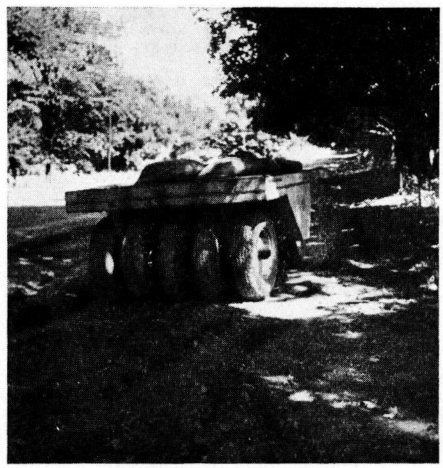

Figure 8. Truck Wheel Roller

Tar-stabilized bases, should not be considered finished until some sort of a weather-resisting and traffic-resisting seal coat or wearing course has been placed over the foundation.

This seal coat or wearing course should not be placed until the moisture content in the tar-stabilized base has been reduced to six or eight per cent. This may require two weeks or more, depending upon climatic and weather conditions.

CONCLUSION

By the proper use of tar, existing soils can be made water resistant, and a rela-

tive improvement can be obtained in their bearing power

The addition of sand or similar aggregate will assist in the stabilization, although grading is not of major importance in tar stabilization

The laboratory tests in use at present are tentative and will probably be changed materially

The heaviest grade of tar that can be mixed satisfactorily should be used in the stabilization

The tendency is toward leaner mixes with greater depths

The construction operations are fairly well standardized, although improvement in mixing and consolidating machinery may be expected