BITUMINOUS STABILIZATION PRACTICES IN THE UNITED STATES

Subgrade Practice

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The term soil stabilization, as used in this paper, refers to the practice of changing the characteristics of the natural materials in order that they may render more efficient service in the subgrade. The discussion presented in this paper deals with subgrade practices and not with surface stabilization.

Because of the limited funds generally available and the necessity for building a highway system of large mileage, it is imperative that the engineer use local materials in so far as possible. However, the great majority of local materials are not suitable in the natural state and must be treated in some manner to obtain the desired results. The use of bitumen is one method of economically rendering these local materials suitable for use. This paper will also be confined to a general discussion of stabilization practices in the United States with the use of bitumen.

The use of bitumen accomplishes two very definite purposes:

1. Waterproofing the individual soil particles and thereby rendering them highly resistant to water, which would otherwise be absorbed by capillarity.
2. Forming on the individual soil particles a coating of hard asphalt which will give stability to the aggregate because of the natural cohesiveness of the bitumen.

The characteristics of gravels, sands and silts are due to the characteristics of the individual particles comprising them. The difference in particle size in this group does not materially affect the characteristics of the material except to increase the capillary action with decrease in size of particle. The internal friction is high, there is no appreciable cohesion, and there is a high rate of permeability. The problem with these materials is one of increasing stability by coating the particles with asphalt thus rendering the individual particles more adhesive. On the other hand the change in surface area of the individual particles of clays and colloids materially alters the characteristics of the materials. Therefore, instead of dealing with individual particles, we are handling groups of particles. Also the chemical composition has changed and ionic forces come into effect. These cohesive soils have low internal friction, high cohesion, high capillarity, low permeability, and high plasticity. The problem in this case is one of waterproofing the individual soil particles thereby rendering them more resistant to the action of capillary water.

There are several generally adopted principles governing the use of bituminous materials in stabilization. It is generally conceded, and the theory has been substantiated by actual construction experience, that moisture is essential and that for best results compaction must be made at the optimum moisture content. For the determination of the optimum moisture and maximum density, the Proctor test has been almost universally adopted. The character of the asphaltic material to be used in any particular project has a bearing here for the lower the viscosity of the asphaltic material, the more nearly it takes the place of moisture. Therefore when using an asphaltic material of low viscosity, less moisture can be used to obtain the maximum density of the completed mix.

Complete mixing of an asphaltic material with the aggregate is absolutely essential. Each particle should be thoroughly coated to produce the proper results. It is a known fact that incomplete mixing has been the direct cause of failures on numerous projects. The presence of moisture in the mix materially aids in obtaining the proper dispersion of the asphalt throughout the aggregate.

Much has been written concerning the use of asphaltic oils, both residual and cut-back, in the surfacing of low-cost roads. However, little has been presented concerning the use of these materials as stabilizing agents for subgrade soils.

All types of bituminous materials have been used successfully in base stabilization, but much still remains to be learned concerning the types, grades, and methods of manipulation best suited for any particular purpose. Bituminous materials are used primarily as waterproofers, not as binders because while some binding qualities are present, especially in the more viscous grades, the bituminous stabilized base mixture is generally too friable to withstand the abrasive action of traffic, therefore the function of bitumen in soil stabilization is to reduce the amount of capillary water that may enter the mix and to increase the resistance of the active soil particles to the harmful effects of the moisture that does enter.

Construction methods are similar in all states reporting the use of asphaltic oils for stabilization. Any surfacing present and any additional aggregate to be used is mixed with the soil by scarifying the subgrade to the specified depth, and wetting with water to approximately the optimum moisture content. The bituminous material is then added and thoroughly mixed until a uniform composition is obtained. This mixture is then laid down and compacted, generally with sheepsfoot type tampers, until the density of the compacted material is not less than that obtained by laboratory compaction at the optimum moisture content. After initial compaction, the entire road bed is bladed with a motor grader or maintained to a uniform cross section, and finally compacted with a 5- to 7-ton roller. Some states report the use of pneumatic-tired rollers, in the place of the ordinary steel rollers, with good results.

Generally, good results have been obtained by all states using both residual (SC) oils and cut-back (MC) oils. However, Iowa reports that the use of SC oils has not been satisfactory. Mr. V. G. Gould, Assistant Bituminous Engineer of the Iowa Highway Commission, makes this statement, "Although soil-aggregate and rolled stone mixtures only have been placed a sufficient length of time to warrant conclusions, yet to date all other types used, appear satisfactory except soil-aggregate mixtures using either positive or negative SC oils." In direct contrast, Missouri reports equal success with either MC or SC oils as the stabilizing agents. These contrasting views especially when presented from states which are leaders in the field amply illustrate the statement made previously that the use of bituminous materials in subgrade stabilization is still in the experimental stage.

The use of tars, both coal and pine tar, is substantially the same as that of asphalt. States reporting the use of tars conclude that uniformly good results have been obtained. Kentucky reports that while the tar stabilized base was slower in setting, the ultimate result was very good and completely satisfactory.

According to the theory propounded by Mr. C. L. McKesson, "Instability in the types of soils involved in this discussion is believed to be due to the presence of appreciable quantities of colloidal clays which are firm and hard when dry, but which become highly plastic in the presence of water. Asphalt in emulsions is present in extremely fine particles, most of which are as fine or finer than the particles in the gluey colloidal clay. In stabilization work these minute particles of asphalt are uniformly distributed throughout the entire clay mass and when the mass is subjected to drying, with the resultant interfacial surface tensions, the asphalt is carried into and around the colloidal clay particles completely or substantially destroying their water wetting propensities, and producing a definite water repellant property.

"In soil stabilization work, it is not expected or intended to render the soil sufficiently hard or tough to resist destructive, abrasive action of traffic, but simply to render the soil resistant to water from capillarity and thus to retain in the soil the bearing strength characteristic of the same soil when in a dry compacted condition."

The general practices with emulsified asphalt are substantially the same in all states reporting the use of this material. The material to be stabilized is first scarified, bladed into a windrow and the subgrade shaped to plan and profile. The windrowed material is then wetted to the plastic limit and thoroughly mixed to a uniform consistency. Part of the stack is then laid out and sprayed with the emulsified asphalt and thoroughly mixed with harrows or motor graders. This general procedure is followed until all the windrowed material has been thoroughly mixed. The stabilized material is then laid, dried to the optimum moisture content and bladed to grade, and profile, and rolled.

For best results in using emulsified asphalt, certain definite points have been established, the observation of which makes for a more uniform mix and better job. These general rules have been gathered from reports of states using this material.

1. Ample water must be available.
2. The stack must be kept moist to about the plastic limit until mixing is complete.
3. Spreading, rolling and dragging must be done when the material is at the proper consistency, which is about the optimum moisture content.

It is important that the emulsified asphalt contain no appreciable amount of soap or other soluble emulsifying agent, because experiments have shown that soaps in excessive amounts are very detrimental to the life of the surface. Missouri concluded that oil treated soil sprayed with 0.31 to 0.59 gal. per sq. yd. of a 4 per cent soap solution, showed superior results to the untreated oiled earth, but when the same material was treated with 0.88 gal. per sq. yd. of 4 per cent soap solution, very definite failure resulted. While the use of soap was evidently primarily designed to increase the amount of surface active material, these tests demonstrated clearly the danger of using an excessive amount of soap solution, or asphalt emulsions containing soap as the emulsifying agent.

Experiments in Missouri, Idaho, California, and other states using this material, definitely prove the value of emulsified asphalt as a base stabilizer, which because of the water content disperses through the aggregate better than other types of asphaltic materials. However, to serve properly as a stabilizing agent, emulsified asphalt must have certain definite characteristics. It must be a mixing type, that is, it must thoroughly coat all soil particles; it must be miscible with water in all proportions; it must be capable of mixing with clay or the finest rock dust without balling; it must be able to lose its water vehicle rapidly after mixing; it must leave the remaining asphalt, after dehydration, uniformly dispersed as a light film upon all soil particles.

Emulsified asphalt is adaptable to road mixing, machine mixing and even hand mixing by rakes, hoes and shovels. However, extreme care must be used to insure complete and thorough mixing of the emulsion throughout the base. Several failures have been noted due to partial dispersion of the emulsion, which when the vehicle evaporated, left reservoirs of asphalt in the base. Reports have been received verifying the versatility of this material as a stabilizing agent. The only particular objection to it is one of economy. It has not as yet been adequately demonstrated whether the increased cost of emulsified asphalt over SC and MC oil, when used as base stabilizers, is offset by increased life of surface. This question can only be answered by the actual lives of surfaces under which these materials have been used as base stabilizers.

In order to make this paper as comprehensive as possible, a questionnaire was sent to all states, requesting information concerning their stabilization practices. A good response was received and a brief resume is included in this report. Many states do not use bituminous stabilization because of an abundance of natural gravelly materials. However, most states have made experiments in this field. Missouri, California, Kentucky, Florida, Nebraska and South Carolina have been outstanding pioneers in this movement.

MISSOURI[1]

Observations from bituminous stabilization experiments, conducted in Missouri from 1927 to 1932, showed that a thin mat with stable support will successfully withstand the weathering and abrasive effects of traffic. Soils will give satisfactory support so long as the moisture content is kept below a certain critical point. Missouri then sought a practical method of keeping the moisture below this critical point, the theory being that if this could be done, it would only be necessary to provide a thin renewable surface course for resisting the action of weather and traffic.

[1] See also page 292.

In the fall of 1935, 47 experimental sections were constructed including variations in the percentage of fines (40-mesh material), type and percentage of bitumen, quantity of water added and chemical activating substances. The thickness of the subgrade treatment was 4-in.

Observation of this project after the first winter disclosed that the sections stabilized with the cheaper SC and MC oils were performing as well as those stabilized with the more expensive emulsions.

Using the experience gained on these experimental sections, ten and one-half miles of this type of bituminous base stabilization were constructed under contract in 1936. The base thickness was increased to 5-in., and with the exception of a short section where tar was used as the stabilizing agent, all sections made use of SC-3 and MC-4 oils. The results proved very satisfactory and further substantiated the conclusions reached on the results of the previous experimental sections.

SOUTH CAROLINA

South Carolina began experiments with tar as a stabilizing agent in 1927 with a project on a fine sandy soil which proved quite successful. In 1935 a second project was built using two grades of tar; a light tar applied first, followed by one of a heavier grade. The results indicated that moisture was probably necessary to improve the mixing qualities of the tar. Further it was noticed that moisture control was essential if sheepsfoot roller compaction was to be successful. Approximately 2.6 miles of this type of stabilization were laid with sandy soils and 5.6 miles with clay soils. The sandy section was very successful but some failures have developed in the clay section.

A modified Proctor test is used for the measurement of compaction. Instead of a 5-lb. rammer dropped 12-in. a 12-lb. rammer is dropped 22-in. This gives greater density with lower optimum moisture content and is used because the regular method gives a water content that will lubricate the soil particles when the tar is added.

RC-type cut-back asphalt has been successfully used on sandy soil and approximately 275 miles of this type have been laid. Experiments using RC oils in clay soils have not proven satisfactory.

NORTH CAROLINA

In North Carolina, tar has been used satisfactorily as a stabilization agent on several projects, approximating 40-miles in length. The use of asphalts has been confined largely to sand mixtures, and good results have been obtained using RC cut-backs on both road mix and plant mix jobs. Emulsions have been used on one project which is 18-months old and on another which has just been completed. Both projects appear satisfactory.

KENTUCKY

Kentucky has experimented using tars, SC and MC oils and emulsions. Uniformly good results have generally been obtained. However, difficulty has been encountered in maintaining the proper field control. The tendency has been to make the mixes too rich with the bituminous materials. Projects showing failure have been reworked and with the addition of granular material have then proven satisfactory. These projects are all of too recent a date to draw reliable conclusions.

OHIO

Ohio reports satisfactory results with tars and SC oils. Some 30 miles have been so stabilized. The experience indicates that a lean mix, well compacted, makes a very satisfactory base for a light surface treatment. Experience with emulsions indicates satisfactory results, but absolute moisture control must be maintained.

IOWA

Iowa's experience indicates that SC oils are susceptible to moisture displacement, and, therefore, MC oils are preferred for stabilization. Need for a heavy, well compacted base is also shown.

The following formula has been used for the determination of the quantity of bitumen necessary:

$$G = 240 \times A \times B \times (1 + V)$$

Wherein,

G = Quantity of Bituminous Material required in gallons per ton of Aggregate.

A = Surface area of aggregate in square feet per pound computed from analysis of aggregate.

B = Bitumen Index

V = Allowance for volatile portion of bitumen expressed as a decimal fraction.

NEBRASKA

About one-fourth of the area of Nebraska is included in the sand hill region of the state, where the soil is predominately dune sand.

As graded roads were constructed, a blanket of silt or clay soil was used as a surface course in locations where such materials could be found. In a few instances, clay soil for this purpose was shipped by rail. Scarcity of clay and gravel in this area, prompted the first experiments to stabilize the sand with liquid asphaltic material. Since 1928, 252 miles of this type of pavement have been built.

The soil of the sand dune section is made of wind blown sand eroded in comparatively recent geologic times. In some sections the breaking down by weathering of the feldspar and minerals, other than quartz, have contributed sufficient fine material to give a loamy texture to the soil. The gradation of the dune sand is uniform with about 85 per cent passing the No. 50 mesh sieve and with 2 to 5 per cent smaller than the No. 200. The loamy sand has about the same amount smaller than the No. 50 sieve and from 15 to 30 per cent smaller than No. 200.

Early experiments in oiling this sand with SC-3 oil with no filler added, were not wholly satisfactory from the standpoint of stability, as it took the road two years to develop a set. Three and one-half gallons of oil were required for a 5-in. thickness. Similar results were secured using SC-3 and a combination of SC-3 and MC-2. Four gallons of oil per square yard were used for these sections.

In 1929 and 1930 an experiment was conducted making use of SC-2 and MC-2 asphaltic material. Three per cent of limerock dust was added to the sand on alternate half-mile sections. The MC-2 sections were stable, but those using SC-2 were soft. In 1932 twenty per cent of soil was added to the SC-2 sections and after remixing, all sections were satisfactory.

Since 1930 type SC-3 oil has been used in the construction of 125 miles of road while 110 miles have been mixed with MC-2. During 1936 and 1937, type MC-2 has been used exclusively. Although best results have been obtained using MC oils, experience has shown the SC oils can be used successfully, if the blow sand has from 20 to 30 per cent passing the 200 mesh sieve. It is desirable to have about 18 per cent filler in the MC-2 mixtures.

Nebraska uses the following formula to control the oil in these sand mixtures:

$$P = AG\,(0.02a) + 0.04b + 0.06c + Sd$$

wherein:

- P = Percentage of bitumen required.
- a = Percentage by weight of aggregate retained on No. 50 sieve
- b = Percentage by weight of aggregate passing the No. 50 sieve and retained on the No. 100 sieve.
- c = Percentage by weight of aggregate passing No. 100 sieve and retained on No. 200 sieve.
- d = Percentage by weight of effective filler material in the combined aggregate (arithmetic average of the results obtained by the wash test and by the dry sieving).
- S = A factor depending upon the fineness and absorptiveness of the effective filler material.
- A = An absorption factor for the aggregate which in the case of Platte River gravel is equal to unity and is determined for other aggregates for each individual job. The factor should be applied to only the portion of the combined aggregate that is absorptive.
- G = A specific gravity factor which is computed by dividing the bulk specific gravity of the aggregate being used into 2.62.

Nebraska submitted specifications for two bituminous base stabilization projects which differed from other states' specifications in that the contractor was required to reduce the moisture content to 2 per cent before final rolling and compaction. This was accomplished by alternate disking and rolling.

FLORIDA

Sand stabilization has reached a high point of successful development in Florida on account of the large areas of sandy soil and demand for good roads at low cost. The success of this type of stabilization depends upon:

1. A warm, dry construction period.
2. Light to medium traffic.
3. Sandy soil.
4. Good drainage.

A good grading of the soil is desirable

although not necessary. Many sands which have been stabilized have been uniform in size having very little plus 10 mesh material and 80 to 90 per cent of plus 40 mesh material. An effort is made to obtain a stability of 25 lb. per sq. in. which is considered necessary for best results. The tests that have proved successful and most useful are stability and the bearing value.

The amount of bitumen is determined in the laboratory by trial mixes. So far no successful formula has been evolved. The construction methods are briefly described as follows: The sandy soil is first scarified to about two inches below the proposed depth of the base and cleaned of all roots and other organic materials. The top 3 to 4 in. is first processed by applying 1½ gal. per sq. yd. of the asphaltic material in increments of 0.35 gal. per sq. yd. Each application is thoroughly mixed with a disc harrow. The mixed top is then bladed back to both sides and the bottom is mixed in a similar manner. When mixing has been completed the material is brought to grade and profile. The top mix is then windrowed back in three installments, each being given a 0.35 treatment and mixed with harrows. The entire surface is then brought to grade and profile and rolled with a 5-ton tandem roller.

Sand bituminous bases are considered a success in Florida. While no conviction is held that they are a solution for all road ills due to sandy soils, regardless of location, available materials, and volume of traffic, they do have merit and utility where the existing road material is predominantly sand, where a warm dry construction season is the rule, where traffic is of medium volume, and where good drainage can be obtained.

WYOMING

Wyoming completed a 30-mile project in 1930 which has proven entirely satisfactory. The mixture of fairly well graded blow sand stabilized with 60 per cent of 100 penetration residue was laid with the expectation that a surface treatment would be added. However, the base held up so well that the surface was never placed.

CALIFORNIA

California has been the leader in the use of asphalt emulsions. One very successful project was laid in 1937 using this material as a stabilizing agent under a portland cement concrete pavement.

Mr. L. H. Taylor, in his paper dealing with stabilization practices in Oakland City, reports that emulsified asphalt was used very successfully for stabilization of several projects over very bad soil conditions. On Lakeside Drive the original surface was laid on filled ground. The fill was made of a fine blue-gray silt, having a capillary attraction so great that the entire subgrade was continually saturated and was so unstable that it was a continual fight to keep the street open for traffic. In the stabilization of this base 13-in. of quarry waste composed chiefly of decomposed rhyolite, was treated with emulsified asphalt. This base was then covered with a 3-inch wearing course. This treatment has to date proven very satisfactory.

Both Idaho and Nevada have successfully used emulsified asphalt on projects during the past few years. The only particular objection in either case being one of economy. Nevada laid 7000 feet of stabilized slurry base in 1935. On this project about 10 per cent of emulsified asphalt was plant mixed with the aggregate. The mixture was hauled to the desired location, placed, rolled and slush rolled. After the mixture dried out the surface was broomed and a 2½-in. plant mix surface was placed. At the present time this project is in excellent condition.

It is apparent from the questionnaire replies that projects using the various stabilization methods are all of too recent date to disclose their ultimate value to the highway engineer. However, it is interesting to note that the profession is aware of the fact that some treatment of the subgrade soils is necessary if the average life of highway surfaces is to be increased.

The entire subject of bituminous stabilization can probably be summarized by a few definite principles formulated from the replies received in response to the questionnaire.

1. The primary object of bituminous stabilization is waterproofing to prevent capillary action.
2. The secondary object of bituminous stabilization is increased stability of the aggregate through the natural cohesive qualities of the bitumen.
3. For emulsions, water content should be about that required for the plastic limit for mixing and at the optimum for compaction.
4. Soap must be used very sparingly.
5. For SC and MC oils, water content should be about optimum for best results for both mixing and compacting.
6. All bituminous materials can be used successfully under the proper conditions.
7. Bituminous bases are too friable to stand the abrasive action of traffic and so must be surface treated.
8. Principal laboratory tests are for stability and absorption.
9. Bitumen must be thoroughly mixed with the aggregate.
10. Drainage is of prime importance.